ISSN 0973-1830

Volume 12: 2014
Special Issue Number 2

SOYBEAN RESEARCH

Society for Soybean Research and Development
Directorate of Soybean Research
Khandwa Road, Indore 452 001
Madhya Pradesh, India

Society for Soybean Research and Development

(Founded in 2003)
(Registration No. 03/27/03/07918/04)

MEMBERSHIP TARIFF

Annual Subscription	**India**	**Abroad**
Individual	Rs. 500/-	US$ 125/-
Students	Rs. 250/-	UD$ 100/-
Institutions	Rs. 2000/-	US$ 200/-
Corporate	Rs. 20000/-	US$ 2000/-
Life Membership	Rs. 3000/-	US$ 1000/-

(Add Admission Fees Rs. 50/- or US$ 5/- to above subscription)

NAAS RATING 3.04

SOYBEAN RESEARCH

ISSN 0973-1830 **Volume 12 (Special issue No. 2): 2014**

CONTENTS

An official publication of Society for Soybean Research and Development, Indore
The 'Soybean Research' is indexed in Soybean Abstract of CAB International, UK and Indian Science Abstracts of NISCAIR, India

The Society for Soybean Research and Development thankfully acknowledges the financial assistance received from the Indian Council of Agricultural Research, New Delhi for printing of the Journal.

Soybean Research (Special Issue Number 2): 1-7: 2014

Progress in Vegetable Soybean Improvement

R M NAIR[1*], YAN M-R[2] and EASDOWN W J[1]
[1]AVRDC – The World Vegetable Center South Asia, ICRISAT Campus, Hyderabad, 502324, AP, India
[2]AVRDC – The World Vegetable Center, PO Box 42, Shanhua, Tainan 74199, Taiwan
E mail: ramakrishnan.nair@worldveg.org

ABSTRACT

Vegetable soybean is popularly known as edamame in Japan, maodou in China and green soybean in North America. The immature pods are boiled and the seeds extracted as a highly nutritious snack food. Demand is increasing as vegetable soybean gains recognition for its nutritional value, paving the way for the expansion of the crop in developing and developed countries. China, Japan, Taiwan, Thailand, Indonesia and Vietnam are the major vegetable soybean producing countries. AVRDC – The World Vegetable Center has played a pivotal role in promoting vegetable soybean through the development of improved lines. Provision of sufficient quantities of quality seed to farmers, adoption of integrated pest and disease management practices, and development of recipes for local tastes would further expand the production and consumption of this nutritious crop.

Keywords: vegetable soybean, breeding, production, consumption

Vegetable soybean (*Glycine max* (L.) Merrill) or *edamame* differs from grain soybean mostly in its large seed size (≥ 30 g/100 dry seeds). However, in some countries like Nepal, grain soybeans are harvested at the green pod stage and marketed as vegetable soybeans, and grain soybean varieties also have been used as vegetable soybean in China, Taiwan, and Thailand. However such beans are unpalatable and bias consumer attitudes toward using soybean as a vegetable. Recently, the introduction of new, high-quality vegetable soybean varieties has changed consumer attitudes in all of these countries. Vegetable soybean is slightly sweeter compared with the grain type, which is oily and slightly bitter. The dry seed coat color varies, from yellow, green and brown to black (Shanmugasundaram and Yan, 2004).

Nutritional importance

Vegetable soybeans are rich in protein (13 %), cholesterol-free oil (5.7 %), phosphorus (158 mg/100 g), calcium (78 mg/100 g), vitamin B_1 (0.4 mg/100 g) and B_2 (0.17 mg/100 g). They also contain isoflavones (Fig. 1) and vitamin E (Shanmugasundaram and Yan, 1999). The trypsin inhibitor activity in vegetable soybean is lower than in grain soybean. Compared to vegetable pigeon pea (*Cajanus cajan*) and green peas (*Pisum sativum*), vegetable soybean provides more protein of a higher quality, and is considered an excellent and complete protein source (Carter and

[1]Vegetable Breeder (Legumes); [2] Principal Research Assistant; [3]Regional Director, South Asia

Shanmugasundaram, 1993). Pod and green bean appearance, taste, flavor, texture, and nutritional value, in that order, are the five most important quality requirements for vegetable soybean (Masuda, 1991).

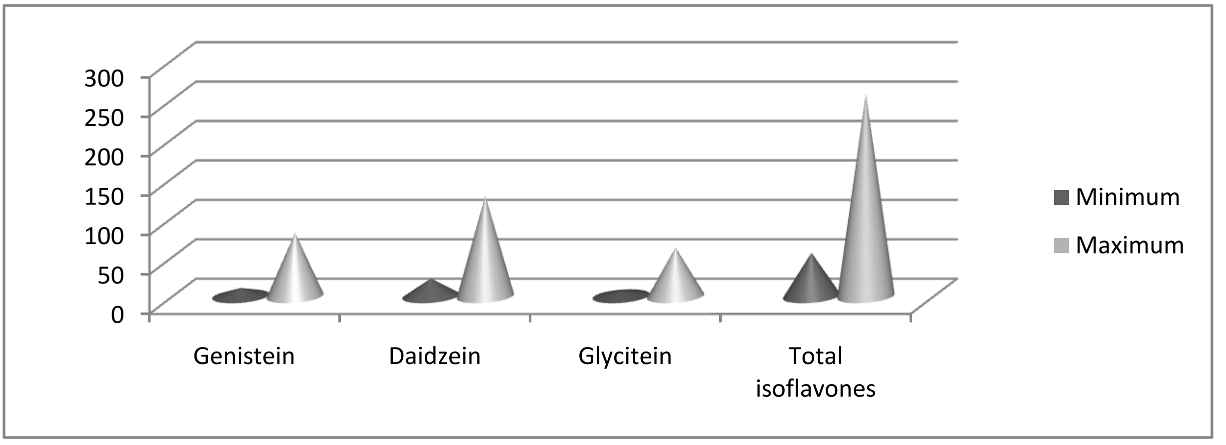


Fig. 1. Major isoflavones (μg/g) in vegetable soybean: Source: Mebrahtu *et al.* (2004). **Global statistics**

`

Vegetable soybean is commonly cultivated in a rice-based cropping system, or on the bunds of rice fields. In almost all Asian countries, vegetable soybean is planted in the spring, summer, and autumn in open fields; planting dates differ with the season location and cultivar, depending upon temperature and day length. The beneficial effects of

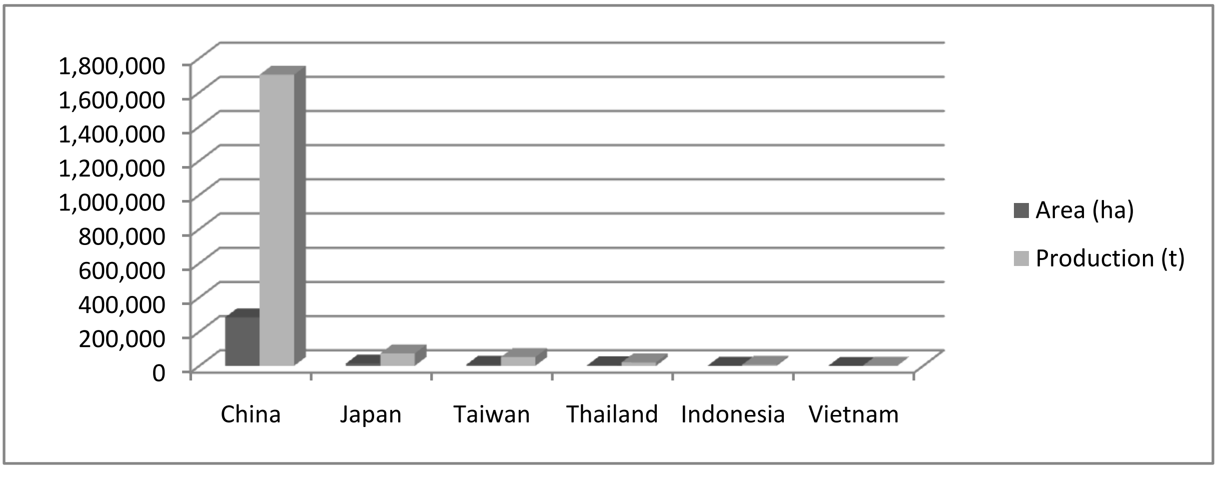


Fig. 2. Area and production of major vegetable soybean producing countries (*Source*: Shanmugasundaram *et al.*, forthcoming)

growing vegetable soybean include the production of high value grain (10 t/ha) within a short period of time (65-75 days), the provision of nitrogen to the following cereal crop, which increases cereal yields, and the availability of a highly nutritious stover (30 t/ha) for livestock feed or for use as a green manure.

China, Japan, Taiwan, Thailand, Indonesia and Vietnam are the major vegetable soybean producing countries (Fig. 2), and the crop is widely grown and consumed across China. The average productivity of vegetable soybean cultivated during the spring and summer seasons in China ranges from 4.5 to 6.0 t per ha, and 6.0 to 7.5 t per ha, respectively. Prior to 1975, the total area and production of vegetable soybean in Taiwan was negligible, but both increased from 6,500 ha and 40,000 t in 1980 to nearly 10,000 ha and around 65,000 t by 1990, respectively (Cheng, 1991; Lin and Cheng, 2001). However, due to the increasing value of land and high cost of labor, vegetable soybean production slowly decreased from 1999 in Taiwan (Fig. 3), and its share of global production was taken by China, Thailand, and Indonesia, where production costs are cheaper. The majority of the vegetable soybean produced is exported to Japan.

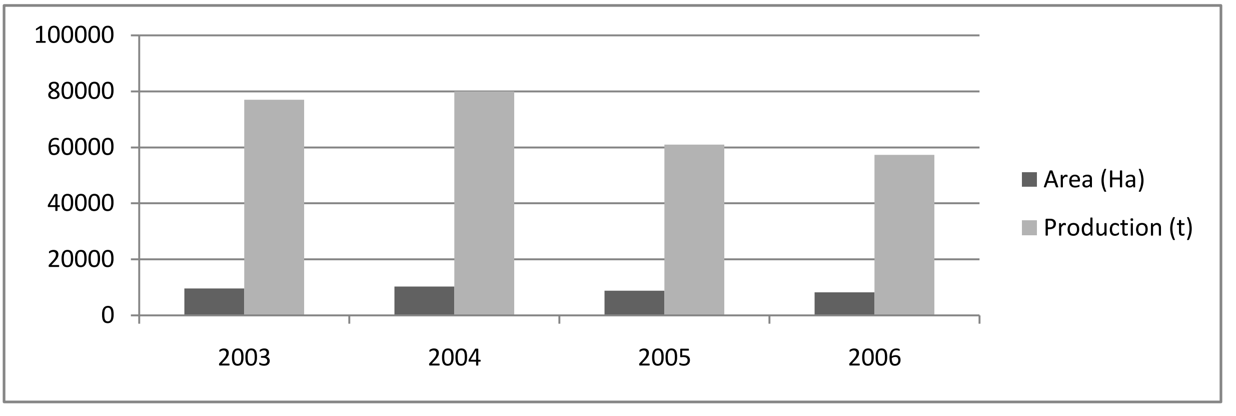


Fig. 3. Area and production of vegetable soybean in Taiwan from 2003 to 2006 (*Source*: Shanmugasundaram *et al.*, forthcoming)Varietal improvement

AVRDC – The World Vegetable Center began developing improved vegetable soybean lines in 1981. The Center's gene bank houses 15,316 *Glycine* accessions and vegetable soybean types account for about 15 per cent of the *G. max* collection. More than 3,000 breeding lines have been distributed to researchers worldwide, including those that are less sensitive to photoperiod and temperature to extend adaptability to tropical zones. Selections from local landraces and the transfer of desirable traits from grain soybean have been employed in the breeding program. The main traits of interest to breeders are higher pod yield, the pod size and color, seed size and color (yellow, green, brown or black), the number of seeds per pod, seed appearance, higher sugar content, flavor, early maturity, better nodulation capacity, suitability for mechanical harvesting, and resistance to pests and diseases. The main pests of concern are bean flies (*Melanagromyza sojae*, *M. phaseoli*, *Ophiomyia centrosematis* and *Doloichostigma* sp.) and pod borer (*Heliothis armigera*). The main diseases are soybean rust (*Phakopsora pachyrhizi* and *P. meibomiae*) downy mildew (*Peronospora manshurica*), anthracnose (*Colletotrichum truncatum* and *C. gloeosporioides*), purple seed stain (*Cercospora sojina*), and s*oybean mosaic virus* (SMV).

A total of 15 countries, including Bangladesh (GC 83005-9), India (GC 98009-1-1-2), Pakistan (AGS 190) and Sri Lanka (AGS 190) have released more than 38 vegetable soybean cultivars from AVRDC breeding materials (Shanmugasundaram *et al.*, forthcoming). The cultivars released since 2006 are presented in Table 1.

As a part of its ongoing work, AVRDC is testing 16 new lines of vegetable soybean in multilocation trials across India, with a wide range of seed colors and qualities. These include lines with basmati rice flavor—a popular taste that commands a high price premium. To enhance the taste of vegetable soybean, breeders have successfully utilized fragrance (2 –acetyl -1- pyrroline content) genes from the Japanese cultivars 'Dadachamame' and 'Chakaori' to develop vegetable soybean lines with a basmati rice flavor. Molecular markers for the fragrance trait have been developed (Juwattanasomran *et al.,* 2010), which will facilitate the selection for the trait in breeding programs. In an evaluation trial of vegetable soybean conducted during 2002-03 in Taiwan, Chou *et al*., (2003) recorded isoflavaone level of 1473 µg per g and 0.55 ppm of 2 –acetyl -1-pyrroline. Evaluation of seven new AVRDC basmati vegetable soybean lines at the Indian Council for Agricultural Research - Regional Centre for Eastern Region, Ranchi in the east Indian state of Jharkhand showed that five lines, AGS-447, AGS-456, AGS-457, AGS-458, and AGS-461, gave the best performance and were also earlier in flowering and pod setting than the others (Nair *et al.,* 2013).

.

Promoting vegetable soybean

Global awareness of the use and benefits of vegetable soybean has been increased through the efforts of AVRDC – The World Vegetable Center. As a result, vegetable soybeans are now produced and marketed in Zimbabwe, Mauritius, Uganda, Tanzania, Zambia, Sudan, and Mozambique (Chadha and Oluoch, 2004). Recently, the state of Arkansas has been designated as the *edamame* capital of the USA. It is estimated that the current area under vegetable soybean in the USA is about 2000 ha (Cartright and Medders (2012). Based on research conducted by AVRDC's regional scientists in Central Asia and the Caucasus, vegetable soybean is also expanding into Azerbaijan, Kazakhstan and Uzbekistan (Ravza Mavlyanova, personal communication).

Seed production

One of the major challenges in promotion of a new crop is to provide sufficient quantities of seed of improved cultivars to farmers. In India, vegetable soybean cultivar 'Swarna Vasundhra' (GC89009-1-1-2) was released in 2008 by the Central Variety Release Committee *(*CVRC) of the Government of India. This is an elite germplasm line (EC 384907) introduced from AVRDC, Taiwan and recommended for release and cultivation in Jharkhand and Bihar in the *kharif* season. The shelled seeds are very bold and bright green in color. Average yield is 15 t per ha. 'Swarna

Table 1. Lines developed by AVRDC – The World Vegetable Center released by co-operators since 2006

Local name	AVRDC ID #	Year	Country of release	Remarks
Edamame 1	AGS 292	2006	Zimbabwe	Marketing started in 2007 by Seed Co (Zimbabwe and Malawi)
Ilkhom	Misono Green	2007	Uzbekistan	Early maturing, high yielding, high protein and oil content, performs well as repeated crops
Swarna Vasundhara	GC89009-1-1-2	2008	India	AVRDC Newsletter (9 October 2008)
Universal	G12917 (Natsunoka)	2008	Uzbekistan	Early maturing, high yielding, high protein and oil content, performs well as repeated crops
Sulton	AGS 423	2010	Uzbekistan	Mid-maturing, high yielding, high protein and oil content, performs well as repeated crops
Mtsvane parkiani	AGS292	2011	Georgia	HY, EM, high sugar contents and isoflavone contents, photo-less sensitive
Sabostne 1	VI045038/ Jasuto 75	2011	Georgia	HY, EM, photo-less sensitive
Inju	AGS437	2012	Kazakhstan	

DM = resistant to downy mildew; EM = early maturing; HY = high yielding

Vasundhra' showed the best performance in terms of graded pod yield across three years during the *kharif* season in Jharkhand (Pan *et al.,* 2007). 'Swarna Vasundhra' has been the mainstay of the crop's expansion in India to date. Thanks to the efforts of an AVRDC-Sir Ratan Tata Trust project, seed of this cultivar has been produced by more than 300 farmers in the state of Jharkhand and is helping to meet local demand for seed. The main need now is to increase vegetable soybean production to a level beyond that which can be absorbed by local markets, and to promote it in other parts of India to create a strong and permanent demand for this new crop (Nair *et al.,* 2013).

Integrated pest and disease management

Insect pests and diseases affect the productivity of vegetable soybean (Talekar and Chen, 1983; Lai *et al.,* 2004), causing damage to the crop from emergence to harvest (Talekar, 1987). Crop losses can be as high as 100% (Talekar and Chen, 1983). Indiscriminate use of pesticides has led to pesticide resistance in insects such as bean flies and lepidopterous defoliators (Yeh *et al.,* 1991) and pesticide residue may hinder the export potential of vegetable soybean (Srinivasan *et al.,* 2009). Increasing concern about environmental quality, human health, and safer agricultural products has led to the development of organic vegetable soybean production in Taiwan and Southeast Asia (Ma *et al.,* 2008). To support these initiatives, AVRDC developed an integrated pest management (IPM) strategy (Srinivasan *et al.,* 2009) composed of the following components: (i) sex pheromone traps for *Spodoptera exigua*, *S. litura,* and *Helicoverpa armigera* throughout the growing season; (ii) yellow sticky paper traps for whitefly and leafhopper throughout the growing season; (iii) spraying of neem pesticide (Biofree – I®, 2.5 ml/l), followed by neem with *Bacillus thuringiensis* (Bt; Xentari®; 1 g/l during spring and 0.25 g/l during autumn) in subsequent sprayings to control early season sucking insects and defoliators, respectively; and (iv) spraying of neem, Bt and *Maruca vitrata* nucleopolyhedrovirus (109 OBs/l) for pod borers three times during the pod setting stage. The IPM strategy implemented in Taiwan was found to reduce damage due to pests, especially pod borers, in organic vegetable soybean production systems and contributed to higher graded pod yield. However, the yield obtained may be lower than current farmers' practices, which are based mostly on chemical pesticides. To make organic vegetable soybean viable in tropical locations a premium price for the seed is needed to encourage growers to adopt the IPM strategy (Srinivasan *et al.,* 2009). Demonstration of the safety of organic vegetable soybean by measuring the pesticide residue levels in produce from conventional crops should also be encouraged.

Management practices such as crop rotation, field sanitation, solar sterilization by transparent plastic film mulching, the use of high quality seed, planting of disease-resistant cultivars, seed treatment utilizing effective antagonists such as *Trichoderma* spp. (drenching with the *Trichoderma harzianum* T2 strain (100X) at 10 days after sowing, followed by 3 more applications at one week intervals) will help keep diseases such as root rot (*Rhizoctonia solani*) and anthracnose under control (Shanmugasundaram *et al.,* forthcoming).

Discussion

Consumer acceptance is vital to the success of a new crop. Promoting vegetable soybean recipes designed to suit local tastes would help gain wider acceptance of the crop. This has been successfully accomplished in the state of Jharkhand in India, where tribal communities have started to consume vegetable soybean as a substitute for garden pea (*Pisum sativum*) and also have developed their own recipes.

The further expansion of the crop into new regions will require creating greater awareness about the nutritive value of vegetable soybean, increasing the supply of good quality seed, and monitoring for major pests and diseases in the new locations.

REFERENCES

Cartright K and Medders H. 2012. Vegetable Soybean Company to make Mulberry 'edamame capital' of US. (http://arkansasagnews.uark.edu /6583.htm) accessed Oct. 2012.

Carter T E and Shanmugasundaram S. 1993. Vegetable soybean (*Glycine max*). *In*: J T Williams (Ed.), *Pulses and Vegetables,* Chapman and Hall, New York, USA, pp. 219-39.

Chadha M L and Oluoch M O. 2001. Adaptation and utilization of AVRDC vegetable soybean lines in eastern and southern Africa. *In*: *Proceedings of Second International Vegetable Soybean Conference,* Washington State University, Tacoma, Washington, USA, pp. 29–33.

Cheng S H. 1991. Vegetable soybean area, production, foreign and domestic trade in Taiwan. *In*: Shanmugasundaram S (Ed.) *Proceedings of Vegetable Soybean – Research Needs for Production and Quality Improvement Workshop,* Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan, pp. 17–21.

Chou K L, Lee Y H and Chen C M. 2003. Development of new variety and functional health food of aromatic vegetable soybean *In*: *Annual Report of Dryland Food Crops Improvement*, Agricultural Research Institute, Council of Agriculture, Executive Yuan, Republic of China, pp. 152-65.

Juwattanasomran R, Somta P, Kaga A, Chankaew S, Shimizu T, Sorajjapinun W and Srinives P. 2010. Identification of a new fragrance allele in soybean and development of its functional marker. *Molecular Breeding* **29**(1): 13-21.DOI 10.1007/s11032-010-9523-0.

Lai P S, Lien T J, Chen R S and Tsay J G. 2004. The occurrence of downy mildew of vegetable soybean and its detection by PCR. *Plant Protection Bulletin* **46**: 155-62.

Lin F H and Cheng S T. 2001. Vegetable soybean development for export to Japan – A historical and technical perspective. In: *Proceedings of Second International Vegetable Soybean Conference,* Washington State University, Tacoma, Washington, USA, pp. 87–91.

Ma C H, Juroszek P, Palada M, Srinivasan R, Wang T C and Yang R Y. 2008. Integration of production technologies for organic vegetable soybean in Taiwan. *HortScience* **43**(4): 1106.

Masuda R. 1991. Quality requirement and improvement of vegetable soybean. *In*: Shanmugasundaram S (Ed.), *Proceedings of Vegetable Soybean – Research Needs for Production and Quality Improvement Workshop*, Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan, pp. 92–102.

Mebrahtu T, Mohamed A, Wang C Y and Andebrhan T. 2004. Analysis of Isoflavone contents in vegetable soybeans. *Plant Foods for Human Nutrition* **59**: 55–61.

Nair R M, Ravishankar M, Pan R S, Bhushan K B, Kaur D P, Ranchod G R, Yan M-R and Easdown W E. 2013. Vegetable soybean: a crop with potential to improve human nutrition and diversify cropping systems in northeast India. *In*: *Fifth International Symposium on Human Health Effects of Fruits and Vegetables* (FAV Health 2012) held in UAS Dharwad (India) 7-11 January 2013.

Pan R S, Singh A K, Kumar S and Rai M. 2007. Stability of yield and its components in vegetable soybean (*Glycine max*). *Indian Journal of Agricultural Sciences* **77**(1): 28-31.

Shanmugasundaram S. 2005. Designing vegetables with improved nutritional contents. *In*: Ramasamy C, Ramanathan S and Dakshinamoorthy M (Eds.), *Perspectives of Agricultural Research and Development*, Tamil Nadu Agricultural University, Coimbatore, India, pp. 541–61.

Shanmugasundaram S, Nair R M, Yan M R and Palada M C Vegetable soybean (Edamame) *In*: *Handbook of Vegetables*, Volume II (Eds. K V Peter and P Hazra). Forthcoming.

Shanmugasundaram S and Yan M R. 2004. Global extension of high value vegetable soybean. *In*: Moscardi F, Hoffmann-Campo C B, Saraiva O F, Galerani P R, Krzyzanowski F C and Carrão-Panizzi M C (Eds.), *Proceedings VII World Soybean Research Conference and VI International Soybean Processing and Utilization Conference*, Foz do Iguassu, PR, Brazil, pp. 915–20.

Shanmugasundaram S and Yan MR (1999) AVRDC vegetable soybeans for nutritional security, income generation and soil sustainability. *Proceedings of the WSRC-VI,* Chicago, USA, 4-7 August 1999, pp. 450.

Srinivasan R, Su F-C, Huang C-C, Lin M-Y and Hsu Y-C. 2009. *Integrated Pest Management in Organic Vegetable Soybean Production Conference on International Research on Food Security, Natural Resource Management and Rural Development*, University of Hamburg, 6-8 October 2009.

Talekar N S and Chen B S. 1983. Seasonality of insect pests of soybean and mungbean in Taiwan. *Journal of Economic Entomology* **76**(1): 34-7.

Yeh C C, Hartman G L and Talekar N S. 1991. Plant protection technology for vegetable soybean. Pp. 85-91. *In*: *Proceedings of the Workshop on Vegetable Soybean: Research needs for Production and Quality Improvement*, April 29 – May 2, 1991, Taiwan.

Soybean Research (Special Issue Number 2): 8-18: 2014

Molecular Characterization of *Beauveria bassiana* (Balsamo) for Management of Foliage Feeders in Soybean (*Glycine max* L.) – An overview

R S MARABI*[1], G K SATPUTE**[2], YOGRANJAN[3], S B DAS*[4] and O P VEDA*[5]
****Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004 and***
*****Directorate of Soybean Research (Indian Council of Agricultural Research), Indore 452 001, Madhya Pradesh, India***
E mail: rsmarabi78@rediffmail.com

ABSTRACT

Under density dependent factors, entomopathogenic fungi play an important role against insect-pests and are distributed in a wide range of habitats especially in diverse agro-ecosystem. About 380 species of insects have been reported worldwide on soybean. Among them, green semilooper, Chrysodexis acuta *(Fabricius) and tobacco caterpillar,* Spodoptera litura *(Fabricius) are major foliage feeder insects causing significant yield loss. To control these insect-pests a number of chemical insecticides are used injudiciously, which led to development of resistance in the insects, pest resurgence, adverse effect on natural enemies and create residual effect on environment. Exploitation of environmentally safe entomopathogens as biocontrol agents may be resorted to combat the devastating insect pests. The anamorphic entomopathogenic fungi* Beauveria bassiana *(Balsamo) is a potential natural enemy against foliage feeders of soybean. The evolution of fungal entomopathogenicity has been found to be associated with the production of some similar secondary metabolites. A large number of insecticidal and other bioactive secondary metabolites identified from* B. bassiana *are the cyclopeptides, beauvericin, bassianolide and beauverolide, the yellow pigment pyridines tenellin and bassiatin and the dibenzoquinone oosporein. Cytochrome P450s are involved in many essential cellular processes and play diverse roles in detoxification, degradation of xenobiotics, and the biosynthesis of pathogenesis related secondary metabolites. There are 6 ω- hydroxylase cytochromeP52enzymes in* B. bassiana, *which catalyze the first step in the ω-oxidation pathway of alkanes. The presence of CYP52s is consistent with efficiently metabolizing insect epicuticle alkanes. The insect fungal pathogens have 159 protein kinensis which are involved in pathogenesis, besides fungal growth, conidiation, stress responses, toxin production and sexual reproduction. This information will be beneficial in future molecular studies of insect-fungus interactions, and will facilitate in the development of cost-effective, mycoinsecticidal-property based, a viable crop protection technology.*

Key words: *Beauveria bassiana,* entomopathogenesis, IPM, secondary metabolites, *Spodoptera litura,* transformant

Among legumes, soybean [*Glycine max* (L.) Merrill], also classed in preeminent oilseeds, is recognized for its high contents of protein (38–45 %) as well as oil (around 20 %). It is a primary source of high-value secondary co-products which include lecithin, vitamins, nutraceuticals and antioxidants. The global demand for soybean remained strong and

[1and3]*Assistant Professor;* [2]*Senior Scientist;* [4and5]*Professor*

continues to grow, for its use as ingredients in the multitude of formulations, and keeps pace with the ever growing market of food, feed and industrial products. On account of utility and demand, the contribution this crop makes to the current global economy is estimated conservatively at € 48.6 billion (Wilson, 2008).

India falls fifth in rank (14.68 million tonnes) in soybean production from an area under cultivation of about 10.84 million hectare (Anonymous, 2013a), preceded by USA ranks first with its production 84.19 million tonnes followed by Brazil (74.82 million tonnes) and Argentina (48.88 million tonnes). More than 90 per cent of the production in India is contributed by leading soybean producing states, *viz;* Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka, where Madhya Pradesh alone aids its milestone contribution of about 52.35 per cent (6.28 mt) production from 58 per cent (about 5.67 mha) area (Anonymous, 2013b; William and Akiko, 2009; Jaiswal, 2011). Soybean *per se* ranks third in vegetable oil economy in India, after groundnut and rapeseed mustard.

Extensive farming during a few decades has experienced many biotic and abiotics constraints to the yield of soybean crop. A considerable biotic threat reclines beyond enormous soybean production. About 380 species of insects-pests and among them, particularly some major orthopteran pests attack soybean crop from cotyledon stage to harvesting stage, with a potential to limit economic production worldwide (Lukman, 1971). These defoliators, *viz;* tobacco caterpillar, *Spodoptera litura* (Fabricius), green semiloopers, *Chrysodeixis acuta* (Walker), *Thysanoplusia orichalcea* (Fabricius), *Spilarctia obliqua* (Walker) and *Helicoverpa armigera*(Hübner)feed on foliage, flowers and pods which cause significant yield losses (Singh and Singh, 1990). The green semilooper and tobacco caterpillar are voracious foliar feeders on soybean crop and found to be a serious threat to soybean production. The yield loss caused by green semilooper at flower initiation and pod filling stages ranged from 7.29-45.51 per cent and 9.43-46.49 per cent, respectively (Singh and Singh, 1991). Whereas, in a recent outbreak of tobacco caterpillar on soybean in Kota region of Rajasthan lead to an estimated loss of Rs 3,000 million. The pest has caused epidemic on soybean crop in Vidarbha region of Maharashtra in August, 2008 (Dhaliwal and Koul, 2010).

Management of crop pests customarily and heavily rely on synthetic chemicals, however, deleterious effects arising with the injudicious use of chemical insecticides in large quantities paved the way for development of resistance in the insects, pest resurgence and adverse effect on natural enemies, and residual effect on environment.The concept of environmentally sound integrated pest management (IPM) practices such as the use of biological control agents, cultural practices and host plant resistance are now being successfully incorporated into the routines of soybean farming. It is based on the application of pest control measures and reduction in the amount/frequency of chemical pesticides applied to an economically and ecologically acceptable level. Exploitation of environmentally safe entomo-pathogens as biocontrol agents, in the tune of IPM, may be resorted to combat these devastating insect-pests. The comparison of entomopathogens with conven-tional chemical pesticides is primarily from the perspective of their efficacy and cost. Additional advantages which cover safety aspects of other non-target organisms and humans, reduction of chemical pesticide residues in food, conservation of other natural enemies, and increased biodiversity in managed ecosystems make them good candidates for use in IPM systems (Romanowski, 2002).

Entomopathogenic fungi as an effective biological alternative aids in the natural ecological regulation component of many insects by mediating epizootics that lead to exponential declines in host populations (Meyling and Hajek, 2010). The entomo-pathogenic fungi are distributed in a wide range of habitats especially in diverse agro-ecosystem and take advantage of their natural association with the crop ecosystem. About 700 species of fungi from around 90 genera have expressed their virulence to insects. Most are found within the deuteromycetes and entomo-phthorales but some insect-pathogenic fungi have constrained host ranges (e.g., *Aschersonia aleyrodis* infects only scale insects and whiteflies) while other fungal species have a wide host range, with individual isolates being more specific, *viz*; *Beauveria bassiana, Metarhizium anisopliae* and *Verticillium lacanii. B. bassiana*is one of the best-known genera of entomopathogenic fungi and registered numerous marketable mycoinsecticide formulations worldwide (Thomas, 2007).

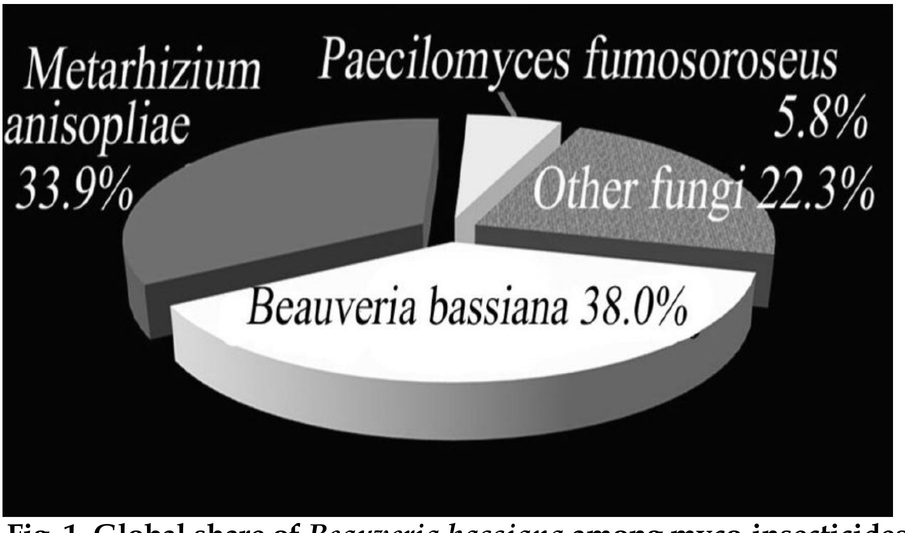


Fig. 1. Global share of *Beauveria bassiana* among myco-insecticides

***Beauveria bassiana*: Characterizationof aprospective entomopathogenic fungus**

A white muscardine fungus *Beauveria bassiana* (Balsamo) Vuillemin, an ascomycete of broad host range, demonstrates the potential entomopathogenic fungi and has a leading position to control pests such as borers and whiteflies of major crops including soybean, and ecologically hazardous pests such as fire ants and termites (Zhang *et al.*, 2011).Hosts of agricultural significance include insects of lepidoptera, coleoptera, orthoptera, hemiptera and several genera of isoptera order, which are infected by this bio-agent. This filamentous fungus belongs to a class deuteromycetes (imperfect fungus) and has been well characterized in respect to pathogenicity to the insects. A remarkable feature of *B. bassiana* is high host specificity of many of its isolates. A high level of persistence in the host population and in the environment provides long-term effects of the fungi on pest suppression.

As a contact bio-pesticide, entomopathogenic fungi target to parasitize susceptible hosts *via* direct penetration of the cuticle, covered by an outermost lipid layer mainly composed of highly stable very long chain structures, with the initial and potentially determining interaction occurring between the fungal spore and the insect epicuticle. *B. bassiana* expressing the neurotoxin showed a 15-fold increase of insecticidal activity against Masson's pine caterpillar (*Dendrolimus punctatus*), and its action on the larvae of *D. punctatus* and *Galleria mellonella* was accelerated 24 and 40 per cent (Lu *et al.*, 2008), respectively. These studies have found significance in the feasibility of enhancing fungal biocontrol potential by gene transformation. However, none of the genes transformed into the fungal pathogens was an intestine-specific virulence factor to enhance fungal infection *per se*, although foliage feeders may ingest a large number of conidia sprayed on crop leaves. Fungal infection of aphids was accelerated by over-expressing a silkworm chitinase or a hybrid chitinase in *B. bassiana* (Fang *et al.*, 2005 and Fan *et al.*, 2007).

Structural and chemical mechanisms of infection

Infection of the fungus begins with attachment of the spore either to the cuticle or mouth parts of insects to reach the haemocoel. The penetration of spores to cuticles is mediated by expression of a host of cuticle degrading enzymes and other factors in insects (Holder and Keyhani, 2005; Cho *et al.*, 2006). *B. bassiana* secretes the enzymes such as proteases and hydrolases that .facilitate breaching of the insect cuticle (Padmavathi *et al.*, 2003). The dry spores of *B. bassiana* possess an outer layer composed of interwoven fascicles of hydrophobic rodlets. This rodlet layer appears to be unique to the conidial stage and has not been detected on the vegetative cells. The adhesion of dry spores to the cuticle was suggested to be due to non-specific hydrophobic forces exerted by the rodlets (Boucias *et al.,* 1988). In addition, lectins, a kind of carbohydrate binding glycoproteins, have been detected on the conidial surface of *B. bassiana (*Wan *et al*., 2003). *B. bassiana* conidia germinate on the host surface and differentiate an infection structure termed appressorium. The appressorium represents an adaptation for concentrating physical and chemical energy over a very small area so that ingress may be achieved efficiently. Thus, formation of the appressorium plays a pivotal role in establishing a pathogenic interaction with the host. Appressorium formation may be influenced by host surface topography. Biochemical investigations indicate the involvement of the intracellular second messengers Ca2+ and cyclic AMP (cAMP) in appressorium formation (St Leger *et al.,* 1991). The ingested fungal spores/ conidia by foliage feeders, such as caterpillars, do not germinate and cause substantial infection in the gut due to the lack of intestine-specific virulence factors, and are voided in the faeces (St Ledger *et al.*, 1996). Pathogenicity of the entomopathogenic fungi varied with different developmental stages of the insect pest. Generally, early instars of the larvae are vulnerable to *B. bassiana* than late instars.

The death of the insect results from a combination of factors *viz;* mechanical damage resulting from tissue invasion, depletion of nutrient resources, sluggishness and toxicosis (Wan *et al.*, 2003). The host tissue incursion and parallel nutrient exhaustion occur by *in vivo* growth of hyphal bodies followed by penetration into the integument and, finally, evasion of the host immune system (Pendland *et al*., 1993; Lewis *et al*., 2009). Grown-up hyphal bodies turn into mycelial stage, which ultimately emerges from the insect producing externally borne conidiophores leading to the death of the insect (Zhang *et al*., 2011). Following the death of the host, fungal growth reverts back to the typical hyphal form – the saprotrophic stage. The ability to convert to the yeast-like phase may be a prerequisite for pathogenicity. In soybean crop, this anamorphic entomopathogenic fungi *B. bassiana* (Balsamo) has naturally been associated and proved to be a potential enemy against foliage feeders, particularly, *C. acuta* and *S. litura*. Among the environmental factors higher relative humidity at vegetative and flowering phase of soybean crop not only helps in proper seed setting and thereby ensures good seed yields, but also favours the cause of potential pathogenicity of *B. bassiana* to its foliage feeders.

Entomopathogenicity in *B. bassiana*: Metabolic adaptations, signaling cues and gene modulation

Favourable environmental conditions are required for conidia of *B. bassiana* to come in contact with cuticle of insect for infection. The entomopathogenic fungus *B. bassiana* acts slowly on insect pests through cuticle infection. A study by Qin *et al*. (2010) revealed thatfungal conidia can be used as vectors for spreading the highly insecticidal Vip3A protein through conidial ingestion and cuticle adhesion for control of foliage feeders such as *S. litura* and *C. acuta*. A transgenic strainof *B. bassiana* (BbV28) expressing Vip3Aa1 (a Vip3A toxin) was created to infect the larvae of the oriental leafworm moth, *S. litura*. Vip3Aa1 (approximately 88 kDa) was highly expressed in the conidial cytoplasm of BbV28 and was detected as a digested form (approximately 62 kDa) in the larval midgut 18 and 36 h after conidial ingestion. The larvae infected by ingestion of BbV28 conidia showed typical symptoms of Vip3A action, *i.e.*, shrinkage and palsy. However, neither LC (50) nor LT (50) trends differed between BbV28 and its parental strain if the infection occurred through the cuticle only. The evolution of entomopathogenicity of *Beauveria* has been found to be associated with the production of large array of biologically active secondary metabolites including nonpeptide pigments and polyketides with their specified functions.

Bassianolides interfere ionophoreantibiotic besides other peptides,

Table. Mode of action of mycotoxins produced by *B. bassiana*againstfoliage feeders

Mycotoxin	Mode of action	Reference
Oosporein	React with proteins leading to enzyme malfunction	Wilson (1971); Eyal *et al*.(1994)
Bassianin	Inhibit erythrocyte membrane and cell lysis	Mochizuki *et al*.(1993)
Tenellin	Membrane disruption; Cell lysis	Jeffs and Khachatourians (1997)
Beauvericin	Increase permeability of cell membrane; Cell death	Gupta *et al*.(1995)
Oxalic acid	Solubilize cuticular protein	Kodaira (1961)

viz. beauveriolides (Hamill, 1969; Elsworth, 1977), and secreted metabolites (Xu *et al*., 2009). Behavioural symptoms, such as partial or general paralysis, sluggishness and decreased irritability in mycosed insects are consistent with the synergistic action of these active secondary metabolites and neuromuscular toxins. There exists specific genes that regulate the biosynthesis of metabolites involved in fungal development, virulence, detoxification, insect immune avoidance and stress responses as depicted by comparative genome sequencing (Xiao *et al*., 2012), expressed sequence tag analyses (Cho *et al*., 2006), insertion mutagenesis (Wang *et al*., 2012) and gene functional studies (Fan *et al*., 2011) of *B. bassiana.* Adhesion of *B. bassiana* with insects is mediated by hydrophobins which governs hydrophobicity and virulence. At least two hydrophobins (Hyd1 and Hyd2) are responsible for rodlet layer assembly, contributing to cell surface hydrophobicity, adhesion to hydrophobic surfaces, and virulence (Zhang *et al*., 2011; Cho *et al*., 2007).

The surface composition of the insect cement and waxy layers includes various amounts of hydrocarbons (alkanes, alkenes and their methyl-branched derivatives), fatty acids and esters, alcohols, ketones, and aldehydes, with minor components including triacylglycerols, epoxides, and ethers, as well as tanned (cross-linked) proteins that impact and direct important aspects of environmental and behavioral interactions of the insect (Howard, 2005; Anderson, 2010). Seidl (2008) reported constitutive expression of GH18 family chitinases in *B. bassiana* to degrade insects` cuticle. Expression of a variety of hydrolytic enzymes such as trypsins, subtilisins, aspartic proteases, and carboxypeptidases subsists in relatively higher concentration in *B. bassiana* and have potential role in spore germination and growth of fungus across the surface of host and subsequent penetration of cuticular layers (Zhang *et al*., 2011). Xiao *et al*. (2012) reported eight genes in the *B. bassiana* genome that encode *Bt* Cry-like δ-endotoxins, suggesting *B. bassiana* to have greater oral toxicity than other fungi. Besides proteases and chitinases, virulence-related genes already characterized in *B. bassiana* include a MAP kinase mediating cell growth (Luo *et al*., 2012), a neuronal calcium sensor regulating extracellular acidification (Fan *et al*., 2012), a GH73 family of β-1,3-glucanosyltransferase maintaining cell well integrity and a cytochrome P450 enzyme degrading cuticular fatty acids (Zhang *et al*., 2011).

The first round of degradative pathway is presumably carried out by a cytochrome P450 enzyme system, where the metabolites traverse the peroxisomal membrane, and after successive transformations, provides the appropriate fatty acyl CoA for complete degradation in the peroxisomes and/or mitochondria, the site of β-oxidation in fungi (Pedrini *et al*., 2007). The biochemical mechanism encompasses NADPH-dependent addition of a terminal hydroxyl to the substrates (ω-hydroxylase). Thus far, eight cytochrome P450 (CYP) genes, four catalases, three lipase/esterases, long chain alcohol and aldehyde dehydrogenases, and a putative hydrocarbon carrier protein have been implicated as potentially participating in cuticular lipid degradation in *B. bassiana* (Pedrini *et al*., 2010; Pedrini *et al*., 2013). To date, the enzymatic activity and role of only one such protein, BbCYP52X1, has been confirmed as contributing to hydrocarbon assimilation and virulence *via* characterization of a targeted insertion mutant of the gene and heterologous expression and characterization of the protein in a yeast expression system (Zhang *et al*., 2012). Targeted gene-knockouts of the other

CYP genes had no effect on virulence, suggesting either that these proteins do not play a role in cuticular hydrocarbon assimilation or that functional redundancy masked any phenotypes (Pedrini *et al*., 2013). It can be inferred from current evidences concerning interaction between *B. bassiana* and foliage feeders of soybean crop that entomopathogenesis is a consequence of metabolic adaptations, signaling cues and gene modulation.

Molecular Studies in entomopathogenic fungi *B. bassiana*

Implementation of polymerase chain reaction-based (PCR) tools for characterization of organisms such as *B. bassiana* has greatly advanced the understanding of the phylogenies and species in entomopathogenic fungi. A number of unspecific DNA-based methods have been used specially in *B. bassiana* (Glare *et al*., 2008). Universally primed (UP) PCR has been used to separate sympatric isolates of *Beauveria* and was used to place isolates in genetic groups (Meyling and Eilenberg, 2006). UP PCR is based on longer general primers and a higher annealing temperature which makes it more robust in terms of reproducibility (Bulat *et al*., 1998, Bulat *et al*., 2000, Lubeck *et al*., 1999). Thakur *et al*. (2005) and Sandhu and Vikrant (2004) studied forty-eight isolates of indigenous strains of *B. bassiana* collected from Central India employing protease zymography and RAPD analysis. High genetic and biochemical diversities were indicated with a clear group of strains from Lepidopteran and Coleopteran insect hosts.

Beauveria species were characterized using RFLPs (Restriction Fragment Length Polymorphism), AFLPs (Amplified Fragment Length Polymorphism), inter-simple-sequence repeats (ISSRs), simple sequence repeats (SSRs), or microsatellites (Bidochka *et al*., 2001; De Muro *et al*., 2003 and Inglis *et al*., 2008). Internal transcribed spacer sequences (ITSs) have been widely used in fungal systematic (Bowman *et al*., 1992 and Driver *et al*., 2000). Digestion of PCR products of specific DNA regions, such as genes or ITS (internal transcribed spacer), with restriction enzymes yields fragments of variable sizes. In the case of the genus *Paecilomyces*, the analysis of sequences of the large and the small subunit *r*RNA gene has already indicated the polyphyly of the genus (Oborník*et al*., 2001 and Inglis and Tigano, 2006). Recent development of microsatellite markers (Rehner and Buckley, 2003; Enkerli *et al*., 2005) has surely provided an insight in the population ecology of*B. bassiana*.Ithas been linked to plants as an endophytic fungus (Arnold and Lewis, 2005).

EST (expressed sequence tag) analysis of entomopathogenic fungus *Beauveria* (*Cordyceps*) *bassiana* has been studied using cDNA libraries (Cho *et al*., 2006). *B. bassiana* is the anamorph (asexually reproducing form) of *Cordyceps bassiana*. Determination of temperature and relative humidity (RH) requirements would, further, allow the definition of places and periods with a higher probability of epizootic occurrence. By keeping the goal to enhance the insecticidal activity of conidia, generation of genetically stable transformant has been mentioned elsewhere (Qin *et al*., 2010).

Although several comprehensive studies have been made in recent years to characterize *B. bassiana*with respect to pathogenicity in major insects of lepidoptera, coleoptera, orthoptera, hemiptera and isoptera order, much regarding the molecular determinants that mediate these interactions in both the pathogen and susceptible foliage feeders related to soybean remains to be revealed. Such an understanding would certainly lead to new insights with increasing efficacy of mycoinsecticides as part of IPM practices in soybean. Decision making efforts towards the IPM should be to turn down the injudicious use of chemical pesticides and confined only on target pests keeping them under economic threshold level to view eco-friendly. Functional verification of genes responsible for entomopathogenecity can shed light on the ecology and evolution of virulence for their utilization in rational design of strategies at the increasing effectiveness of *B. bassiana* for management of these foliage feeders. The information will be beneficial for further strengthening the molecular studies as well as genetic engineering of insect-fungus interactions to facilitate the development of cost-effective, entomopathogenic-property based viable protection technology for foliage feeders in soybean.

REFERENCES

Andersen S O. 2010. Insect cuticular sclerotization: A review. *Insect Biochemistry in Molecular Biology* **40**: 166-78.

Anonymous. 2013a. Agricultural Statistics Division, Directorate of Economics and Statistics, New Delhi.

Anonymous. 2013b. Commissioner Land Records, Gwalior, Madhya Pradesh.

Arnold A E and Lewis L C. 2005. Ecology and evolution of fungal endophytes and their roles against insects. *In*: *Insect- Fungal Associations: Ecology and Evolution*, F E Vega and M Blackwell (Eds), pp 74–96, Oxford University Press.

Bidochka M J, Kamp A M, Lavender T M, Dekoning J and De Croos J N A. 2001. Habitat association in two genetic groups of the insect-pathogenic fungus *Metarhizium anisopliae*: uncovering cryptic species? *Applied and Environmental Microbiology* **67**(3): 1335–42.

Boucias D G, Pendland J C and Latge J P. 1988. Nonspecific factors involved in attachment of entomopathogenic deuteromycetes to host insect cuticle. *Applied and Environmental Microbiology* **54**: 1795–1805.

Bowman B H, Taylor J W, Brownlee A G, Lee J, Lu S D and White T J. 1992. Molecular evolution of the fungi: relationship of the *Basidiomycetes*, *Ascomycetes*, and *Chytridiomycetes*. *Molecular Biology and Evolution* **9**(2): 285–96.

Bulat S A, Lubeck M, Alekhina I A, Jensen D F, Knudsen I M B and Lubeck P S. 2000. Identification of a universally primed-PCR-derived sequence-characterized amplified region marker for an antagonistic strain of *Clonostachys rosea* and development of a strain-specific PCR detection assay. *Applied and Environmental Microbiology* **66** (11): 4758–63.

Bulat S A, Lubeck M, Mironenko N, Jensen D F and Lubeck P S. 1998. UP-PCR analysis and ITS1 ribotyping of strains of *Trichoderma* and *Gliocladium*. *Mycological Research* **102** (8): 933–43.

Cho E M, Liu L, Farmerie W and Keyhani N O. 2006. EST analysis of cDNA libraries from the entomopathogenic fungus *Beauveria* (*Cordyceps*) *bassiana*. I. Evidence for stage-specific gene expression in aerial conidia, in vitro blastospores and submerged conidia. *Microbiology* **152** (9): 2843-54.

Cho E M, Kirkland B H, Holder D J, Keyhani N O. 2007. Phage display cDNA cloning and expression analysis of hydrophobins from the entomopathogenic fungus *Beauveria* (*Cordyceps*) *bassiana*. *Microbiology* **153**: 3438-47.

De Muro M A, Mehta S and Moore D. 2003. The use of amplified fragment length polymorphism for molecular analysis of *Beauveria bassiana* isolates from Kenya and other countries, and their correlation with host and geographical origin. *FEMS Microbiology Letters* **229**(2): 249-57.

Dhaliwal G S and Koul O. 2010. *Quest for Pest Management: From Green Revolution to Gene Revolution*, Kalyani Publishers, New Delhi, pp 386.

Driver F, Milner R J and Trueman J W H. 2000. A taxonomic revision of *Metarhizium* based on a phylogenetic analysis of rDNA sequence data. *Mycological Research* **104**(2): 134-50.

Elsworth J F and Grove J F. 1977. Cyclodepsipeptides from *Beauveria bassiana* Bals. Part 1 Beauverolides H and I. *Journal of the Chemical Society, Perkin* **13**: 270-3.

Enkerli J, Kolliker R, Keller S and Widmer F. 2005. Isolation and characterization of microsatellite markers from the entomopathogenic fungus *Metarhizium anisopliae*. *Molecular Ecology Notes* **5**(2): 384-86.

Eyal J, Mabud A, Fischbein K L, Walter J F, Osborne L S and Landa Z. 1994. Assessment of *Beauveria bassiana* Nov. EO-1 strain, which produces a red pigment for microbial control. *Applied Biochemistry and Biotechnology* **44**: 65-80.

Fan Y, Fang W, Guo S, Pei X, Zhang Y, Xiao Y, Li D, Jin K, Bidochka M J and Pei Y.2007. Increased insect virulence in *Beauveria bassiana* strains over-expressing an engineered chitinase. *Applied and Environmental Microbiology* **73:** 295-302.

Fan Y, Ortiz-Urquiza A, Kudia R A and Keyhani N O. 2012. Bbcsa1, a fungal homolog of neuronal calcium sensor-1 regulates extracellular acidification and contributes to virulence in the entomopathogenic fungus *Beauveria bassiana*. *Microbiology* doi:10.1099/mic.0.058867-0.

Fan Y, Zhang S, Kruer N and Keyhani N O. 2011. High-throughput insertion mutagenesis and functional screening in the entomopathogenic fungus *Beauveria bassiana*. *Journal of Invertebrate Pathology* **106**: 274–9.

Fang W G, Leng B, Xiao Y H, Jin K, Ma J C, Fan Y H, Feng J, Yang X Y, Zhang Y J and Pei Y.2005. Cloning of *Beauveria bassiana* chitinase gene *Bbchit1* and its application to improve fungal strain virulence. *Applied and Environmental Microbiology* **71:** 363-70.

Glare T R, Reay S D, Nelson T L and Moore R. 2008. *Beauveria* caledonicais a naturally occurring pathogen of forest beetles. *Mycological Research* **112** (3): 352-60.

Gupta S, Montillor C and Hwang Y S. 1995. Isolation of novel Beauvericin analogues from the fungus *Beauveria bassiana. Journal of Natural Products* **58**(5): 733-738.

Hamill R L, Sullivan H R, and Gorman M. 1969. Determination of pyrrolnitrin and derivatives by gas-liquid chromatography. *Applied Microbiology* **18**: 310-2.

Holder D J and Keyhani N O. 2005. Adhesion of the entomopathogenic fungus *Beauveria* (*Cordyceps*) *bassiana*to substrata. *Applied and Environmental Microbiology* **71**: 5260-6.

Howard R W and Blomquist G J. 2005. Ecological, behavioral, and biochemical aspects of insect hydrocarbons. *Annual Review of Entomology* **50**: 371-93.

Inglis G D, Duke G M, Goettel M S and Kabaluk J T. 2008. Genetic diversity of *Metarhizium anisopliae* var. *anisopliae* in southwestern British Columbia. *Journal of Invertebrate Pathology* **98**(1): 101-13.

Inglis P W and Tigano M S. 2006. Identification and taxonomy of some entomopathogenic *Paecilomyces* spp. (Ascomycota) isolates using rDNA-ITS sequences. *Genetics and Molecular Biology* **29**(1): 132-36.

Jaiswal A and Hugar L B. 2011. An economic analysis of soybean cultivation vis-à-vis its competing cropsin Madhya Pradesh. *Karnataka Journal of Agricultural Sciences* **24**: 591-92.

Jeffs L Band Khachatourians G G .1997. Toxic properties of Beauveria pigments on erythrocyte membranes. *Toxicon* **35**(8): 1351-6.

Kodaira Y. 1961. Toxic substances to insects produced by *aspergillus ochraceus* and Oopsora destructor. *Agricultural and Biological Chemistry* **25**(3): 261-2.

Lewis MW, Robalino IV and Keyhani N O. 2009. Uptake of the fluorescent probe FM4-64 by hyphae and haemolymph-derived in vivo hyphal bodies of the entomopathogenic fungus *Beauveria bassiana*. *Microbiology* **155**: 3110-20

Lu D D, Pava-Ripoll M, Li Z Z and Wang C S.2008. Insecticidal evaluation of *Beauveria bassiana* engineered to express a scorpion neurotoxin and a cuticle degrading protease. *Applied and Environmental Microbiology* **81:** 515-22.

Lubeck M, Alekhina I A, Lubecks P S, Jensen D F and Bulat S A. 1999. Delineation of *Trichoderma harziannum* into two different genotypic groups by a highly robust fingerprinting method, UP-PCR, and UP-PCR product cross-hybridization. *Mycological Research* **103** (3): 289-98.

Luckmann W H. 1971. The insect-pests of soybean. *World Farm* **13**(5): 18-9 and 22.

Luo X, Keyhani NO, Yu X, He Z, Luo Z, Pei Y and Zhang Y. 2012. The MAP kinase Bbslt2 controls growth, conidiation, cell wall integrity, and virulence in the insect pathogenic fungus *Beauveria bassiana*. *Fungal Genetics and Biology* **49** (7): 544-55.

Meyling N V and Eilenberg J. 2006. Isolation and characterization of *Beauveria bassiana* isolates from phylloplanes of hedgerow vegetation. *Mycological Research* **110** (2): 188-95.

Meyling N V and Hajek A E. 2010. Principles from community and metapopulation ecology: application to fungal entomopathogens. *Biocontrol* **55**:39-54.

Mochizuki K, Ohmori K, Tamura H, Shizuri Y, Nishiyama S, Miyoshi E and Yamamura S. 1993. The structures of bioactive cyclodepsipeptides, Beauveriollides I and II, metabolites of entomopathogenic fungi *Beauveria* sp. *Bulletin of the Chemical Society of Japan* **66**: 3041-6.

Obornik M, Jirku M and Dolezel D. 2001. Phylogeny of mitosporic entomopathogenic fungi: is the genus *Paecilomyces* polyphyletic? *Canadian Journal of Microbiology* **47**(9): 813-19.

Padmavathi J, Devi K Uma and Rao C Uma Maheswara. 2003. The optimum and tolerance pH range is correlated to colonial morphology in isolates of the entomopathogenic fungus *Beauveria bassiana*–a potential biopesticide. *World Journal of Microbiology and Biotechnology* **19**: 469-77.

Pedrini N, Crespo R and Juárez M P. 2007. Biochemistry of insect epicuticle degradation by entomopathogenic fungi. Comparative Biochemistry and Physiology Part C: *Toxicology and Pharmacology* **146**: 124-37.

Pedrini N, Ortiz-Urquiza A, Huarte-Bonnet C, Zhang S and Keyhani N O. 2013. Targeting of insect epicuticular lipids by the entomopathogenic fungus *Beauveria bassiana*: Hydrocarbon oxidation within the context of a host-pathogen interaction. *Frontiers in Microbiology* **4**: 24.

Pedrini N, Zhang S, Juarez M P and Keyhani N O. 2010. Molecular characterization and expression analysis of a suite of cytochrome P450 enzymes implicated in insect hydrocarbon degradation in the entomopathogenic fungus *Beauveria bassiana*. *Microbiology* **156**: 2549-57.

Pendland J C, Hung S Y and Boucias D G. 1993. Evasion of host defense by in vivo-produced protoplast-like cells of the insect mycopathogen *Beauveria bassiana*. *Journal of Bacteriology* **175**: 5962–69.

Qin Y, Ying SH, Chen Y, Shen ZC, Feng MG. 2010. Integration of insecticidal protein Vip3Aa1 into *Beauveria bassiana* enhances fungal virulence to Spodoptera litura larvae by cuticle and *per os* infection. *Applied and Environmental Microbiology* **76**: 4611-8.

Rehner S A and Buckley E P. 2003. Isolation and characterization of microsatellite loci from the entomopathogenic fungus *Beauveria bassiana* (Ascomycota: Hypocreales). *Molecular Ecology Notes* **3**(3): 409-411.

Romanowski V. 2002. *Engineered Baculovirus Insecticides*, the 35th annual meeting of the Society of Invertebrate Pathology, Foz Do Iguassu, Brazil.

Sandhu S S and Vikrant P. 2004. Myco-insecticides: control of insect pests. In: *Microbial Diversity: Opportunities and Challenges*, Gautam S P, Sandhu S S, Sharma A and Pandey A K (Eds), Indica Publishers, New Delhi, India, 2004.

Seidl V. 2008. Chitinases of filamentous fungi: a large group of diverse proteins with multiple physiological functions. *Fungal Biology Reviews* **22**: 36-42.

Singh O P and Singh K J. 1990. Insect pests of soybean and their management. *Indian Farming* **39**(100)**:** 9-14.

Singh O P and Singh K J. 1991. Economic threshold level for green semilooper, *Chrysodeixis acuta* (Walker) on soybean. *Tropical Pest Management* **37**: 399-402.

St Leger R J, Joshi L, Bidochka M J, and Roberts D W. 1996. Construction of an improved mycoinsecticide overexpressing a toxic protease. *Proceedings of the National Academy of Sciences*, USA **93**: 6349-54.

St Leger R J, Roberts D W and Staples R C. 1991. A model to explain differentiation of appressoria by germlings of *Metarhizium anisopliae*. *Journal of Invertebrate Pathology* **57**: 299-310.

Thakur R, Rajak R C and Sandhu S S. 2005. Biochemical and molecular characteristics of indigenous strains of the entomopathogenic fungus *Beauveria bassiana* of Central India. *Biocontrol Science and Technology* **15** (7): 733-44.

Thomas M B and Read A F. 2007. Can fungal biopesticides control malaria? *National Review Microbiology* **5**: 377-83.

Wan Hong, Andreas Leclerque and Hans Ulrich Schairer. 2003. Development of a new dominant selectable marker, sorR, for fungal transformation. (Biotechniques, In preparation) mmi_**7613 811..826.**

Wang Z L, Lu J D and Feng M G. 2012. Primary roles of two dehydrogenases in the mannitol metabolism and multi-stress tolerance of entomopathogenic fungus *Beauveria bassiana*. *Environmental Microbiology* **14**: 2139-50.

William S and Akiko A. 2009. *History of Soybeans and Soyfoods in Africa (1857-2009): Extensively Annotated Bibliography and Sourcebook,* Soyinfo Center, Lafayette, USA, pp 485.

Wilson B J. 1971. Miscellaneous *Aspergillus* toxins. *In*: Ciegler A, Kadis S and Aje S J (Eds). *Microbial toxins: A Comprehensive Treatise*, **6,** Academic Press (New York): 288-9.

Wilson R F. 2008. Soybean: market driven research needs. *In*: *Genetics and Genomics of Soybean*, Springer, New York, pp 3-15.

Xiao G, Ying S H, Zheng P, Wang Z L, Zhang S, Xie X Q, Shang Y, St Leger R J, Zhao G P, Wang C and Feng M G. 2012. Genomic perspectives on the evolution of fungal entomopathogenicity in *Beauveria bassiana*. *Scientific Report* **2**: 483.

Xu Y, Orozco R, Kithsiri Wijeratne E M, Espinosa-Artiles P, Leslie Gunatilaka A A, Patricia Stock S, Molnár I. 2009. Biosynthesis of the cyclooligomer depsipeptide bassianolide, an insecticidal virulence factor of *Beauveria bassiana*. *Fungal Genetics and Biology* **46**: 353-64.

Zhang S Z, Xia Y X, Kim B and Keyhani N O. 2011. Two hydrophobins are involved in fungal spore coat rodlet layer assembly and each play distinct roles in surface interactions, development and pathogenesis in the entomopathogenic fungus, *Beauveria bassiana*. *Molecular Microbiolology* **80**: 811-26.

Zhang S, Widemann E, Bernard G, Lesot A, Pinot F, Pedrini N and Keyhani N O. 2012. CYP52X1, representing new cytochrome P450 subfamily, displays fatty acid hydroxylase activity and contributes to virulence and growth on insect cuticular substrates in entomopathogenic fungus *Beauveria bassiana*. *Journal of Biological Chemistry* **287**: 13477-86.

Zhang S, Xia Y X and Keyhani N O. 2011. Contribution of the gas1 gene of the entomopathogenic fungus *Beauveria bassiana*, encoding a putative glycosylphosphatidylinositol-anchored beta-1,3-glucanosyltransferase, to conidial thermotolerance and virulence. *Applied and Environmental Microbiology* **77**: 2676-84.

Soybean Research (Special Issue Number 2): 19-32: 2014

Breeding Strategies for Breaking Yield Barrier in Soybean Production in India

PUSHPENDRA[1], KAMENDRA SINGH[2], M K GUPTA[3], PRAVEEN KUMAR[4] and PRIYANKA BHARETI[5],
Department of Genetics and Plant Breeding,
Govind Ballabh Pant University of Agriculture and Technology,
Pantnagar 263 145, Uttarakhand, India
E mail: pushpendra_sb@yahoo.co.in

ABSTRACT

*Soybean [*Glycine max *(L.) Merrill] has now been established as number one oilseed crop in India. Poor adoption of improved production and protection technology and narrow genetic base of Indian soybean varieties are the major constrains for low productivity (1.27 t/ha). Various option, such as widening the genetic base through introgression of desirable gene form wild and primitive species,* Glycine soja, Glycine tomentela *(2n = 78) and exotic germplasm preferably from tertiary gene pool (GP 3) are available for raising the genetic yield potential. Designing plant ideotype possessing high biological yield with optimum harvest index, induction of longer juvenility trait, four seededness with high pod density per nod, appropriate maturity* etc.*, are some other important considerations.* Glycine soja*, UPSM 534, EC 241780 and EC 241778 are the potential sources of resistances and are being used to transfer the resistance in high yielding background separately for important disease like YMV and rust resistance. Mutation breeding is another option for defect rectification from promising genotypes as well as creation of genetic variability, utilization of hybrid vigour using male sterility for the development of commercial hybrids, identification of transgressive segregates from the diverse multi-parental crosses* etc.*, are the important considerations need to divert attention for breaking the yield barriers. Transfer of desirable gene across the sexual barrier using DNA marker technology and application of marker assisted selection for identification of QTLs for yield and yield contributing traits may open up avenues for further soybean improvement programme.*

Key words: Four seededness, ideotype**,** juvenility trait, narrow genetic base, QTLs, YMV

Soybean (*Glycine max* (L.) Merrill), an important oilseed plant, is called "protein hope of future" for its nutritive value. Soybean is strictly self-pollinating legume with 2n = 40 chromosomes belongs to family *Fabaceae*. The estimates of world soybean area, production and productivity for 2012-13 are 108.75 m ha, 268.00 mt and 2.25 t per ha, respectively and the crop alone contributes about 57 per cent of total oilseeds production that makes soybean the world's number one oilseed crop. In India, soybean is continuing number one oilseed crop followed by rapeseed and mustard, groundnut and sunflower. The country has seen an unprecedented growth in soybean area which was just 0.03 m ha in 1970 and has reached to 10.6 m ha in 2012 with production 12.67 m t (Anonymous, 2012-13). However, productivity is hovering around 1.2 t per ha as compared to world productivity of 2.25 t per ha. Soybean plays an important role in the oil

[1]Professor; [2]Professor; [3] Technical Assistance; [4]Ph. D. student; [5]Senior Research Fellow

economy and foreign earning as it contributes 43 per cent and 25 per cent to the total oilseeds and edible oil produced in the country. The USA, Brazil and Argentina now dominate global soybean production. These three countries harvested 81 per cent of the world soybean production. Today, soybean occupies a significant place in Indian agriculture and has been instrumental in changing the socio-economic status of the farmers, particularly in central part of India. Soybean has the ability to fix atmospheric nitrogen through its symbiotic interaction with rhizobia and therefore, has served as a model species for sustainable agriculture, due to its reduced need for added nitrogen fertilizer as well as its ability to supply fixed nitrogen in crop rotations.

During the last three decades of soybean improvement, significant advances in improvement of soybean yield potential have been made in India. The efforts have been made through various means by using existing and induced genetic diversity for yield and related traits. By reviewing the soybean breeding for yield and related characters in India, Bhatnagar and Karmakar (1995) and Karmakar (2001) had suggested that there is a need to use of diverse germplasm for breeding programme for the improvement of yield and yield related traits. They also stressed upon the need for enhancing high yield potential of 3.5-4.0 tonnes per ha for medium maturity and 2.5-3.0 tonnes per ha for early maturity group of varieties. Raut (1988) advocated exploiting the heterosis for improvement of high yield based on inter-relationship of quantitative characters. To develop suitable strategy for improving the productivity levels of soybean it is imperative to access the status of present yield level and gap between the potential yield and actual yield obtained by the farmers.

Constraints

The challenges growers face in soybean production are unpredictable weather, diseases, insect-pests, weeds and variable soil quality. Soybean is affected by all of these variables. Some strategies for increasing yields include the use of fertilizers and pesticides, while others involve developing new plant varieties that are best suited to the needs of the farmers. Farming practices may control some of these abiotic constraints, but many such as, drought, flooding and frost may be tackled through appropriate breeding approaches. In more arid climates, drought can reduce the productivity at both vegetative growth stage and time to maturation, reducing the pod formation and reduction in seed size.

Important physiological attributes such as, leaf area index, crop growth rate, relative growth rate, net assimilation rate and specific leaf weight can address various constraints of a variety for increasing its productivity. For optimum yield in soybean, the leaf area index should be from 3.5 to 4.5 (Jin Woong *et al.*, 2005). The dry matter accumulation may be the highest if the leaf area index attains its maximum value within the shortest possible time. In soybean, low yield potentiality is mainly for its reproductive attributes where flower production and fruit development stages incorporate to vegetative growth at same time. Therefore, developing reproductive sinks are competitive for assimilates to vegetative sinks. The capability of efficient partitioning between the vegetative and reproductive phase may produce high economic yield (Maola, 2005). Floral abscission is also a great barrier in high yield potentials. From 70-85 per cent of soybean flowers do not develop into mature pods and abscise. Poor plant population at farmer's field is one of the major constraints for poor yield. In order to harness to high yield potential of improved varieties under tropical conditions, the breeders should be vigilant to retain good seed longevity and resistance to pod shattering while selecting a higher seed yield components.

Management for productivity enhancement

Some important aspects emerged as a result of interaction among the scientist and the soybean growers are enumerated below.

1. Cost of cultivation must be brought down by adopting improved low cost cultivation practices and mechanization.
2. Adoption of recommended appropriate production and protection technology will result in further increase of yield to 3.5-4.0 t per ha.
3. Varietal cafeteria approach should be followed, at least 4-5 promising varieties, suitable for the recommended area should be grown for better elasticity in case of any calamity.
4. Higher seed replacement rate would yield better results, where farmers generally used their own commercially produce of previous year for planting of next crop. The farmer's seed should be replaced with certified seed after every 3 years.
5. Farmers should be trained in the technology of production of high quality seed. Moreover private sector should be encouraged along with public sector to make available high quality seed of new varieties at reasonable price.
6. Crop rotation must be encouraged. After three years of soybean cultivation, one non-legume crop should be grown on the same field. This will minimize the incidence of disease, pest and depletion of soil fertility.
7. In regions facing problems of frequently excess and shortage of soil moisture due to heavy or scanty rains, planting of soybean on ridges would yield better results.
8. Timely availability of high quality seed of improved varieties, fertilizers and agro-chemicals should be ensured at reasonable price.
9. Balanced application of major and minor plant nutrients is essential for higher production and quality of produce. Sulphur application with recommended dose 20-30 kg per ha was found effective.

Varietal history

Before 1940, soybean was mostly grown as a forage crop and in general, the cultivars were prone to lodging and pod shattering. Intensive soybean breeding programmes were initiated under AICRP on soybean improvement project at Govind Ballabh Pant University of Agriculture and Technology Pantnagar, Uttar Pradesh (now Uttarakhand) and Jawaharlal Nehru Krish Vishwa Vidyalaya, Jabalpur, Madhya Pradesh during 1968, where conventional breeding strategies have made significant improvements in soybean yield, quality, disease and insect-pest resistance and consequently soybean became a major from a minor crop in about 60 years. Overall goal of plant breeders had been focused on to increase yield with improved quality and resistance to biotic and abiotic stresses. So far more than 100 varieties have been released for various agro-ecological zones of the country. Karmakar and Bhatnagar (1996) reviewed the breeding progress of soybean varieties released in India. Up to 1970, numbers of varieties were developed through introduction and selection from exotic and indigenous material. Subsequently, between

1980 and 1990, majority of varieties were developed through hybridization and a few through selection and mutation. The breakup of varieties developed through different breeding methods as introduction (8), selection (16), mutation (5) and through hybridization (37). Depending on their breeding history earlier varieties released in India can be grouped into different selection cycles *viz*., Selection cycle 1: originated through selection from exiotic and indigenous germplasm, Selection cycle 2: varieties of selection cycle 1 further used to generate new variability through hybridization or mutation breeding and superior genotypes selected and released as new improved varieties.

The yield gain from breeding for 43 varieties released during the period ranging from 1969-1993 was assessed by Karmaker and Bhatnagar (1996). The mean seed yield of varieties in Selection cycle 2 was approximately 19 per cent higher than the average yield of Selection cycle 1. This was the result of 16 per cent increase in harvest index and 5 per cent increase in biomass. The annual genetic gain in seed yield of soybean varieties in India between the periods was approximately 22 kg per ha. The yield potential of recently released varieties have attained 3.5-4.0 t per ha. Bhardawaj *et al.* (2002) examined the pedigrees of 66 soybean varieties released in India during 1968 to 2000. They traced back to 76 ancestors. The cultivar Bragg from the United States was the most frequently used ancestor and occurred as a direct parent in 15 out of 66 pedigrees.

Broadening the genetic base

Introducing novel germplasm sources in breeding programmes, such as plant introductions (PIs), may provide the necessary genetic variability for the continuous development and adaptation of cultivars to biotic and abiotic factors. Therefore, plant germplasm is a natural source to broaden the current soybean genetic base (Chung and Singh, 2008). The potential of soybean breeding is enormous, currently, a small fraction of the existing accessions in germplasm collections contribute to the genetic base of the present cultivars. Tiwari (2001) and Karmakar (2001) observed that the genetic base of Indian released varieties is very narrow as the trend of hybridization is locally adopted, elite x elite germplasm lines. Therefore, there is need for broadening the genetic base of soybean varieties. Narrow genetic base of the cultivated varieties is considered as the direct cause of genetic vulnerability. Normally, natural populations may suffer from natural calamities but they are still genetically more flexible to adapt themselves or to evolve with the calamities while commercial cultivars are genetically uniform that their population is inflexible enough to do so (Simmonds, 1979). The wild soybean contained higher protein content than the cultivated soybean with the highest recorded content as high as 55.7 per cent (Li, 1990) and its seed oil is rich in linolenic acid. These precious wild soybean resources have unpredictable potential for exploitation of the high protein and disease resistant varieties as well some other useful gene sources. Wild soybean has also been responsible for widening the genetic basis of the cultivated soybean, that can reciprocally intercross with cultivated soybean without any reproductive isolation producing fertile progenies and its genes are easily transferred into cultivated soybean.

Breeding approach for yield enhancement

Yield is a complex polygenic trait influence with genotypic x environment interaction and dependent upon several other agronomic characters. In soybean, major yield component are number of nodes per plant, number of pods per plant, seeds per plant, seed size, dry matter and harvest index, *etc*. For yield enhancement major emphasis of breeding programme should be focused on to synthesize a variety with all the variable combination of these characters. It is quite obvious that it is not possible to incorporate the desirable combination in one genotype. Different trait combinations are important in different variety that is responsible for high yield. In some cases high pod number per plant could be responsible for high yield, while in others large seed size may be responsible. Following important considerations needs to be taken care of, while generating the breeding material for soybean improvement.

- There is a need of further strengthening of soybean germplasm resources both indigenous and exotic and proper evaluation under hot spots as well as multiplication testing and identification for the characters of economic importance.
- There is a need to procure finishing product/breeding lines/germplasm from Brazil, IITA and China.
- Use of single seed descent and off-season nurseries for effective evaluation and selection of desirable genotypes.
- Adequate the population size particularly for the traits dealing with quantitative inheritance and for identification of transgressive sergeants.
- Fostering the development of private sector breeding programme by developing protocol in collaboration with public sector.
- Incorporation of new traits related to yield enhancement *viz*.; improvement of biomass, harvest index, value addition, incorporation of long- juvenile trait and rapid seed fill, development of bold seeded lines relating good seed longevity, resistance to mechanical damage in seeds, food uses, pyramiding genes for resistance to rust and YMV, pre-breeding to combine the resistance available in different donor lines.

Seed yield advantage of narrow row soybean cultivation has shown variable results.

The optimum seed yield was influenced by portioning of photosynthates into the seed production. Number of pods per plant is yield contributing traits. Increase pod load at treated node was not compensated by the reduction in pod number compensatory decrease in seed size. Overall significant trend to greater total seed weight per plant was associated with increase of pod number. Foliar applications of selected cytokines could temporarily increase pod number.

In soybean yield variation of single cultivar across location and years associated with change in number of seed per unit area. The yield component is largely determined during the period that begins in flowering and extends through pod set duration of critical period in soybean may modified by manipulating plant response to environmental factors controlling development mainly temperature and photoperiod. Long photoperiod has also been found to increase the duration of post flowering phase, increase biomass and yield per plant. Expansion to long photoperiod has been found to increase seed numner by means of higher node production and fertility.

Extent of seed loss due to pod shattering may range from negligible to significant depending upon genetic constitution of variety, time of harvesting and environmental conditions. Better production could be attended by developing the resistant varieties against pod shattering to minimize the shattering loss. The further genetic enhancement of yield in soybean and its stability under rainfed condition is of utmost importance. The major biotic stress, which reduce soybean productivity under Indian conditions are diseases like yellow mosaic virus, rust, rhizoctonia, anthracnose, *etc.* and insect-pests like stemfly, girdle beetle and various defoliators. Being a rainfed crop, drought is a major abiotic stress, which limits the productivity of soybean in India. Therefore, breeding for tolerance to drought is important consideration for increasing the average productivity in the major areas, where the drought causing significant yield loss. Looking at the future climate change, the breeding programme should also focus on development varieties with tolerance to high temperature conditions and better response to alleviate levels of CO_2. Early maturity is an important breeding objective, just to fit it in the multi-crop situation and secondly to escape moisture stress in late season.

Identification of breeding need

Gai *et al.,* (1999) advocated the basic approach to enhance the productivity of soybean by accumulating the positive yield genes into one line from diverse source and accordingly classified the strategies and approaches for future breeding towards high yield.

- Setting target for yield improvement
- Genetic yield potential through further assembling of positive yield genes
- To support yield genes with plant architecture genes as their genetic background
- To ensure the yield potential utilizing through genetic control of negative factors
- Improving productivity of soybean through genetical enhancement
- Enhancing and enriching the gene pool to broaden the genetic base and maintenance of genetic wealth
- Development of new varieties that would fit into diversed crop management regimes in changing weather patterns
- Exploitation of heterotic vigor to create an opportunity development of hybrids for further increasing yield potential
- Exploitation of new biotechnological tools with conventional breeding exercising efficient selection in reduced time frame
- Breeding varieties that could cope with biotic and abiotic stresses

Incorporation of long juvenile trait

Incorporation of long juvenile trait to delay flowering under short day condition has been found to impart high yielding ability lines for photoperiodic adaptation to different sowing date. Since long juvenility trait causes a delay in flowering and maturity, it is necessary to identify lines that show rapid seed fill so that maturity of the line is not delay beyond the acceptable level. Germplasm lines possessing long juvenile trait *viz.,* PI 159925, PI 240664, Santa Maria, Ocepar 8, Ocepar 9 and Paragonia were introduced from Brazil and USA, may be utilized by combining longer juvenile trait along with genes for high total biomass and high harvest index. Similarly using of *Glycine soja* that has 75-80 days vegetative phase and 45-50 days as reproductive phase (quick seed fill phase) and its derived lines (pre-breeding lines) may be used for enhancing long juvenility trait along with short seed fill stage. Breeding work at Pantnagar is under progress to generate pre-breeding lines possessing longer juvenile phase coupled with high yield and other yield contributing traits *viz.*, high biomass and harvest index using *Glycine soja* as a donor parent.

Long juvenility *i.e.,* delayed flowering under short day conditions, is important for obtaining high biomass and high yield in the context that the growing period in India is about 100 days compared to 130 to 140 days in USA. The yield comparisons across the countries and latitude should be based on productivity per day rather on absolute yield realization. Characters *viz.*, high pod-fill duration/high rate of seed-fill, super nodulation and promiscuity, high pod number per unit area, and more number of seeds per pod are also important and breeding programms have taken these into account.

Plant idotype

One of the important strategies for improving soybean seed yield will be developing cultivars with ideal plant type or ideotype. Short petiole is potentially useful to improve soybean yield by altering the soybean canopy profile and increasing planting density (You *et al.,* 1995). Though the petiole length of a soybean plant is changeable by photoperiod and light quality (Thomas and Raper, 1985), distinctively short petiole is heritable and can be used for soybean improvement programme. One of the effective strategies for increasing seed yield is to develop new cultivars with ideotype which contributes to both improving photosynthesis and efficient distribution of photosynthates. Kokubun (1988) investigated the characteristics of high yielding soybean cultivars in relation to yield determining process, and suggested an ideotype with the upper leaves vertically closed as a high yield model. The non-branching habit is very important characteristic of ideotype for seed crops, which causes an increase in the planting density and the seed yield particularly delayed planting. Cooper (1981) suggested that the use of semi-dwarf genotype, higher plant population, high fertility and supplemental irrigation are the requirement for harnessing the high yield potential in soybean. The ideal soybean plant for high yield should have determinate or semi-determinate growth habit (suited to short growing session), erect and non-lodging, rapid leaf area index development and seed fill duration, and maturity duration of 95-100 days. Besides yield, the other essential characters required for soybean in tropics are resistance to pod shattering and good seed longevity.

For yield improvement, yield components *viz.*, pods per plant, number of nodes per plant, seed weight, harvest index and total biomass production is being the basis for the increased production as well as productivity in soybean. Improved genotype should have useful correlation with these yield determining traits coupled with sturdy plant type free from lodging and shattering. Accumulation of total dry matter at R1 (first flowering) and at R5 (start of seed filling) are promising predictors for optimum yield in soybean.

Four seededness

Soybean breeders focused attention on three major components of yield *viz.*, number of pods per plant, number of seeds per plant, and seed size to enhance yield, so far. However, an increase in yield often results from increase in the number of seeds per pod. In this regard, the four seeded pod trait has shown a good promise. Expression of 2-3 seeds per pod is common feature in most of the existing cultivar in soybean. A few plants with increased frequency of four seeded pods were identified in a segregating generation derived from the interspecific cross of cultivated soybean, *Glycine max*, with its proposed wild progenitor *Glycine soja* (Seib. and Zucc.). The inheritance of four seeded pods in crosses originating from an EMS-derived mutant with its parental cultivars, exibited control of single recessive locus with a segregation ratio of 3:1 (low to high seeds per pod values). Comparison between four seeded pod cultures and common cultures (without four seeded pods), Shrivastava *et al.* (2009) revealed that among four seeded pod cultures 81.5 per cent (24.5 % four seeded and 57 % three seeded) pods were contributed by pods with higher number of seeds. Whereas, among common cultures only 40.7 per cent pods were shared by three seeded pods and remaining 59.3 per cent by two and one seeded pods. In this way, 16.3 per cent more three seeded pods and 36.6 and 4.2 per cent less two seeded and one seeded pods, respectively were recorded among four seeded pod cultures than common cultures. However, common cultures were found superior for number of pods per plant recording more average (56.5) and maximum (92.6). As four seeded pods and number of pods are independently inherited traits, the hybridization between genotypes of four seeded pods and common cultures with higher number of pods may lead to better recombinants. The proposed four seeded plant ideotype may enhance 27 per cent yield potential of future cultivars. Morphological markers, narrow leaflet and microsatellite markers Sat_107 had close linkage with the locus responsible for four seeded pods (3.2± 1.1 cM) and both were effective in selecting the four seeded pods traits, although with different efficiencies. From the breeding point of view, the number of seeds per pod and its weight has the significance and positive relevance as a quantitative yield component. It revealed that the gene responsible for four and three seeded pods follows a certain ratio with diferential expressivity. The gene responsible for four seeded pods had low expressivity (25 %) at the basal parts of the plant, equal (50 %) in the middle but higher (75 %) at the distal parts of the plants in relation to three seeded pods. Four and three seeded pods did not differ in the penetrance as both have nearly 50 per cent penetrance at the plant level. However four seeded pods had high penetrance in the distal parts (67 %), whereas low at basal part (31 %). Thus four and three seeded pods with low penetrance appeared to be weak or instable at different stage of development. It revealed that higher yield might be achieved through hybridization between lines that have heavy top and heavy bottom with high penetrance of four seeded pods.

Mutation breeding

Mutation breeding in soybean has lagged behind as compared to the other economically important crops. Maluszynski *et al.* (2000) compiled information on cultivars produced using induced mutations. They listed 89 soybean cultivars developed by various mutagens worldwide, and China had released 54 of those soybean varieties. Liu *et al.,* (2004) listed 55 soybean varieties released through mutagenesis in China. These varieties contained many improved traits particularly for oil and protein, earliness, drought tolerance, yield and disease resistance. Mutagenic induction in soybean has produced considerable genetic variation for both qualitative and quantitative traits (Rawlings *et al.*, 1958; Papa *et al.,* 1961; Santos *et al.,* 1970; Imam, 1978 and Maheshwari *et al.,* 2003) from which desirable and useful mutants could be selected. The traits meliorated by mutation include high oleic acid content (Tagaki *et al.,* 1998), fatty acid composition (Hammond and Fehr, 1983; Fehr *et al.,* 1991; Wilcox and Cavins, 1990), high protein content (Srisombun *et al.,* 2009), increased pod number per plant (Tambe and Apparao, 2009), herbicide tolerance (Sebastian and Chaleff, 1987; Sebastian *et al*., 1989), plant type (Khan *et al.,* 2004), early maturity (Neto and Alves, 1997) and breaking linkage block (Hajika *et al.,* 1995). In India seven soybean cultivars *viz*., Birsa Soy 1, VL Soy-1, NRC 2, NRC 12, Pusa 97 12, TAMS 38 and TAMS 98 21 have been released for different climatic zone by mutagenesis. Manjaya and Nandanwar (2007) have identified four high yielding mutants (M-21, M-76, M-91 and M-107) had 15-20 per cent higher yield than the best control.

Male and female reproductive structures play an important role in seed development in plants. Abnormalities in male or female reproductive structures can lead to sterility. In soybean, *Glycine max* (L.) Merrill, about 75 sterility mutants have been identified and most of them have been mapped to chromosomes. Mapping results have shown that some chromosomal regions are hot spots for fertility genes. Fine mapping of some of the male-sterile, female-fertile mutants and male-sterile, female-sterile mutants resulted in identification of candidate genes for fertility. A CACTA-like transposable element that is responsible for reversion from sterility to fertility has been identified, and complete association between the presence of a transposon and sterility also has been shown. Soybean primary trisomics have been used to locate genes on chromosomes. Cytoplasmic male sterility, with nuclear restoration and maintainer genes, has been identified in soybean (Palmer *et al.,* 2011). Commercial production of hybrid seed has not been achieved. The high cost of the F1 seed is the obstacle. Seed-set on male-sterile plants is a strong indicator of insect pollinator preference. In soybean, identification of an environmentally stable male-sterility system could make hybrid seed production commercially valuable. An environmentally sensitive male sterile, female fertile mutant (*ms8*) has been identified. Inheritance studies showed that sterility in the mutant is inherited as a single gene. Breeding for defect elimination particularly susceptibility to important diseases like yellow mosaic virus, rhizoctonia aerial blight, rust and earliness using mutagenesis may be an effective way to enhance the high yield potential in soybean. Mutagenesis is also an effective tool that can be exploited to break the linkage between two closely linked genes.

Breeding for hybrid soybean

Attempts to produce commercial hybrid soybean cultivars have not succeeded because of (i) unavailability of a good system of producing male sterile plants, (ii) the seeds set on male sterile plants is often very low due to its unattractive flower for insect vector, and (iii) the difficulty in producing hybrids greatly limits the number of parental combinations that can be tested in order to find commercially acceptable heterosis. A patent, No. 4 545 146 (October 8, 1985), has been granted for hybrid soybean production (Davis, 1985). Sun *et al.* (1997) isolated a stable, cytoplasmic nuclear male sterile soybean line (cms; A line) and its maintainer (B line) from an interspecific hybrid between *G. max* and *G. soja*. This system has been used to develop experimental hybrid cultivars. Several genic (nuclear) male sterile (gms) soybean lines (ms1 through ms 9) are available, male sterile lines can be used to produce hybrid seeds. More than 99 per cent of the seed set on monogenic ms1 ms1 male-sterile plants resulted from natural crossing (Brim, 1973). Distinguishing morphological markers that are visible in seedlings and are tightly linked with gms would facilitate early identification of gms plants. Skorupska and Palmer (1989) recorded close linkage between the w1 locus (white flower and green hypocotyls) and the ms 6 locus. Lewers *et al*. (1996) suggested a cosegregation method for hybrid soybean production by utilizing w1 ms6 genetic stock: purple hypocotyl seedlings are removed shortly after germination leaving only male-sterile plants. Adequate level of degree of heterosis is essentially desired and had been an important issue in hybrid soybean production, as in case of other self pollinated crops.

Palmer *et al.,* (2001) suggested five important components, namely (i) stable male-sterile and female–fertile lines, (ii) efficient pollen transfer mechanism, (iii) parents of superior level of heterosis, (iv) higher percentage of normal seed- seed in male sterile female fertile plant, and (v) production of large quantities of hybrid seed for developing hybrid soybean.

In 2003, Chinese scientists bred the first hybrid soybean with more than two decades of unlimited efforts; they have developed and used a cytoplasmic nuclear male sterility system in soybean for the production of large amount of hybrid seed for commercial production. So far limited success has been made towards development of hybrid soybean in USA and more research is needed from both public and private sector.

Interspecific hybridization

Soybean breeders have not fully exploited the wealth of genetic diversity from exotic germplasm including soybean's progenitor *Glycine soja* (Singh and Hymowitz, 1999). *Glycine soja* may be an excellent source of genetic variability, although it harbors several undesirable genetic traits, for example, vining growth habit, lodging susceptibility, lack of complete leaf abscission, seed shattering, and small black coated seeds However, *Glycine soja* has been shown to be more genetically diverse than *Glycine max* and the undesirable traits can be separated from the desirable ones during the course of selection in successive backcross generations and possibly through marker assisted selection. Attempts to broaden the genetic base of soybeans by utilizing *Glycine soja* were reported by Hartwig (1973), Carpenter and Fehr (1986) and Carter *et al*. (2004). Hartwig (1973) reported highly productive and high-protein lines derived from soybean and *Glycine soja* hybrids. Ertl and Fehr (1985) concluded that introgression of *Glycine soja* germplasm into soybean cultivars was an effective method for increasing their yield potential. To obtain a relatively high frequency of useful segregants for cultivar development, three backcrosses to the soybean were preferred. However, small seeded (seed of < 100 mg) cultivars, such as 'SS201' and 'SS202' (Fehr *et al*., 1990a, b), and 'Pearl' (Carter *et al*., 1995), and PS 1225 (Pushpendra *et al.,* 2008) have been developed where *Glycine soja* was used as a non-recurrent parent. *Glycine soja* harbors genes for tolerance to metribuzin (4 Amino 6 (1,1 dimethylethyl) 3 (methylthio) 1,2,4 triazin 5(4H) one) (PI245331, PI163453; Kilen and He, 1992), resistant to soybean cyst nematode (PI468916; Kabelka *et al*., 2006), higher seed yield resistant to yellow mosaic virus (Singh *et al.,* 1974), tolerant to hairy caterpillar, high protein content (Concibido *et al*., 2003) and is a rich source of genetic diversity (Ohara and Shimamoto, 2002). These invaluable traits could be exploited to broaden the genetic base of soybean.

Advances through incorporation of molecular technology

Although conventional breeding has made a significant contribution to soybean yield increases in last 60 years, but the progress is slow specially for improving quantitative traits due to significant environmental effects, time consuming long selection process and problems associated with selecting appropriate genotype. The expansion of soybean genetic base may lead to the introduction of new favorable alleles to polygenic traits. Considering the great amount of genes hypothesized to be involved in the control of agronomic characteristics, it is unlikely that modern cultivars have concentrated the best alleles corresponding to all loci of economic interest. Undoubtedly, several favorable alleles were lost through genetic bottlenecks during soybean domestication and introduction in producing regions. The choice of accessions to be incorporated in a breeding programme must include those carrying and transmitting favorable rare alleles, absent from elite germplasm. Accessions highly dissimilar to elite genotypes are likely to provide novel alleles to the traits of interest. Therefore, the knowledge of the genetic variation within accessions in germplasm collections is essential to the choice of strategies to incorporate useful diversity into the programme, to facilitate the introgression of genes of interest into commercial cultivars and to understand the evolutionary relations among accessions. Microsatellite or simple sequence repeats (SSR) markers are considered useful to the assessment of genetic diversity among organisms. Crop containing foreign genes are known as transgenic or genetically modified (GM) or more often known as biotech crop. Genetic engineering in combination with conventional plant breeding has produced additional tool to enhance efficiency.

Molecular technologies are capable to dissect quantitative traits into their individual components known as quantitative trait loci (QTL). New genomic technology as marker assisted selection (MAS), uses of molecular marker closely linked to target gene/QTL as a molecular tag and can be used for quick indirect selection of the target QTL/gene. Selection can be done at one early stage of plant growth even before maturation thus enhancing conventional breeding process and aiding genetic improvement of traits of interest. MAS can be enhance the efficiency of conventional breeding in various ways such as:

a) MAS is independent to season and location consideration for the trait whose expression is dependent upon certain environmental condition allow for screening of important trait.
b) Gene pyramiding by incorporating different alleles for multiple trait or multiple alleles related to single trait.
c) Selection of parental lines with wider genetic base as genetic variance of a population for the metric trait, such as yield will increase as the parents differ for genes that affect the trait.

More than 80 QTLs have been reported in soy base for seed yield and yield related traits like lodging, plant height and seed weight. Narrow genetic base is one of the reasons for slow yield increase of soybean. Greater genetic diversity may increase the rate of yield improvement. QTL mapping of yield from soybean PI and exotic germplasm demonstrated the possibility to incorporate yield enhancing alleles from diverse source into soybean elite lines. Mining of beneficial alleles from wild relatives and transfer into cultivated species is of utmost important for soybean improvement programme. In soybean using molecular markers, a number of beneficial alleles as soybean rust, soybean mosaic virus (Hayes *et al.*, 2000), yellow mosaic virus, yield and yield related traits from wild and unadopted soybean germplasm have been extracted and may be used for improvement of elite germplasm lines as well as widening the genetic base. Molecular markers like SSR and SNP may play a significant role in full exploitation of exotic germplasm. Concibido *et al.,* (2003) found a yield enhancing quantitative trait loci (QTL) from *Glycine soja* (Seib & Zucc.) by evaluating a population of 265 BC_2 individuals. The yield QTL was located on linkage group B_2 (V26) of soybean. QTL locus demonstrated a 9.4 per cent yield advantage over individual that did not contain the exotic heliotype. Roundup Ready® Soybeans produced by Monsanto is an example of the successful application of genetic transformation technology to crop improvement. Pioneer® used molecular marker technology to develop soybean variety 94M80 that broke world soybean yield record in 2006 by achieving 139 bushels/area setting a new world record.

REFERENCES

Anonymous. 2012–2013. *Director's Report and Summary Tables of Experiments 2012-13*, All India Coordinated Research Project on Soybean, ICAR, National Research Centre for Soybean, Indore, Madhya Pradesh, India.

Bharadwaj C H, Satyavathi C T, Tiwari S P and Karmakar P G. 2002. Genetic base of soybean (*Glycine max*) varieties released in India as revealed by coefficient of parentage. *Indian Journal of Agricultural Sciences* **72**: 467-9.

Bhatnagar P S and Karmakar P G. 1985. Achievements and prospects of breeding research in soybean (*Glycine max*) in India. *Indian Journal of Agricultural Sciences* **65**: 1-9.

Brim C A. 1973. Quantitative genetics and breeding. *In*: Soybeans: Improvement, Production, and Uses, *Agronomy Monograph* **16**: 155–86. Caldwell B E (Ed), American Society of Agronomy, Madison, Wisconsin.

Carpenter J B and Fehr W R. 1986. Genetic variability for desirable agronomic traits in populations containing *Glycine soja* germplasm. *Crop Science* **26**: 681–6.

Carter T E Jr, Nelson R L, Sneller C H and Cui Z. 2004. Genetic diversity in soybean. *In*: Soybeans: Improvement, Production, and Uses, 3rd Edition, *Agronomy Monograph* **16***:* 303–416. Boerma H R and Specht J E (Eds), American Society of Agronomy, Inc./Crop Science Society of America, Inc./ Soil Science Society of America, Inc., Madison, Wisconsin.

Carter T E Jr, Huie E B, Burton J W, Farmer F S and Gizlice Z. 1995. Registration of 'Pearl' soybean. *Crop Science* **35**: 1713.

Chung G and Singh R J. 2008. Broadening the genetic base of soybean: A multidisciplinary approach. *Critical Reviews in Plant Sciences* **27**: 295–341.

Concibido V La, Vallee B, Mclaird P, Pineda N, Meyer J, Hummel L, Yang J, Wu K and Delannay X. 2003. Introgression of a quantitative trait locus for yield from *Glycine soja* into commercial soybean cultivars. *Theoretical and Applied Genetics* **106**: 575–82.

Cooper R L. 1981. Development of short stature soybean cultivars. *Crop Science* **21**: 127-31.

Davis W H. 1985. Route to hybrid soybean production. *United States Patent No. 4 545146*, October 8, 1985.

Ertl D S and Fehr W R. 1985. Agronomic performance of soybean genotypes from *Glycine max* x *Glycine soja* crosses. *Crop Science* **25**: 589–92.

Fehr W R, Cianzio S R, Welke G A and LeRoy A R. 1990a. Registration of 'SS201' soybean. *Crop Science* **30**: 1361.

Fehr W R, Cianzio S R and Welke G A. 1990b. Registration of 'SS202' soybean. *Crop Science* **30**: 1361.

Fehr W R, Welke G A, Hammond E G, Duvick D N and Cianzio S R. 1991. Inheritance of elevated palmitic acid contenet in soybean seed oil. *Crop Science* **31**: 1522–4.

Gai J Y, Xu D H, Gao Z, Zhao T, Shimamoto Y, Abe J, Fukushi H and Kitajima S. 1999. Genetic diversity of annual species of soybeans and their evolutionary relationship in China, pp 515. *In*: Kauffman, H E (Ed.). *Proceedings of World Soybean Research Conference, VI*, Chicago, IL. Aug. 1999. Superior Print, Champaign, IL.

Hajika M, Igita K and Nakazawa Y. 1995. Induction of soybean (*Glycine max* (L.) Merill) line lacking all seed lipoxygenase isozymes. *Japan Agricultural Research Quarterly* **29**: 73-6.

Hammond E G and Fehr W R. 1983. Registration of A6 germplasm line of soybean (Reg. No. GP45). *Crop Science* **23**: 192–3.

Hartwig E E. 1973. Varietal development. *In*: Soybeans: Improvement, Production, and Uses, *Agronomy Monograph No.* **16**: 187–210. Caldwell B E (Ed), American Society of Agronomy, Inc., Madison, Wisconsin.

Hayes A J, Ma G, Buss G R and Saghai Maroof M A. 2000. Molecular marker mapping of Rsv4, a gene conferring resistance to all known strains of soybean mosaic virus. *Crop Science* **40**: 1434-7.

Imam M M. 1978. Mutagenesis in soybeans. *Proceedings of XIV International Congress of Genetics*, Moscow.

Jin Woong C, GwanSoo P, Yamakawa Y and Ohga S. 2005. Comparison of yield in Korean small seed soybean cultivars with main stem and branch production. *Journal of the Faculty of Agriculture, Kyushu University,* **50**(2): 511-9.

Kabelka E A, Carlson S R and Diers B W. 2006. *Glycine soja* PI 468916 SCN resistance loci's associated effects on soybean seed yield and other agronomic traits. *Crop Science* **46**: 622–9.

Karmakar P G. 2001. Speeding up the development of new soybean varieties. In: *Proceedings of India Soy Forum, Indore,* pp 65-9.

Karmakar P G and Bhatnagar P S. 1996. Genetic improvement of soybean varieties released in India from 1969 to 1993. *Euphytica* **90**: 95–103.

Khan R, Alkharouf N, Beard H, Macdonald M, Chouikha I, Meyer S, Grefenstette J, Knap H and Matthews B. 2004. Microarray analysis of gene expression in soybean roots susceptible to the soybean cyst nematode two days post invasion. *Journal of Nematology* **36**: 241–8.

Kilen T C and He G. 1992. Identification and inheritance of metribuzin tolerance in wild soybean. *Crop Science* **32**: 684–5.

Kokubun M. 1988. Design and evaluation of soybean ideotypes. *Bulletin of the Tohoku National Agricultural Experiment Station* **77**: 77-142.

Lewers K S St, Martin S K, Hedges B R, Widrlechner M P and Palmer R G. 1996. Hybrid soybean seed production: comparison of three methods. *Crop Science* **36**: 1560–7.

Li F S. 1990. Chinese *G. Soja* Collection Catalog. China Agricultural Press, Beijing, China line lacking all seed lipoxygenase isozymes. *Japan Agricultural Research Quarterly* **29**: 73-6.

Liu L, Van Zanten L, Shu Q Y and Maluszynski M. 2004. Officially released mutant varieties in China. *Mutation BreedingReview* **14**: 18–22.

Maheshwari J J, Dhole V J, Shanti P and Rathod D R. 2003. Radiation induced variability for quantitative characters in soybean. *Journal of Soil and Crops* **13**(2): 314-6.

Maluszynski M, Nichterleim K, Van Zanten L and Ahloowalia B S. 2000. Officially released mutant varieties.The FAO/IAEA database. *Mutation Breeding***12**: 4–6.

Manjaya J G and Nandanwar R S. 2007. Genetic improvement of soybean variety JS 80 21 through induced mutations. *Plant Mutation Reports* **13**: 161-5.

Maola K F. 2005. Effect of gamma radiation on some important morpho-physiological and yield attributes in M2 mutants in lentil. *M S Thesis*, Dept. *Crop Botany,* BAU, Mymensigh.

Neto A T and Alves M C. 1997. Induction of mutations for earliness in the soybean cultivar Paraná. *Brazilian Journal of Genetics* **20**: 10.

Ohara M and Shimamoto Y. 2002. Importance of genetic characterization and conservation of plant genetic resources: The breeding system and genetic diversity of wild soybean (*Glycine soja*). *Plant Species Biology* **17**: 51–8.

Palmer R G, Gai J, Dalvi V A, and Suso M J. 2011. Male sterility and hybrid production technology. *In*: A Pratap and J Kumar (Eds.), *Biology and Breeding of Food Legumes,* CAB International, UK, pp 193-207.

Palmer R G, Gai J, Sun H and Burton J W. 2001. Production and evaluation of hybrid soybean. *Plant Breeding Review* **21**: 263-307.

Papa K S, Williams J H and Hanway D G. 1961. Effectiveness for quantitative characters in the third generation following irradiation of soybean seeds with X-rays and thermal neutrons. *Crop Science* **1**: 87-90.

Pushpendra, Singh K, Singh B V and Gupta M K. 2008. Pant soybean 1225-An improved variety of soybean with broad genetic base. *Soybean Research* **6**: 72-6.

Raut V M, Halvankar G B and Patil V P. 1988. Heterosis in soybean (*Glycine max* (L.) Merrill) *Soybean Genetics Newsletter* **15**: 57-60.

Rawlings J O, Hanway D G and Gardner C O. 1958. Variation in quantitative characters in soybean after seed irridation. *Agronomy Journal* **50**: 524-8.

Santos I S, Fukusawa C A, Elec V J and Dela Rosa A M. 1970. Acclimatization and improvement of Lincoln variety soybean through mutation breeding. *In* : *Improving Plant Protein by Nuclear Techniques*, Proc. Symp., IAEA, Vienna, pp 189.

Sebastian S A and Chaleff R S. 1987. Soybean mutants with increased tolerance for sulfonyl urea herbicides. *Crop Science* **27**: 948–52.

Sebastian S A, Fader G M, Ulrich J F, Forney D R and Chaleff R S. 1989. Semidominant soybean mutation for resistance to sulfonylurea herbicides. *Crop Science* **29**: 1403–8.

Shrivastava A N, Shrivastava M K and Chouhan A. 2009. A novel approach of soybean (*Glycine max*) ideotype utilizing four seeded pod trait. *In*: *World Soybean Research Conference* VIII, Beijing, China, August 10-15, 2009: pp 57-58.

Simmonds N W. 1979. *Principles of Crop Improvement*, Longman, London and New York, pp 408.

Singh R J and Hymowitz T. 1999. Soybean genetic resources and crop improvement. *Genome* **42**: 605–16.

Singh B B, Singh B D, and Gupta S C. 1974. P. I. 171443 and *G. formosana* resistant sorces for yellow mosaic. *Soybean Genetics Newsletter* **1**: 17-8.

Skorupska H and Palmer R G. 1989. Genetics and cytology of ms6 male sterile soybean. *Journal of Heredity* **80**: 304–10.

Srisombun S, Benjamas K, Chitima Y and Jeeraporn K. 2009. Soybean variety improvement for high grain protein content using induced mutation. *IAEA/RCA Project RAS/5/045*, Feb 16-20, 2009, Vietnam.

Sun H, Zhao L and M. Huang. 1997. Cytoplasmic-nuclear male sterile soybean line from interspecific crosses between *G. max* and *G. soja*. *In Proceedings of the 5th World Soybean Research Conference,* Chiang Mai, Thailand, February 21-27, 1994. B. Napompeth, Ed. Kasetsart University Press, Bangkok, Thailand, pp 99-102.

Takagi Y, Rahman S M and Anai T. 1998. Construction of novel fatty acid composition in soybean oil by induced mutations. Report of a symposium held 14-15 July, 1998, Ibaraki, *Japan Gamma Field Symposia* No. **37**(52): 17-28.

Tambe A B and Apparao B J. 2009. Gamma-rays induced mutations in soybean (*Glycine max* (L.) Merrill) for yield contributing traits. Induced Plant Mutations in the Genomics Era, *Proceedings of an International Joint FAO/IAEA Symposium,* pp 95-6.

Thomas J F and Raper C D Jr. 1985. Internodes and petiole elongation of soybean in response to photoperiod and end of day light quality. *Botanical Gazette* **146**: 495-500.

Tiwari S P. 2001. Indian scenario and needs in soybean genetic resources. *In*: *Proceedings of India Soy Forum, Indore*, pp 48-57.

Wilcox J R and Cavins J F. 1990. Registration of C1726 and C1727 soybean germplasm with altered levels of palmitic acid. *Crop Science* **30**: 240.

You M, Zhao T and Gai J. 1995. Performance and inheritance of short petiole trait of a new soybean mutant. *Soybean Genetics Newsletter* **22**: 71–5.

Soybean Research (Special Issue Number 2): 33-43: 2014

Influence of Excessive Moisture Stress on Genetic Parameters in Soybean

A N SHRIVASTAVA[1], S K PANDEY[2] and S KOBAYASHI[3]
Department of Plant Breeding and Genetics, Jawaharlal Nehru Krishi VishwaVidyalaya, Jabalpur 482 004, Madhya Pradesh, India
E-mail: ans_jnkvv@rediffmail.com

ABSTRACT

Soybean being a rainy season crop, is encountered by excessive moisture stress at different critical phases and substantial losses in yield is experienced. In view of such a situation, it becomes imperative to estimate the influence of excessive moisture stress on genetic parameters and to isolate the tolerant genotypes to be used as future cultivars and/or be utilized as pre-breeding lines. Eighteen newly developed genotypes and seven popular released varieties were exposed to water logging at three critical stages and compared with normal conditions. Observations were recorded on days to 50 per cent flowering, days to maturity, number of nodules, nodules fresh weight, nodules dry weight, height at flowering, height at maturity, number of nodes, inter-nodal length, number of branches, number of pods, number of seeds, biological yield, harvest index, 100 seed weight and yield. The extent of genetic variability was exhibited very large for all the sixteen characters showing highly significant mean sum of squares in both control and excessive moisture conditions. Drastic to moderate reduction in mean was observed for most of the traits ranging from 7.60 to 36.85 per cent under excessive moisture condition in comparison to control, but negligible effect was found on days to 50 per cent flowering, days to maturity and number of nodes. High heritability estimates were exhibited for most of the traits except number of nodes and inter-nodal length as moderate and number of branches as low in both the conditions. Preponderance of additive gene action was found in case of number of nodules , nodules fresh weight, nodules dry weight, number of pods, number of seeds, biological yield, harvest index, 100 seed weight and seed yield as these traits expressed high heritability coupled with high or moderate genetic advance otherwise non additive gene action was found for remaining traits. JS 97-52 and Bragg were identified as high yielding genotypes and JS 95-60, JS 20-87, JS 20-69 and RVS 2007- 1 as tolerant donors for excessive moisture conditions.

Key words: Excessive moisture, genetic parameters, soybean, tolerance

Soybean *[Glycine max (*L.) Merrill] ranks first among the oilseed crops in the world and India both. It contributes around 43 per cent and 25 per cent to the total oilseeds production and edible oil pool, respectively of the country. In addition to substantial share in edible oil, the crop earns annually more than 70 thousand million rupees through export of de-oiled cake. Being a protein rich crop with many nutraceuticals, provides health benefits. The home consumption in the form of food is also showing encouraging trend. It is fetching very high price ranging 30,000-45,000 rupees per tonne in the local market. Soybean cultivation has substantially elevated the social and economic status of farmers as well as employment generation through soybean based industries.

[1]Principal Scientist; 2Scientist; 3Chief Advisor, Japan International Cooperation Agency

In the year 2012, soybean cultivation reached to 10.7 million hectares producing 12.7 million tonnes with productivity of productivity 1,185 kg per ha in India. In Madhya Pradesh, the area reached to 5.81 million hectares producing 6.68 million tonnes with productivity of 1,150 kg per ha (Anonymous, 2012). Soybean has been adopted and commercially cultivated in the states of Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh. Soybean has emerged very fast since early eighty's recording an unprecedented expansion in India with 15-20 per cent annual growth rate in area and production, and achieved a vital position in Indian agriculture. However, in spite of commendable expansion, its productivity is quite low (1.2 t/ha) as compared to other major soybean growing countries (2.3 t/ha). The better performance of the crop is associated with congenial weather and adoption of improved production technologies. Soybean being a *kharif* rainfed crop in India, erratic monsoon, climatic changes and varied eco-edaphic conditions are the major constraints limiting soybean productivity. Excessive soil moisture condition is one of the most detrimental abiotic stresses, which is experienced in one or the other years, regions and crop phases causing substantial loss in total production. Yield of soybean is more affected by water logging at the reproductive phase than vegetative phase (Scott *et al*., 1989; Oosterhuis *et al.,* 1990; Linkemer *et al.,* 1998). Under such conditions, significant reduction in growth, biomass production and yield has been observed in comparison to the control plants at all growth stages (Hajare *et al*., 2001). Different genotypes showed different tolerance and ability to produce yield under water logging (Van Toai *et al.,* 1994). The genetic improvement regarding tolerance can be achieved through understanding genetic variability, association of different characters with yield, heritability, genetic advance and type of gene action involved in expression of various characters. Very limited genetic studies have been conducted under the artificially created excessive moisture conditions in India. Keeping in view the immense value of above aspects, the present investigation was conducted.

MATERIAL AND METHODS

Experimental material comprised of 25 genotypes (10 advanced line from Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur, 07 from Rajmata Vijayaraje Sindia Krishi Vishwa Vidyalaya, Gwalior and 08 popular varieties) in two sets of environments; one as control (E1) following well drained field conditions with full package of practices and other set exposed to the excessive moisture conditions (E2) at seedling stage (15-20 days after sowing, DAS), vegetative stage (35-40 DAS) and reproductive stage (55-60 DAS) with same package of practices (Plate 1). The experiment was conducted adopting randomized block design with three replications at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur under a collaborative research project with Japan International Cooperation Agency during *kharif* 2012. The plot size was maintained was 2 m x 1.8 m keeping row to row distance of 45 cm and plant to plant distance of 5 cm.

Observations were recorded taking five competitive plants from each replication and each treatment on sixteen traits *viz.*, days to 50 per cent flowering, days to maturity, number of nodules per plant, nodules fresh weight per plant, nodules dry weight per plant, plant height at flowering, plant height at maturity,

Water logging

Control

Plate 1. Picture showing water logging and control conditions

number of nodes per plant, inter-nodal length, number of branches per plant, number of pods per plant, number of seeds per plant, biological yield per plant, harvest index (%), 100 seed weight and yield per plant. Statistical analyses were performed on analysis of variance, coefficient of variance, heritability and genetic advance, correlation coefficient, path coefficient analysis. A dependent variable "per cent reduction from excessive moisture to the control treatment" was calculated according to the formula: Yield reduction = (control - excessive moisture)/control * 100.

RESULTS AND DISCUSSION

Genetic variability

The analysis of variance (Table 1) indicated that the mean sum of squares due to genotypes were highly significant for all the sixteen traits *viz*., days to 50 per cent flowering, days to maturity, number of nodules per plant, nodules fresh weight per plant, nodules dry weight per plant, plant height at flowering and maturity, number of nodes per plant, inter-nodal length, number of pods per plant, number of seeds per plant, biological yield per plant, harvest index, 100 seed weight and yield per plant under both control and excessive moisture conditions except for number of branches per plant found significant in control condition. Which indicated sufficient variability for all the characters under study and there is a greater scope of genetic improvement for tolerance against excessive moisture conditions in soybean. In control condition, eight traits *viz*., number of nodules per plant, plant height at flowering and maturity, number of branches per plant, number of pods per plant, number of seeds per plant and yield per plant exhibited higher magnitudes of mean sum of squares and remaining eight traits showed lower magnitudes than excessive moisture condition, which indicated differential influence of different environments on genotypes and traits. Similar findings have been reported by Malik *et al.* (2006), Muhammad *et al*. (2006) and Sharma *et al.* (2012) under normal condition whereas, Hou and Thseng (1991), Van Toai *et al*. (1994),

Table 1. Analysis of variance for yield and its contributing traits for different genotypes of soybean in different environments

Source of variation	DF	Environment	Mean sum of squares							
			Days to 50 % flowering	**Days to maturity**	**Nodules (No/plant)**	**Nodules fresh weight (g/plant)**	**Nodules dry weight (g/plant)**	**Plant height at flowering (cm)**	**Plant height at maturity (cm)**	**Nodes (No/ plant)**
Replications	2	E1	1.733	2.613	13.762	0.0004	0.002	9.491	4.820	0.973
		E2	3.040	1.493	5.012	0.010	0.001	3.423	5.318	0.340
Genotypes	24	E1	29.903**	64.314**	425.83**	0.089**	0.015**	90.776**	77.414**	3.055**
		E2	38.113**	80.226**	195.763**	0.114**	0.016**	82.992**	76.381**	3.996**
Error	48	E1	1.273	0.891	5.639	0.009	0.0006	7.306	3.572	0.529
		E2	1.081	3.132	5.507	0.006	0.0005	3.564	6.475	0.382
			Inter-nodal length (cm)	**Branches (No/plant)**	**Pods (No/plant)**	**Seeds (No/plant)**	**Biological yield (g/plant)**	**Harvest index (%)**	**100 Seed weight (g)**	**Seed yield (g/plant)**
Replications	2	E1	0.007	0.387	33.453	39.744	0.962	2.194	**0.004**	**0.373**
		E2	0.122	0.040	39.853	23.668	0.122	0.590	**0.175**	**0.002**
Genotypes	24	E1	0.349**	0.764*	794.028**	2097.609**	44.307**	108.546**	**4.978****	**10.510****
		E2	0.236**	0.609**	419.253**	1414.671**	51.719**	112.900**	**5.996****	**7.867****
Error	48	E1	0.057	0.366	11.606	53.426	1.638	0.841	**0.068**	**0.375**
		E2	0.039	0.274	23.228	18.488	1.172	0.201	**0.070**	**0.199**

**Significant at 5% level; **Significant at 1% level;E1- well drained conditions; E2 – excessive moisture conditions*

Table 2. Parameters of genetic variability, heritability and genetic advance for different traits of soybean in different environments

Characters	Mean			Range				Coefficient of variation (%)	
				Minimum		Maximum			
	E_1	E_2	% Reduction from E1-E2	E_1	E_2	E_1	E_2	E_1	E_2
1	2	3	4	5	6	7	8	9	10
Days to 50 % flowering	40.09	40.48	-0.97	32.33	36.00	45.00	46.00	2.81	2.57
Days to maturity	94.70	94.49	0.22	81.00	80.00	101.00	101.33	0.99	1.87
Nodules (No/plant)	60.60	41.80	31.02	44.60	29.13	77.80	54.20	3.92	5.61
Nodules fresh weight (g/plant)	0.77	0.68	11.69	0.49	0.40	1.13	0.99	12.53	11.35
Nodules dry weight (g/plant)	0.32	0.24	25.00	0.23	0.11	0.50	0.35	7.37	9.43
Plant height at flowering (cm)	48.66	43.91	9.76	40.40	35.00	60.33	52.13	5.56	4.30
Plant heights at maturity (cm)	53.95	49.68	7.91	43.40	39.40	59.67	58.53	3.50	5.12
N nodes (No/plant)	11.67	11.74	-0.60	9.67	9.10	13.34	13.03	6.23	5.27
Internodal length (cm)	4.28	3.91	8.64	3.67	3.47	5.10	4.57	5.58	5.06
Branches (No/plant)	3.71	2.88	22.37	2.67	2.13	4.50	4.17	16.30	18.14
Pods (No/plant)	55.07	35.49	35.55	22.00	22.00	78.67	69.67	6.18	13.58
Seeds (No/plant)	84.26	66.05	21.61	46.50	25.70	156.27	121.70	8.67	6.50
Biological yield (g/plant)	19.70	15.55	21.07	13.41	6.50	26.48	23.64	6.50	6.96
Harvest index (%)	49.95	40.12	19.68	29.56	23.59	58.63	48.40	1.84	1.11
100 seed weight (g)	10.40	9.61	7.60	8.63	7.42	13.05	11.54	2.51	2.76
Seed yield plant (g/plant)	9.77	6.17	36.85	6.28	2.98	12.87	9.03	6.27	7.23

E1- well drained conditions; E2 – excessive moisture conditions

Table 2 contd.

Characters	Phenological coefficient of variation		Genetic coefficient of variation		h^2b (%)		Genetic Advance as % of Mean	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
	11	12	13	14	15	16	17	18
Days to 50 % flowering	8.20	9.05	7.71	8.68	88.20	91.90	14.91	17.14
Days to maturity	4.96	5.68	4.86	5.37	95.90	89.10	9.80	10.43
Nodules (No/plant)	19.90	19.86	19.51	19.05	96.10	92.00	39.41	37.64
Nodules fresh weight (g/plant)	24.70	29.93	21.29	27.69	74.30	85.60	37.79	52.78
Nodules dry weight (g/plant)	22.78	31.63	21.56	30.19	89.50	91.10	32.02	59.36
Plant height at flowering (cm)	12.18	12.48	10.84	11.72	79.20	88.10	19.88	22.66
Plant heights at maturity (cm)	9.84	10.98	9.20	9.72	87.30	78.30	17.70	17.71
N nodes (No/plant)	10.04	10.73	7.87	9.35	61.40	75.90	12.70	16.78
Internodal length (cm)	9.18	8.27	7.29	6.54	63.10	62.50	11.92	10.65
Branches (No/plant)	19.03	21.53	9.81	11.59	26.60	29.00	10.42	12.86
Pods (No/plant)	29.97	35.10	29.37	32.37	95.70	85.00	59.11	61.49
Seeds (No/plant)	32.17	33.30	30.98	32.66	92.70	96.20	61.45	65.98
Biological yield (g/plant)	20.22	27.30	19.15	26.40	89.70	93.50	37.35	52.58
Harvest index (%)	12.13	15.32	12.00	15.28	97.70	99.50	24.43	31.39
100 seed weight (g)	12.55	14.89	12.29	14.63	95.90	96.60	24.81	29.62
Seed yield plant (g/plant)	19.82	26.89	18.81	25.90	90.00	92.80	36.75	51.40

E1- well drained conditions; E2 – excessive moisture conditions

Tomar *et al*. (2007) and Van Toai *et al*. (2010) under excessive moisture condition.

Parameters of genetic variability

Mean, range and coefficient of variance: The drastic reduction in mean values were observed the highest for yield (36.85 %) followed by number of pods (35.55 %), number of nodules (31.02 %), nodules dry weight (25.00 %), number of branches (22.37 %), number of seeds (21.61 %), biological yield (21.07 %), harvest index (19.68 %), moderate reduction for nodules fresh weight (11.69 %), plant height at flowering (9.76 %), inter-nodal length (8.64 %), plant height at maturity (7.91 %) and 100 seed weight (7.60 %) under excessive moisture condition, but negligible effect was found on days to 50 per cent flowering and maturity and number of nodes per plant (Table 2). These results exhibited that excessive moisture influenced most of the yield traits at different magnitudes indicating differential sensitivity whereas, days to 50 per cent flowering, days to maturity and nodes per plant were found least insensitive to excessive moisture. Similar, trends were observed in the reduction of minimum and maximum values of different traits under study. The coefficient of variance was found higher than 10 per cent for nodules fresh weight and number of branches in both environments, whereas for number of pods in excessive moisture and less for remaining traits.

Phenotypic and genotypic coefficient of variation

To obtain the clearer picture related to the variability it was further split into phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV). As usual in this investigation also the PCV estimates were found higher than GCV for traits in both the environments. Both the parameters have exhibited substantially higher values in excessive moisture condition than control except days to 50% flowering and maturity, number of nodules, plant height at flowering and intermodal length exhibited a considerable influence of environment in the expression of PCV and GCV both.

Heritability and genetic advance: Heritability and genetic advance as per cent of mean were calculated for each traits in each environment (Table 2). The estimates of these parameters considered together to find out the preponderance of gene action in the expression of the traits under study and their environmental sensitivity to determine the selection and breeding strategies to be followed in formulation of breeding programme for excessive moisture tolerance.

Heritability estimates have been broadly classified into low (< 50 %), medium (50-70 %) and high (> 70 %) and genetic advance estimates classified into low (< 25 %), medium (25-35 %) and high (> 35 %) in order to draw some conclusion about these parameters.

Number of nodules, nodules fresh weight, number of pods, number of seeds, biological yield and seed yield has depicted high heritability coupled with high genetic advance in both the environments and nodules dry weight in excessive moisture condition. While, high heritability coupled with moderate genetic advance estimates were observed for nodules dry weight in control conditions and harvest index as well as 100 seed weight in both conditions. These results indicated the preponderance of additive gene action in the inheritance of above traits in which effective selection can be made to improve these traits. Whereas, high heritability combined with low genetic advance were observed for days to 50 per cent flowering and maturity, plant height at flowering and maturity, inter-nodal length and number of branches indicated the control of non additive gene action in the inheritance of these traits suggested that later generation selection for the improvement of these traits will be found effective. In agreement with the present findings, Gohil *et al.* (2006) for yield, Malik *et al*. (2006) for 100 seed weight and grain yield and Nag *et al.* (2007) for number of pods and number of seeds have reported high heritability combined with high or moderate genetic advance.

Association and path coefficient analysis

Phenotypic correlation coefficient analysis and path coefficient were estimated for all the traits under study with yield (Table 3). Phenotypic correlation recorded difference in magnitudes and directions in control and excessive moisture conditions indicated the influence of environments. Days to 50 per cent flowering and maturity, nodules fresh weight, plant height at flowering and maturity biological yields, harvest index and 100 seed weight have exhibited

Table 3. Phenotypic correlation coefficient and phenotypic path coefficient of different traits with yield of soybean in different environments

Characters	Correlation coefficient		Direct effect	
	E_1	E_2	E_1	E_2
Days to 50 % flowering	0.5895***	0.4964***	0.0102	0.0147
Days to maturity	0.5115***	0.4890***	0.0017	0.0127
Nodules (No/plant)	0.0242	0.1514	-0.0627	-0.0484
Nodules fresh weight (g/plant)	0.2634*	0.3011**	0.0070	0.0116
Nodules dry weight (g/plant)	0.1917	0.4261***	0.0239	-0.0161
Plant height at flowering (cm)	0.2572*	0.2665*	-0.0589	0.0108
Plant heights at maturity (cm)	0.2509*	0.2973**	0.1131	-0.3055
Nodes (No/plant)	0.5426***	0.5076**	-0.0278	0.2559
Internodal length (cm)	0.2486*	0.2002	-0.0554	-0.2267
Branches (No/plant)	0.2213	0.1236	0.0016	-0.0006
Pods (No/plant)	0.7126***	0.6989***	-0.0058	0.0132
Seeds (No/plant)	0.7760***	0.8939***	0.0269	0.4113
Biological yield (g/plant)	0.7742***	0.7791***	0.9468	0.6048
Harvest index (%)	0.3202***	0.3810***	0.6100	0.6100
100 seed weight (g)	0.3304**	0.1215	-0.0281	0.1518

*E1- well drained conditions; E2 – excessive moisture conditions*number of pods, number of seeds,

significant to highly significant correlation values with seed yield signifying the contribution of these traits for seed yield. Direct effect of phenotypic path coefficient values also recorded change in magnitude and direction in different environments indicated influence of environments. Among these traits, only biological yield and harvest index have exhibited substantial direct effect on yield in both the environments whereas, plant height at maturity in control conditions, number of seeds per plant and 100 seed weight in excessive moisture condition have recorded considerable direct effects on seed yield. Similar findings have been reported by Van Toai *et al*. (2010) and Nigam *et al*. (2012) found number of pods, harvest index and 100 seed weight had positive and significant correlation and considerable direct effect on yield.

On the basis of both analyses it can be concluded that number of seeds, biological yield, harvest index and 100 seed weight are the most important traits to be given emphasis in formulating selection and breeding programme for higher yield under excessive moisture conditions.

Mean and percentage reduction in seed yield of genotypes from control to excessive moisture

The values of mean, deviation and percentage reduction in yield per plant for 25 genotypes (Table 4) revealed that JS 97-52 (12.87 g) and Bragg (12.68 g) were found significantly superior in both control and excessive moisture conditions. While, significantly superior genotypes identified were NRC 37 (12.11 g), JS 20-73 (12.04 g) and RVS 2001-4 (11.69 g) in control conditions and RVS 2007-1 (8.80 g) and JS 20-87 (8.39 g) in excessive moisture condition only. As per the percentage reduction in yield from control to excessive moisture, minimum was recorded by JS 20-87 (20.32 %) followed by JS 95-60 (21.97 %), RVS 2007-1 (23.14 %) and JS 20-69 (26.10 %), which indicated their tolerance ability.

These results suggested that JS 97-52, Bragg, RVS 2007-1 and JS 20-87 found as higher yielding genotypes in excessive moisture and JS 20-87, JS 95-60, RVS2007-1 and JS 20-69 as tolerant genotypes for excessive moisture. Van Toai *et al*. (2010), Kuswantoro (2011) and Nigam *et al.* (2012) have also reported drastic reduction for yield and its related traits similar to the present findings.

Hybridization programme must be followed by inter- crossing between/among high yielding and tolerant genotypes to accumulate and incorporate positive genes for yield and tolerance both in future cultivars. The biotechnological tools may be useful in identifying the QTLs in tolerant genotypes and transferring into the high yielding genotypes in future.

The overall conclusions drawn from the present investigation are as follows.

1. Sufficient exploitable genetic variability exists among the genotypes studied.
2. Number of nodules, nodules fresh weight, nodules dry weight, number of pods, number of seeds, biological yield, harvest index, 100 seed weight and seed yield has indicated the preponderance of additive gene action in their inheritance.
3. Selection and effective breeding for excessive moisture tolerant genotypes can be performed giving emphasis for number of seeds, biological yield, harvest index and 100 seed weight. JS 97-52, Bragg, RVS 2007-1 and JS 20-87 identified as high yielding genotypes under excessive moisture and JS 20-87, JS 95-60, RVS 2007-1 and JS 20-69 as tolerant donor genotypes to be utilized in future breeding for the development of high yielding tolerant genotypes against excessive moisture stress.

Table 4. Mean and deviation of 25 genotypes for yield in different environments

Genotypes	Seed yield (g/plant)				Genotypes	Seed yield (g/plant)			
	E1	**E2**	**Deviation from E1-E2**	**% reduction from E1-E2**		**E1**	**E2**	**Deviation from E1-E2**	**% reduction from E1-E2**
JS 20-50	10.03	6.25	3.78	37.69	JS 97-52	**12.87 I**	**9.03 I**	3.84	29.84
JS 20-53	10.14	6.20	3.94	38.86	Bragg	**12.68 II**	**8.67 III**	4.01	31.62
JS 20-59	8.48	5.24	3.24	38.21	NRC 37	**12.11 III**	6.67	5.44	44.92
JS 20-69	7.70	5.69	2.01	**26.10 III**	NRC 7	6.66	2.44	4.22	63.36
JS 20-71	10.60	6.74	3.86	36.42	RVS 2001-4	**11.69 V**	6.41	5.28	45.17
JS 20-73	**12.04IV**	5.79	6.25	51.91	RVS 2007-1	11.45	**8.80 II**	2.65	**23.14 IV**
JS 20-79	11.00	7.16	3.84	34.91	RVS 2007-2	8.91	5.15	3.76	42.20
JS 20-80	8.47	5.43	3.04	35.89	RVS 2007-3	9.93	5.36	4.57	46.02
JS 20-86	9.33	6.01	3.32	35.58	RVS 2007-4	10.28	7.39	2.89	28.11
JS 20-87	10.53	**8.39IV**	2.14	**20.32 I**	RVS 2007-5	7.86	5.36	2.50	31.81
JS 95-60	6.28	4.90	1.38	**21.97 II**	RVS 2007-6	9.02	5.09	3.93	43.57
JS 93-05	7.39	2.99	4.40	59.54	RVS 2007-7	7.85	5.55	2.3	29.30
JS 335	11.05	7.64	3.41	30.86					

E1- well drained conditions; E2 – excessive moisture conditions

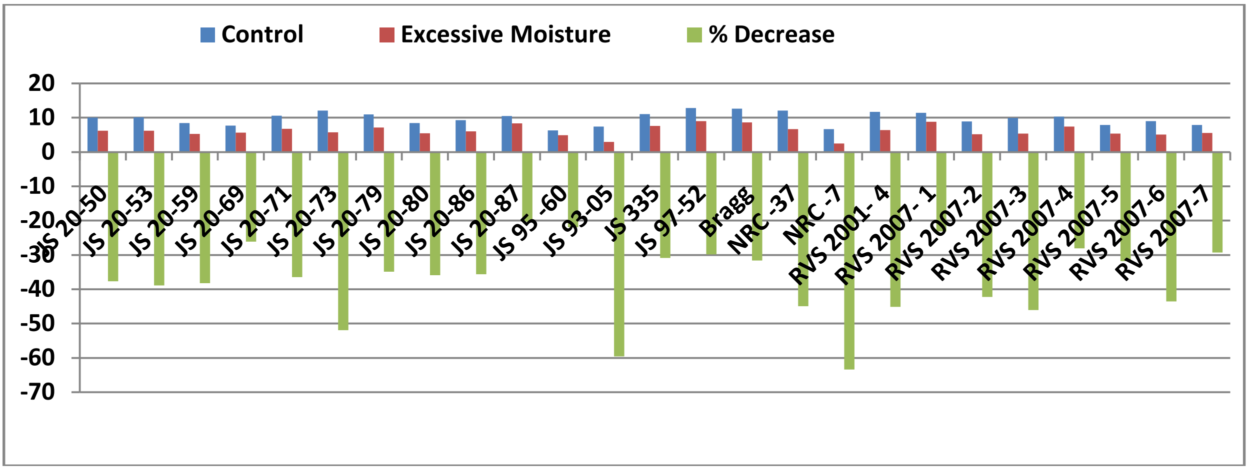


Fig. 1. Upper columns showing comparative yield/plant (g) in control and excessive moisture and lower columns % decrease in yield in excessive moisture condition

REFERENCES

Anonymous. 2012. *Agricultural Statistics at a Glance*, Department of Agriculture and Cooperation, Government of India.

Gohil V N, Pandya H M and Mehta D R. 2006.Genetic variability for seed yield and its component traits in soybean. *Agricultural Science Digest* **26**: 73-4

Hajare T N, Mandal D K, Prasad _ J and Patil V P. 2001. Effect of moisture stress on biomass yield of soybean (*Glycine max*) in Nagpur district, Maharashtra. *Indian Society of Soil Survey and Land Use Planning* **11**: 17-22.

Hou F F and Thseng F S. 1991. Studies on the flooding tolerance of seed varietal differences. *Euphytica* 57: 169-73.

Kuswantoro H. 2011. Respose of soybean genotypes to waterlogging. *Journal of Agronomy*, Indonesia **39**: 19-23.

Linkemer G, Board J E and Musgrave M E. 1998. Waterlogging effect on growth and yield components in late -planted soybean.*Crop Science* **38**: 1576-84.

Malik, M F A, Qureshi A S, Ashraf M and Ghafoor A. 2006. Genetic variability of the main yield related characters in soybean. *International Journal of Agriculture and Biology 8*: 815-9.

Muhammad A, Ali N and Ghafoor A. 2006.Character correlation and path coefficient in soybean. [*Glycine max* (L.) Merrill]. *Pakistan Journal of Botany* **38**: 121-30.

Nag S K, Yadav R K, Sahu L, Salam J L, Soni D K and Ranjan S K. 2007. Study of correlation and path coefficient analysis for yield and its attributes in soybean [*Glycine max (*L.)Merr.]. *Plant Archives* **7**: 175-8

Nigam D, Khare D and Shrivastava A N. 2012. Excess moisture tolerance in soybean.*Soybean Research* **10**: 1-10.

Oosterhuis D M, Scott H D, Hampton R E and Wullschleter S D. 1990. Physiological response of two soybean [*Glycine max (*L.) Merr.] cultivars to short term flooding. *Environmental and Experimental Botany* **30**: 85-92.

Scott H D, DeAngulo J, Baniels M B and Wood L S. 1989. Flood duration effects on soybean growth and yield. *Journal of Agronomy* **81**: 631-6

Sharma K D, Kumar M, Dati S, Singh K N and Sharma S. 2012. Estimation of genetic divergence and selection of promising genotypes for hybridization of soybean under foothill condition of Manipur. *Soybean Research* **10**: 11-7.

Tomer R, Khare D, Shrivastva A N, Patel A, Bhale M S and Shrivastva M K. 2007. Excessive moisture tolerance in soybean. *International Conference on Sustainable Agriculture for Food, Bioenorgy and Lively Hood* **1,** pp 226.

Van Toai T T, Beuerlein J E, Schmitthenner A F and St Martin S K. 1994. Genetic variability for flooding tolerance in soybeans. *Crop Science* **34**: 1112-5.

Van Toai T T, Hoa T T C, Hue N T N, Nguyen H T, Shannon J G and Rahman M A. 2010. Flooding tolerance of soybean [*Glycine max (*L.) Merr.] – Germplasm from southeast Asia under field and screen - house environments. *The Open Agriculture Journal* **4**: 38-46.

Soybean Research (Special Issue Number 2): 44-50: 2014

Study of Principal Component Analyses for Yield Contributing Traits in Fixed Advanced Generations of Soybean [*Glycine max* (L.) Merrill]

BADKUL AMRITA[1], A N SHRIVASTAVA[2], RAJANI BISEN[3], and STUTI MISHRA[4],
Department of Plant Breeding and Genetics,
Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur 482004
Madhya Pradesh, India
E mail: ans_jnkvv@rediffmail.com

ABSTRACT

Yield is a complex entity influenced by several components and environments. Therefore, a technique is required to identify and prioritize the important traits to minimize the number of traits for effective selection and genetic gain. Principal component analysis, basically a well known data reduction technique identifies the minimum number of components, which can explain maximum variability and also to rank genotypes on the basis of PC scores. PCA was calculated using Ingebriston and Lyon (1985) method. In present study, PCA preformed for phenological and yield component traits revealed that out of eleven, only five principal components (PCs) exhibited more than 0.5 eigen value, and showed about 94.62 per cent total variability among the traits. Screen plot explained the percentage of variance associated with each principal component obtained by drawing a graph between eigen values and principal component numbers. PC1 showed 56.29 per cent variability with eigen value 6.19. Graph revealed that the maximum variation was observed in PC1 in comparison to other four PCs. The PC1 was more related to the phenological and yield attributing traits viz., *vegetative phase, plant height, number of branches per plant, number of pods per plant, number of seeds per plant, biological yield per plant, harvest index and yield per plant. Thus, PC1 allowed for simultaneous selection of phenological and yield related traits and it can be regarded as yield factor. PC2 exhibited positive effect for number of seeds per plant and number of seeds per pod. The PC3 was more related to phenological traits, whereas PC4 was more loaded with yield related traits* viz., *harvest index and 100 seed weight. PC5 was more related to plant height. A high value of PC score of a particular advanced line in a particular PC denotes high value for those variables. Code16 hold the first position followed by Code 7 and Code 22 on the basis of PC score in all principal components. Code 21 found in PC 1 (component having maximum characters), in PC 3 and PC 4, can be considered an ideotype breeding material for selection and for further utilization in precise breeding programme.*

Keywords: Advanced fixed genotypes, eigen values, principal component analysis, soybean

The yield level in soybean, at present, is hovering around 1.2 tonne per ha, which is quite low. Yield is a complex entity influenced by several phenological, physiological, yield traits and environment in soybean as true in other crops also. At Jawaharlal Nehru Krishi Vishwa Vidyalaya several advanced generation fixed genotypes have been

esearch Scholar; [2]Principal Scientist; [3]Senior Scientist; [4]Technical Assistant developed of different crosses with concerted efforts mounting appropriate selection pressure. Owing to lack of knowledge regarding relative importance and usefulness of variables, the investigator tries to include all the possible variables and makes the data matrix perceivably large, complicated and beyond comprehension. Therefore, the investigator requires a technique for systematic reduction and summarization of data sets. Principal component analysis, basically a well known data reduction technique identifies the minimum number of components, which can explain maximum variability out of the total variability (Anderson, 1972; Morrison, 1982) and also to rank genotypes on the basis of PC scores.

MATERIAL AND METHODS

The present investigation was carried out at the College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during the *kharif* 2011. The experimental material comprised of 26 fixed advanced generation genotypes of soybean grown in two replications. Observations were recorded randomly on five competitive plants selected from each line and each replication. The observed characters were plant height, number of seeds per pod, biological yield per plant, harvest index, 100 seed weight and yield per plant.

Principal component analysis (PCA) is a standard tool in modern data analysis because it is a simple, non-parametric method for extracting relevant information from confusing data sets. It was calculated using Ingebriston and Lyon (1985) method.

RESULT AND DISCUSSION

PCA preformed for phenological and yield component traits in promising lines of soybean revealed that out of eleven, only five principal components (PCs) exhibited more than 0.5 eigen value, and showed about 94.62 per cent total variability among the traits studied. So, these five PCs were given due importance for further explanation (Table 1).

Table 1. Eigen values, % variance and cumulative eigen values of promising lines of soybean

Traits	Principal component	Eigen values	% variation	Cumulative %
Vegetative phase	PC1	6.191	56.286	56.286
Reproductive phase	PC2	2.034	18.494	74.780
Plant height	PC3	0.917	8.335	83.115
Branches (No/plant)	PC4	0.803	7.296	90.411
Pods (No/plant)	PC5	0.463	4.207	94.618
Seeds (No/plant)	PC6	0.281	2.554	97.172
Seeds (No/pod)	PC7	0.215	1.951	99.123
Biological yield (g/plant)	PC8	0.049	0.446	99.569
Harvest index	PC9	0.042	0.383	99.952
100 seed weight	PC10	0.005	0.041	99.993
Yield (g/plant)	PC11	0.001	0.007	100.000

Screen plot explained the percentage of variance associated with each principal component obtained by drawing a graph between eigen values and principal component numbers. PC1 showed 56.29 per cent variability with eigen value 6.19 which then declined gradually. Semi curve line is obtained which after fifth PC tended to straight with little variance observed in each PC. From the graph, it is clear that the maximum variation was observed in PC1 in comparison to other four PCs, which is selected for explain here. So, selection of lines from this PC will be useful (Fig. 1).

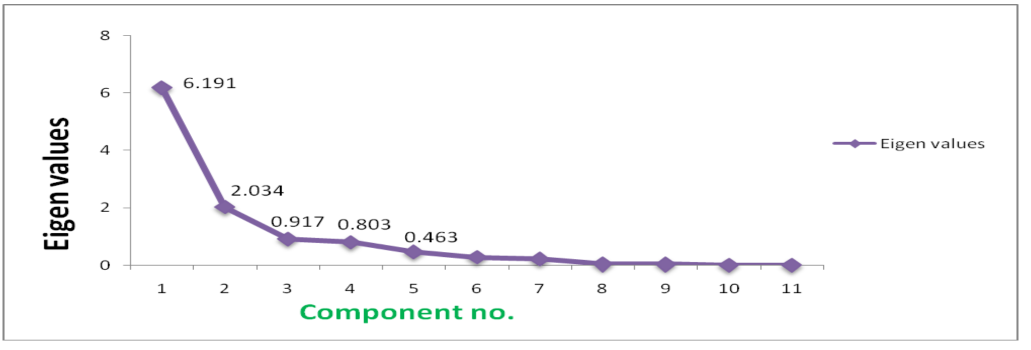


Fig. 1. Screen plot of principal component analysis of soybean genotypebetween eigen value and principal components

Rotated component matrix (Fig. 2) revealed that each principal component separately loaded with various phenological and yield attributing traits under study. The PC1 was more related to the phenological and yield attributing traits *viz.*, vegetative phase, plant height, number of branches per plant, number of pods per plant, number of seeds per plant, biological yield per plant, harvest index and yield per plant. Thus, PC1 allowed for simultaneous selection of phenological and yield related traits and it can be regarded as yield factor. PC2 exhibited positive effect for number of seeds per plant and number of seeds per pod allowed for higher seed yield. The third principal component was more related to phenological traits *i.e.*, reproductive phase whereas PC4 was more loaded with yield related traits *viz.*, harvest index and 100 seed weight. The fifth PC was more related to plant height (Table 2 and 3).

Similar results were obtained by Miladinovic *et al.* (2006) for harvest index, reproductive period, seed weight, vegetative period, yield per plant and plant height. Iqbal *et al*. (2008) reported same for filled pods per plant, grain yield, biological yield per plant, 100 seed weight, harvest index, days to maturity and number of branches per plant and Ojo *et al*. (2012) for number of pods per plant, pod length, pod yield per plant, 100-seed weight and seed yield per plot.

From this study, it was clear that PC1, PC2, PC4 and PC5 were found mostly related to yield attributing traits whereas PC3 was related to phenological traits. As PC1 was constituted by most of the yield attributing traits, an intensive selection procedure can be designed to bring about rapid improvement of dependent traits *i.e.*, yield by selecting the lines from PC1.

PC 1 includes Code 9 which had the highest PC score 1.27 value followed by Code

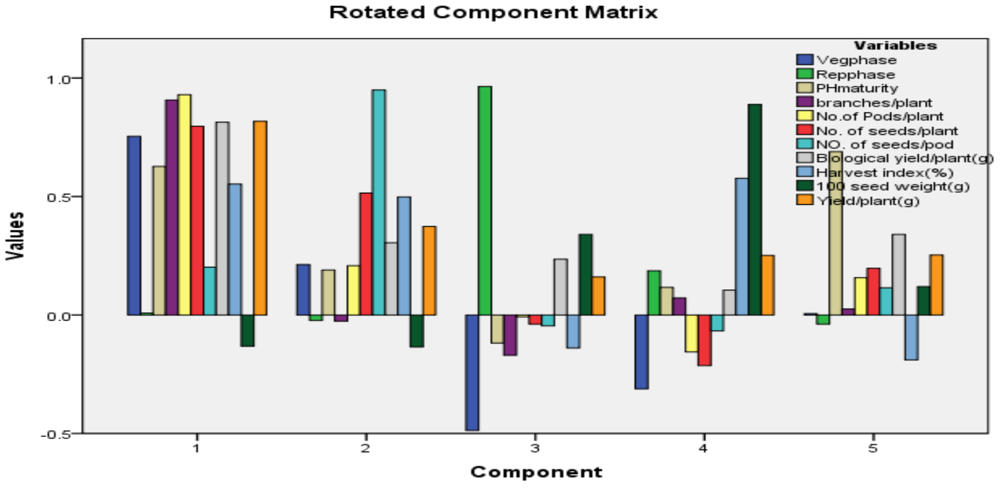


Fig. 2. Phenological and yield traits of soybean genotypes showed in bar diagram

Table 2. Five PC values of rotation component matrix for eleven variables of twenty six genotypes of soybean

Traits	Principal components				
	PC1	PC2	PC3	PC4	PC5
Vegetative phase	0.754*	0.213	-0.487	-0.312	0.006
Reproductive phase	0.008	-0.023	0.965*	0.187	-0.038
Plant height	0.627*	0.190	-0.119	0.117	0.689*
Branches (No/plant)	0.907*	-0.026	-0.170	0.072	0.025
Pods (No/plant)	0.930*	0.208	-0.008	-0.156	0.157
Seeds (No/plant)	0.796*	0.515*	-0.039	-0.214	0.197
Seeds (No/pod)	0.202	0.950*	-0.046	-0.067	0.115
Biological yield (g/plant)	0.814*	0.305	0.236	0.105	0.340
Harvest index	0.553*	0.498	-0.139	0.577*	-0.189
100 seed weight	0.132	-0.135	0.340	0.889*	0.120
Yield (g/plant)	0.818*	0.374	0.161	0.252	0.253

*Extraction method: Principal component analysis; * represents more related traits in each principal component*

23 (1.20), Code 21 (0.87), Code 15 (0.74) and Code 8 (0.73) (Table 4). It indicated that they had high value for phenological and yield related traits such as vegetative phase, plant height, number of branches per plant, number of pods per plant, number of seeds per plant, biological yield per plant, harvest index and yield per plant.

PC 2 includes the genotypes which had high PC score for Code 7 (2.60), Code 18 (1.77),

Table 3. Interpretation of rotated component matrix for the traits having values >0.5 in each PCs

PC1	PC2	PC3	PC4	PC5
		Traits		
Vegetative phase	Seeds (No/plant)	Reproductive phase	Harvest index	Plant height
Plant height	Seeds (No/pod)	-	100 seed weight	-
Branches (No/ plant)	-	-	-	-
Pods (No/plant)	-	-	-	-
Seeds (No/plant)	-	-	-	-
Biological yield (g/plant)	-	-	-	-
Harvest index	-	-	-	-
Yield (g/plant)	-	-	-	-

Code 17 (1.67), Code 16 (0.75) and Code 2 (0.63). It showed they had high value for number of seeds per plant and number of seeds per pod (Table 4)

PC 3 includes Code 21 (1.58) followed by Code 26 (1.28), Code 17 (1.27), Code 2 (1.04) and Code 7 (0.81), which exhibited high value for phenological traits *viz.*, reproductive phase.

PC 4 includes Code 22 which recorded the highest PC score (2.19) followed by Code 16 (1.63), Code 21 (1.08), Code 9 (0.10) and Code 10 (0.93) indicated that they had high value for harvest index and 100 seed weight.

PC 5 includes Code 16 (2.82) which exhibited the highest PC score followed by Code 15 (1.49), Code 5 (1.61), Code 24 (0.67) and Code 6 (0.67) indicated that they had high value for plant height.

Code 9 was found in PC1 and PC4 and had maximum PC score, where as Code 21 was present in PC 1, 3, 4 and had the highest traits for phenological and yield. On the basis of top 5 PC scores in each principal component, genotypes are selected and presented as summarized form (Table 5).

In PC2, number of seeds per plant and number of seeds per pod are yield related traits. PC3 exhibited traits related to phenological traits (reproductive phase). PC4 was related to harvest index and 100 seed weight. In PC5, plant height contributes positive effects on yield attributing traits.

PC scores were calculated for all the advanced lines in 5 principal components and utilized in finding advanced lines, superior for different combination of phenotypic traits. A high value of PC score of a particular advanced line in a particular PC denotes high value for those variables, in that advanced line which the component is representing. Thus, these score can be utilized to propose precise selection indices, whose intensity can be decided by variability explained by each of the PC.

Table 4. PCA scores of soybean genotypes

Genotype	PC1	PC2	PC3	PC4	PC5
Code 1	0.6569	-0.0435	0.4103	-1.8348	-0.3120
Code 2	0.3356	**0.6315**	**1.0354**	-0.5526	-0.1282
Code 3	0.1596	-0.7777	0.6023	-0.1514	-1.6555
Code4	-0.0999	0.5326	-0.6513	-0.0469	0.6529
Code 5	0.1540	-0.3091	-0.1119	-0.1667	**1.6099**
Code 6	0.3834	0.1861	0.0580	-1.4710	**0.6661**
Code 7	-0.6927	**2.5996**	**0.8129**	-0.3840	0.1643
Code 8	**0.7324**	-0.5128	0.5063	-0.2331	-0.5202
Code 9	**1.2703**	-0.5963	0.0132	**0.9998**	-0.1148
Code 10	-0.0708	-0.0389	0.7674	**0.9301**	-0.4895
Code 11	0.7141	-0.1757	-1.5426	0.8219	-0.6504
Code 12	0.3838	0.0699	0.3960	0.8466	-0.9927
Code 13	-0.0864	-0.2734	-1.8555	0.2410	-0.4744
Code 14	0.1240	0.4794	-2.3543	-0.3955	-0.8790
Code 15	**0.7372**	-0.6008	0.7945	0.3423	**1.4921**
Code 16	-0.5837	**0.7540**	0.3793	**1.6287**	**2.8248**
Code 17	-0.5645	**1.6734**	**1.2748**	0.2818	-1.8739
Code 18	0.2848	**1.7672**	-0.3492	-1.4870	0.6009
Code 19	0.4294	0.3983	-1.0360	0.7993	0.5233
Code 20	0.4972	-0.8563	0.5838	-0.0835	-0.1522
Code 21	**0.8743**	-1.6226	**1.5785**	**1.0788**	-0.1131
Code 22	-2.3368	0.1954	-0.8265	**2.1924**	-0.6046
Code 23	**1.1982**	-0.2559	-0.2988	-0.2231	0.4574
Code 24	-2.0831	-2.1473	-0.8444	-1.5842	**0.6694**
Code 25	0.2571	-0.2307	-0.6195	-0.7358	-0.5378
Code 26	-2.6745	-0.8465	**1.2771**	-0.8129	-0.1627

Table 5. Selected genotypes on the basis of PC score in decreasing order in each component

PC1	PC2	PC3	PC4	PC5
Code 9	**Code 7**	**Code 21**	Code 22	**Code 16**
Code 23	Code 18	Code 26	**Code 16**	**Code 15**
Code 21	**Code 17**	**Code 17**	**Code 21**	Code 5
Code 15	**Code 16**	**Code 2**	**Code 9**	Code 24
Code 8	**Code 2**	**Code 7**	Code 10	Code 6

According to the first PC score, Code 9 had highest score followed by Code 23, Code 21 and Code 15 etc., indicating that they were more related to vegetative phase, plant height, *etc.* The highest PC scores in PC2 were recorded by Code 7, Code 18, and Code 17 were closely related to number of seeds per plant and number of seeds per pod. In PC3, highest PC score was exhibited by Code 21 followed by Code 26 and 17 for reproductive phase. At the same time, PC scores of advanced line Code 22 followed by Code 16 and Code 21, etc. in PC 4 related to harvest index and 100 seed weight. PC scores for PC 5 exhibited plant height characteristics in advanced line Code 16 (Table 5). Thus, breeder can select lines having the highest score with desirable combination of quantitative and qualitative traits for further breeding programme.

It can be concluded that PC analysis highlights the characters with maximum variability. So, intensive selection procedures can be designed to bring about rapid improvement of yield attributing traits. PCA also help in ranking of genotypes on the basis of PC scores in corresponding component.

From the above discussion, it is clear that among the advanced lines, Code16 hold the first position followed by Code 7 and Code 22 on the basis of PC score in all principal components. When we considered the entire PC with PC scores and character basis then Code 9 ranked first because it is present in PC 1 as well as in PC 4. Code 9 contributes maximum character because most of the yield related traits are present in PC 1. In PC 4, there are two characters *viz.*, harvest index and 100 seed weight also contributing towards yield attributing traits, so Code 9 performs best in comparison to other genotypes and can be utilized for precise selection to the development of suitable genotypes and also used in best breeding material for the transfer of suitable traits in recipient genotypes. Code 21 also found in PC 1 (component having maximum characters), PC 3 and PC 4 also contributes maximum characters in comparison to Code 9 but score is lower in comparison to Code 9. On that basis, Code 21 is an ideotype breeding material for selection and for further utilization in precise breeding programme.

REFERENCES

Anderson T W. 1972. *An Introduction to Multivariate Analysis*, Wiley Eastem Pvt. Ltd., New Delhi.

Ingebritsen S E and Lyon R J P. 1985. Principal components analysis of multi-temporal image pairs: *International Journal of Remote Sensing* **6**: 687-96.

Iqbal Zafar, Muhammad Arshad, Muhammad Ashraf, Mahmood Tariq and Waheed Abdul. 2008. Valuation of soybean [*Glycine max* (l.) Merrill] germplasm for some important morphological traits using multivariate analysis. *Pakistan Journal of Botany* **40**(6): 2323-8.

Miladinovic Jegor, Hideki Kurosaki, Joe W Burton, Milica Hrustic and Dragana Miladinovic. 2006. The adaptability of short season soybean genotypes to varying longitudinal regions. *European Journal of Agronomy* **25**: 243–9.

Morrison D E. 1982. *Multivariate Statistical Methods* (2nd ed. 4th Print, 1978), McGraw hill Kogakusta Ltd.

Ojo D K, Ajayi A O and Oduwaye O A. 2012. Genetic relationships among soybean accessions based on morphological and RAPDs techniques. *Pertanika Journal of Tropical Agricultural Science* **35**(2): 237–48.

Soybean Research (Special Issue Number 2): 51-56: 2014

Molecular Polymorphism and Diversity for Photoperiodic Genes in Soybean

SANJAY GUPTA[1], MADHU MANIKPURI[2], DEVSHREE THAKUR[3], RAMGOPAL DEVDAS[4], V S BHATIA[5], S M HUSAIN[6] and S K PANDEY[7],

Directorate of Soybean Research (Indian Council of Agricultural Research, Indore 452 016, Madhya Pradesh, India

E mail: sanitaishu@gmail.com

ABSTRACT

Six photo-insensitive [incandescent long day (ILD) insensitive] and twenty one ILD sensitive soybean genotypes were screened through seventeen simple sequence repeat (SSR) markers, located near ILD responsive E1, E3, E4 and E7 genes, and one long juvenility trait specific marker. The polymorphic information content (PIC) ranged from 0.640 to 0.872 with seven SSR loci having the PIC values higher than 0.80. Genotypes were classified in 5 clusters using UPGMA method. These clusters corresponded with photoperiodic response and origin. Photoperiod insensitive genotypes were quite diverse from most of the cultivated varieties. High level of polymorphism between photosensitive and photo-insensitive genotypes at photoperiodic loci and reliable diversity analysis suggest for initiating molecular breeding programmes for this trait.

Key words: Genetic diversity, photoperiod, soybean, SSR

Soybean is grown worldwide from equator to 50° North and 40° South latitudes. The crop has adapted to such a wider range of latitudes through photoperiod mechanism (Xu *et al.*, 2013). Soybean is a photosensitive short day crop and four maturity genes, *viz.* E1, E3, E4 and E7 respond to photoperiod (Tsubokura *et al.*, 2013). Dominant alleles of these genes confer photosensitivity and late maturity while their recessive alleles confer photo-insensitivity and early maturity. Different genotypes adapting to a narrow latitude band have evolved with diverse combination of these genes. Genotypes adapting to higher latitudes have recessive alleles on these loci which make them photo-insensitive to longer day conditions prevailing in those areas (Tsubokura *et al.*, 2013). Soybean genotypes adapted to short day conditions of equatorial region are photosensitive and have dominant alleles on these loci. Between higher latitudes and equatorial region, genotypes have evolved to specific latitudinal bands by the combination of these genes. Precision breeding for developing varieties for a specific area would involve identification of combinations of these genes suitable for that area and their incorporation during breeding process. Since eight maturity genes govern flowering and maturity, phenotypic discrimination of effect of photoperiodic genes among themselves and from other maturity genes during breeding process is practically feasible through molecular markers. In the present investigation we have identified polymorphic markers for all of the photoperiodic loci in soybean and used polymorphic information for clustering these genotypes.

[1,5,6]*Principal Scientist;* [2 and 3] *Research Scholar;* [4]*Senior Scientist;* [7]*Technical Officer*

MATERIAL AND METHODS

Six photo-insensitive genotypes and 21 varieties differing in photoperiodic responses were used for SSR polymorphism and genetic diversity studies (Table 1). Ten leaves, one each from ten plants of 27 soybean genotypes were collected and DNA was isolated by the method described by Doyle and Doyle (1990). SSR analysis was carried out using 17 markers mapped near E1, E3, E4 and E7 photoperiod genes (Cregan *et al*., 1999) (Table 2). One long juvenility trait specific marker was used (Cairo *et al., 2002*). Long juvenile trait delays flowering in short day conditions and confers adaptation to shorter days. Amplification was carried out in a 10 µL reaction mixture consisting of 1X PCR assay buffer (MBI Fermentas, USA), 200 µM of the four dNTPs (MBI Fermentas, USA), 0.5µM each of forward and reverse primers (Sigma India), 0.5 units of Taq DNA polymerase (MBI Fementas, India) and 25 ng template DNA. PCR reactions were carried out using the following cycling parameters: initial denaturation at 94 °C for 3 min, followed by 32 cycles of 94 °C for 1 min, 55 °C for 2 min, 72 °C for 2 min and finally a primer extension cycle of 10 min at 72 °C. The amplification products were separated on 3 per cent metaphor agarose gels. Gels were run for 3 h at 50 V in 1X TBE buffer. The size of the fragments was estimated using a 50-bp DNA ladder (MBI Fermentas, USA).

Table 1. Soybean genotypes and crosses used for the polymorphism analysis by SSR markers

Genotype / Variety	Germplasm/ Cultivar	Country of origin	Genotype / Variety	Germplasm/ Cultivar	Country of origin
	Photo-insensitive			***Photosensitive***	
MACS 330	Cultivar	India	BRAGG	Cultivar	India
EC 325097	Germplasm	Hungary	PK 471	Cultivar	India
EC 333897	Germplasm	USA	PK 472	Cultivar	India
EC 34101	Germplasm	Hungary	PK 416	Cultivar	India
EC 325118	Germplasm	Hungary	JS 90-41	Cultivar	India
EC 390977	Germplasm	-	KHSB 2	Cultivar	India
	Photosensitive		KB 79	Cultivar	India
AGS 25	Germplasm	Taiwan	NRC 37	Cultivar	India
Santa Maria	Germplasm	-	NRC 7	Cultivar	India
JS 97-52	Cultivar	India	Kalitur	Cultivar	India
JS 335	Cultivar	India	JS 71-05	Cultivar	India
EC 538828	Cultivar	USA	Cat 2268	Germplasm	-
JS 95-60	Cultivar	India	EC 241780	Germplasm	Phillipines
JS 93-05	Cultivar	India	EC 241778	Germplasm	Phillipines

The scoring of bands was done as present (1) or absent (0) and data was entered in a binary matrix as discrete variables. Jaccard's coefficient of similarity was calculated and a dendrogram was constructed by using Unweighted Pair Group Method of Arithmetic Mean (UPGMA). The computer package NTSYS-PC Version 2.02

Table 2. SSR polymorphism for photoperiodic genes in soybean

Gene/ Primer /Linkage group	Linkage group	No of allels	PIC	Gene/ Primer /Linkage group	Linkage group	No of allels	PIC
E1/Satt365	C2	7	0.872	E4/ Satt 270	I	6	0.851
E1/ Satt277	C2	9	0.846	E7/ Satt 319	C2	4	0.640
E3/ Satt 229	L	5	0.747	E7/ Satt 489	C2	1	0
E3/ Satt 664	L	1	0	E7/ Satt 100	C2	6	0.805
E3/ Satt 373	L	7	0.758	E7/ Satt 460	C2	1	0
E4/ Satt 354	I	5	0.835	E7/ Satt 658	C2	6	0.798
E4/ Satt 367	I	5	0.672	E7/ Satt 251	C2	6	0.813
E4/ Satt 587	I	1	0	E7/Satt 170	C2	7	0.825
E4/ Satt 105	I	4	0.720				

(Rohlf, 1998) was used for cluster analysis. The polymorphism information content (PIC) was calculated as $1 - \Sigma\, pij^2$ where pij is the frequency of the jth allele of ith marker (Weir, 1990).

RESULTS AND DISCUSSION

Among the 18 primer pairs used in the present study, 13 (72.2 %) were polymorphic, while five primers revealed monomorphic patterns. In total, 82 alleles were detected for the polymorphic SSR primers, with an average of 4.55 alleles per locus. Allele sizes ranged from 100 bp to 300 bp. Summarized data for the SSR loci and their PIC values are presented in table 2. The PIC value, a reflection of allelic diversity and frequency among the soybean genotypes analyzed were generally high for all the SSR loci tested. PIC values ranged from 0.640 to 0.872, with an average of 0.582. Seven SSR loci revealed PIC values higher than 0.80. Among these, Satt365, Satt277, Satt270, Satt354 and Satt170 and Satt251 are noteworthy due to their relatively high polymorphism. Satt 365 and Satt 277, present near E1 gene, identified 7 and 9 alleles with high PIC value of 0.872 and 0.846, respectively. Satt 270 and Satt 354, present near E4 gene, identified 6 and 5 alleles with high PIC value of 0.851 and 0.835, respectively. Satt170 and Satt 251 present near E7 gene identified 7 and 6 alleles with PIC value of 0.825 and 0.813, respectively. The SSR diversity observed in the present study is comparable to those reported by Ristova *et al.* (2010) who detected 4.0 alleles per locus and average PIC value of 4.0 among 28 genotypes using 20 SSR markers. Narvel *et al.* (2000) detected 4.9 alleles per locus and an average marker diversity of 0.56 among 40 plant introductions from several Asian and European countries analysed at 74 SSR loci. Similar results were reported by Tavud- Pirra *et al.* (2009), who observed five alleles per locus and an average marker diversity of 0.65 among 32 breeding lines representing genetic improvement of soybean in Western Europe from 1950 to 2000. A slightly higher SSR diversity was reported by Fu *et al.* (2007), who found 6.3 alleles per locus (included null alleles) and an average polymorphic information content of 0.63 among 45 Canadian soybean cultivars and 37 exotic germplasm accessions analysed at 37 SSR loci. On the other hand, Diwan and Cregan

(1997) reported as many as 10.1 alleles per locus with a mean gene diversity of 0.80 in 35 North American cultivars examined at 20 SSR loci. A high average number of alleles per locus (over 10) have also been reported in several other studies (Wang *et al*., 2006; Wang and Takahata, 2007; Wang *et al*., 2008; Tavaud-Pirra *et al*., 2009; Yoon *et al*., 2007), but in those studies much higher numbers of genotypes were analysed compared to our study.

Cluster analysis based on similarity index grouped soybean genotypes into five groups. Grouping of genotypes was in correspondence with their origin, photosensitivity, long juvenility and other characters. All of the Indian soybean genotypes grouped in cluster I and cluster II while 70 percent of the exotic germplasm grouped in cluster III, IV and V.

Grouping of genotypes according to characters revealed that all the genotypes capable of growing in short day conditions (long juvenile), grouped in first cluster. Among these genotypes Santa Maria is a known source of long juvenility, MACS 330 has been identified to delay flowering in short day condition. AGS 25 has been identified as long juvenile line (Gupta *et al*., 2010), NRC 37 and JS 97-52 are capable of growth under extreme short day conditions (Gupta *et al*., 2010). Among the Indian soybean material, only one variety MACS 330 has been identified as photo-insensitive and this genotype was present in first cluster. MACS 330 has been used for molecular diversity studies in earlier two works from our laboratory (Singh *et al*., 2008: Singh *et al*., 2010) using RAPD, SSR and AFLP markers and in all of these works MACS retained its position in the first cluster as observed in the present study. Although many genotypes are common in this study and earlier two studies, but a few genotypes are new in this work. Further, in the present investigation only SSR markers linked to photoperiodic genes were used while in our earlier two studies SSR, AFLP and RAPD markers distributed throughout the genome were used. Cluster II represented exclusive grouping of high yielding cultivars. Among these cultivars seven are of Indian origin and EC538828 is from USA. EC 538828 is a recent introduction from USA and this variety has many desirable attributes like very bold seed, high yield, drought tolerance and earliness. Cluster III contained single photo-insensitive genotype from USA while cluster IV and V contained 2 and 1 photo-insensitive genotypes from Hungary and USA, respectively. Cluster V contains two other genotypes in addition to photo-insensitive genotypes and these both genotypes are rust resistant genotypes. Diversity analysis of this study is different from other studies, as in the present investigation only SSR markers present near photoperiodic genes have been used. In spite of using a very limited region of soybean genome, a high level of genetic diversity was observed. Since the SSR markers used in this study were related to photoperiodic gene, a very clear grouping of grouping of genotypes according to their photoperiodic response was observed. Identification of polymorphic markers for all of the photoperiodic genes would help initiate marker identification and validation work for these genes which would in turn assist in marker assisted selection. Existence of photoperiodic gene based diversity suggests for initiating breeding programmes involving photosensitive varieties and photoinsensitive genotypes to develop genotypes suitable for different latitudes in India.

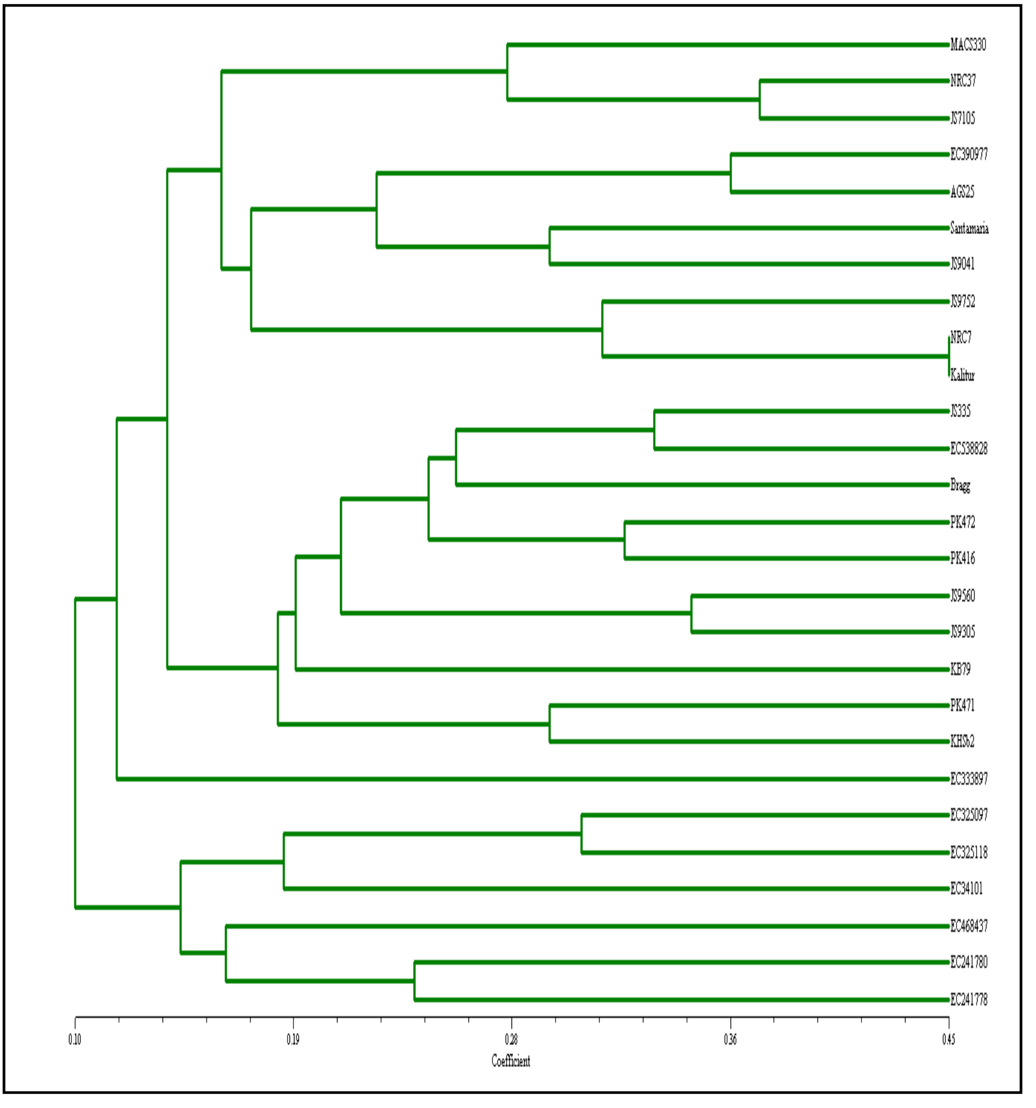


Fig 1. Cluster diagram of molecular diversity in 27 parental soybean genotypes

ACKNOWLEDGEMENT

Authors are thankful to Director, Directorate of Soybean Research for kind support and help in carrying out the work.

REFERENCES

Cregan P B, Jarvik T, Bush A L, Shoemaker R C, Lark K G, Kahler A L, Kaya N, VanToai T T, Lohnes D G, Chung J *et al.* 1999. An integrated genetic linkage map of the soybean. *Crop Science* **39**: 1464-90.

Cairo C A, Stein J, Delgado L, Bortolotti S, Sebasti´an A. Guelman S A,Juan Pablo A, Ortiz J P A and Morandi E N. 2002. Tagging the juvenile locus in soybean [*Glycine max* (L.) Merr.] with molecular markers. *Euphytica* **124**: 387–95.

Diwan N and Cregan P B. 1997. Automated sizing of fluorescent-labeled simple sequence repeat (SSR) markers to assay genetic variation in soybean. *Theoretical and Applied Genetics* **95:** 723-33.

Doyle J J and Doyle J L. 1990. Isolation of plant DNA from fresh tissue. *Focus* **12:** 13-4.

Fu Y B, Peterson G W and Morrison M J. 2007. Genetic diversity of Canadian soybean cultivars and exotic germplasm revealed by simple sequence repeat markers. *Crop Science* **47:** 1947-54

GuptaG K, Sharma A N, Dupare B U, Devidas R and Kumar S. 2010-11. Annual Report, Directorate of Soybean Research, Indore, Madhya Pradesh, India, pp 20.

Narvel J M, Fehr W R, Chub W C, Grant D and Shoemaker E C. 2000. Simple sequence repeats diversity among soybean plant introductions and elite genotypes. *Crop Science* **40**: 1452-8

Ristova D, Šarcevic H, Silvio Šimon S, Mihajlov L and Ivan Pejic I. 2010. Genetic diversity in Southeast European soybean germplasm revealed by SSR markers. *Agriculturae Conspectus Scientificus* **75:** 21-6.

Rohlf F J. 1998. NTSYS-PC numerical taxonomy and multivariate analysis system. exeter software, New York.

Singh R K, Bhat K V, Bhatia V S, Mohapatra T and Singh N K. 2008. Association mapping for photoperiod insensitivity trait in soybean. *National Academy Science Letters* **31:** 281-3.

Singh R K, Bhatia V S, Bhat K V, Mohapatra T, Singh N K, Bansal K C and Koundal K R. 2010. SSR and AFLP based genetic diversity of soybean germplasm differing in photoperiod sensitivity. *Genetics and Molecular Biology* **33:** 319-24.

Tavaud-Pirra M, Sartre P, Nelson R, Santoni s, Texier N and Roumet P. 2009. Genetic diversity in a soybean collection. Crop Science **49:** 895-902.

Tsubokura Y, Matsumura H, Xu M, Liu B, Nakashima H, Anai T, Kong F, Yuan X, Kanamori H, Katayose Y, Takahashi R, Harada K and Abe J. 2013. Genetic Variation in Soybean at the Maturity Locus E4 Is Involved in Adaptation to Long Days at High Latitudes. *Agronomy* **3:** 117-34

Wang K J and Takahata Y. 2007. A preliminary comparative evaluation of genetic diversity between Chinese and Japanese wild soybean (*Glycine soja*) germplasm pools using SSR marker. *Genetic Resources and Crop Evolution* **54:** 157-65.

Wang L X , Guan R X, Li Y H, Lin F Y, Luan W J, Li W, Ma Y S, Liu Z X, Chang R Z1 and Qiu L J. 2006. Genetic diversity of Chinese cultivated soybean revealed by SSR markers. *Crop Science* **46:** 1032-8.

Wang L X, Guan R X, Li Y H, Lin F Y, LuanW J, Li W, Ma Y S, Liu Z X, Chang R Z and Qiu L J. 2008. Genetic diversity of Chinese spring soybean germplasm revealed by SSR markers. *Plant Breeding***127**: 56-61.

Weir B. 1990. *Genetic Data Analysis: Methods for Desecrate Population Genetic Data*. Sinauor Assoc, Sunderland, 376.

Xu M, Xu Z, Liu B, Kong F, Tsubokura Y, Watanabe S, Xia Z, Harada K, Kanazawa A, Yamada T and Abe J. 2013. Genetic variation in four maturity genes affects photoperiod insensitivity and PHYA-regulated post-flowering responses of soybean. *BMC Plant Biology* **13:** 91.

Yoon M, Song Q, Choi I, Specht J, Hyten D and Cregan P. 2007. BARCSoySNP23: a panel of 23 selected SNPs for soybean cultivar identification. *Theoretical and Applied Genetics* **114:** 885-99.

Soybean Research (Special Issue Number 2): 57-63: 2014

Study of Gene Action and Combining Ability for Physiomorphic and Yield Characters in Soybean [*Glycine max* (L.) Merrill]

***JARMAN MAHESH* [1], *S R RAMGIRY* [2] *and SUNIL KUMAR YADAV* [3]**
RAK College of Agriculture (Rajmata Vijayaraje Sindia Krishi Vishwa Vidyalaya), Sehore** 466 001, **Madhya Pradesh, India
E mail: gentic.ksunil@ymail.com, sunil.dadima@gmail.com

ABSTRACT

The present investigation was undertaken to study combining ability and nature of gene action for yield and yield contributing traits in cross involving six parents of soybean genotypes viz., *JS 93-05, JS 335, JS 2000-10, JS 93-37, VLS 59 and JS 88-66 and their* F_1*'s (excluding reciprocal) obtained through diallel cross were evaluated during* kharif *2008 at RAK College of Agriculture, Sehore. Ten quantitative traits were studied during the investigation on five randomly selected plants from each genotype. The data were subjected to combining ability analysis as per method 2, Model I of Griffing (1956) and Hayman (1954) diallel analysis for estimation of the genetic components, GCA and SCA. Analysis of variance revealed that significant level diversity among the traits for both parents and their* F_1*'s. Significant variances indicated by combining ability due to GCA and SCA effect for number of pod per plant, 100 seed weight and seed yield per plant. Among the parents, JS 335, JS 93-05, JS 93-37 were found best general combiner for seed yield per plant, number of pod per plant and 100 seed weight. The SCA variance was observed to be more important for all the traits studied. Cross combination JS 2000-10 x JS 93- 37, JS 93-05 x JS 93-37, JS 335 x VLS 59 and JS 335 x JS 88-66 were found to show significant positive SCA effects for seed yield per plant and yield contributing traits.*

Key words: Combining ability, GCA, gene action, SCA effect, soybean

Soybean [*Glycine max (*L.) Merrill] occupies an area of 73.4 million hectares producing 161.9 million tonnes with the productivity of 2,206 kg per hectare in the world (Anonymous, 2010). In India, it occupies an area of 10.18 million hectare with the production of 12.28 million tonnes and productivity of 1,207 kg per hectare (Anonymous, 2012) which is just half the average productivity of the world. Precise information on the type of gene action helps the plant breeder in formulating successful genetic improvement program for yield and yield contributing characters. Yield being a complex character, is influenced by a number of yield contributing characters controlled by polygene's and also influenced by environment. Combining ability analysis helps in identification of appropriate genotypes for further hubridization programmes.

MATERIAL AND METHODS

Six parents were sown in three rows each of 3 m length with spacing (45 cm x 10 cm), and crosses were made following half diallel in all possible combination resulting in

[1]*Technical Assistant,* [2]*Head of Section,* [3]*Ph D Student*

15 F_1`S. Progenies were planted following the same spacing as parents and observation were recorded on 5 randomly selected plants from each progeny for 10 quantitative traits *viz.*, days to 50 per cent flowering, days to maturity, number of primary branches, plant height, number of pods per plant, number of seeds per pod, seed yield per plant, biological yield per plant, harvest index and 100 seed weight. The data were subjected to combining ability analysis as per method 2, Model I of Griffing (1956), diallel analysis for estimation of the genetic components, *GCA* and *SCA* and components of variance estimated by following Hayman (1954).

RESULTS AND DISCUSSION

Analysis of variance (Table 1) revealed significant differences among the parents, crosses, parents x crosses, GCA, SCA for most of the traits. This indicated the extent of variability and combining ability in the material and crosses, respectively. Primary branches per plant, plant height, pods per plant, seed yield per plant and 100 seed weight had significant GCA and SCA variances which indicated for the preponderance of additive and non-additive gene action, respectively, in the expression of these traits. These results indicated that both selection of progenies in segregating generation and hybrid breeding would be highly effective.

For hybrid seed production, the selection of parents should be based on *per se* performance and combining ability effects. The estimates of GCA effect (Table 2) revealed that JS 335 and VLS 59 were good general combiner for early flowering. All of the parents were good combiners for days to maturity, number of pods per plant, number of seeds per pod, biological yield per plant and 100 seed weight. The parent JS 93-05 was high general combiner for number of primary branches, JS 335 and JS 88-66 for short plant height, JS 93-05 for number of pods per plant, JS 335 and JS 93-05 for seed yield per plant, JS 93-37 and VLS 59 for harvest index, JS 93-05 was high general combiner for 100 seed weight.

SCA effect was both positive and negative for different traits in various crosses (Table 3). Two crosses, namely, JS 335 x JS 200-10 and VLS 59 x JS 88-66 exhibited significantly positive SCA effects for number of primary branches. As for as the plant height is concerned, the 4 crosses namely JS 93-05 x JS 335, JS 93-05 x JS 93-37, JS 335 x VLS 59 and JS 2000-10 x JS 93-37 exhibited significant negative SCA effects. Other promising crosses were JS 93-05 x JS 93-37, JS 335 x VLS 59, JS 335 x JS 88-66 and JS 2000-10 x VLS 59 for number of pods per plant; JS 2000-10 x JS 93-37 for seed yield per plant; JS 93-05 x JS 335 for biological yield per plant; JS 335 x JS 88-66 and JS 2000-10 x JS 93-37 for 100 seed weight.

The ratio of genetic components revealed the presence of additive and non-additive components of heritable variance (Table 4). The test of homogeneity (t^2-test) of arrays gave non-significant values for all the traits, except days to 50 per cent flowering and number of primary branches. The linear egression of covariance on variance was tested for significance (b=0) and for deviation from unity (b=1) by usual t-test indicating the presence of epitasis for days to 50 per cent flowering, number of seeds per pod and 100 seed weight. Hayman (1954) stated that even when a trait exhibits a partial failure of assumption, analysis could still be carried out.

In genetic analysis of seed yield and its component traits, the significant value of non-fixable (H_1 and H_2) and fixable (D) genetic components for number of pods per plant, number of seed per pod and 100 seed weight indicated both additive and non-additiv

Table 1. Analysis of variance for 10 quantitative characters in half diallel of soybean

Source	df	Days to 50 % flowering	Days to maturity	Primary branches (No/ plant)	Plant height (cm)	Pods (No/ plant)	Seed (No/ pod)	Seed yield (g/ plant)	Biological yield (g/plant)	Harvest index (%)	100 seed weight (g)
Replication	2	4.77	56.77	0.82	1.10	2.58	2.47*	0.08	26.08	17.02	1.62**
Treatments	20	6.33	35.92	6.96**	23.65**	96.01**	0.13	0.94**	52.65*	122.59*	6.48**
Parents	5	3.25	37.02	13.65**	12.46**	138.85**	0.05	1.79**	93.12*	260.62**	7.78**
Crosses	14	7.70	37.80	4.84**	25.55**	73.28**	0.13	0.64**	28.24	81.67	6.41**
Parents x crosses	1	2.41	3.97	3.21*	52.98**	200.04**	0.57	0.83	192.11**	5.27	1.04**
Error(TXR)	40	5.76	2.48	0.67	1.56	5.12	0.69	0.24	28.09	52.61	0.13
GCA	5	1.67	10.39	2.39**	4.29**	60.38**	0.038	0.48**	16.10	86.94**	2.41**
SCA	15	2.25	12.50	2.29**	9.08**	22.54**	0.048	0.25**	18.03	25.50	2.07**
Error (gca x sca)	40	1.92	8.27	0.22	0.52	1.70	0.231	0.08	9.36	17.53	0.44

** Significant at 5 %; ** Significant at 1 %*

Table 2. Estimate of general combining ability effect of 6 parents for seed yield and its components in soybean

Parents	Days to 50 % flowering	Days to maturity	Primary branches (No/plant)	Plant height (cm)	Pods (No/ plant)	Seed (No/ pod)	Seed yield (g/plant)	Biological yield (g/plant)	Harvest Index (%)	100 seed weight (g)
JS 93-05	0	-2.06 **	0.94**	0.01	3.01**	0.09 **	0.12	-2.54 **	6.01**	0.63**
JS 335	-0.71 *	-0.49 *	-0.14	-1.12**	-4.49**	0.08 **	0.41**	0.35 **	0.82	0.17*
JS 2000-10	0.04	0.9 *	-0.03	0.74**	1.06*	0.05 **	-0.07	1.41 **	0.17	-0.91**
JS 93-37	-0.21	-1.53 **	-0.06	0.11	2.01**	0.05 **	-0.32**	0.6 **	-1.43	0.30**
VLS 59	-0.71 *	0.9 *	-0.76**	0.78**	-1.82**	-0.08 **	-0.05	0.98 **	2.92*	0.17*
JS 88-66	-0.25	-1.76 **	-0.01	-0.51*	0.22	0	-0.10	0.4 **	-2.64	-0.37**
S.E.(gi)	2.08	3.80	0.153	0.233	0.422	0.01	0.093	0.12	1.35	0.068

** Significant at 5 %; ** Significant at 1 %*

Table 3. Estimates of specific combining ability (sca) effect for seed yield and its components in of 6 X 6 half diallel of soybean

Crosses	Days to 50 % flow-ering	Days to maturity	Primary branches (No/ plant)	Plant height (cm)	Pods (No/ plant)	Seed (No/pod)	Seed yield (g/ plant)	Biolo-gical yield (g/ plant)	Harvest Index (%)	100 seed weight (g)
JS 93-05 X JS 335	-1.8 *	2.93 *	-1.06*	-2.30**	-6.99**	0.15 **	-0.66*	8.00**	-13.8 ***	0.69**
JS 93-05 X JS 2000-10	1.86 *	0.52	-1.23**	0.40	-6.20**	0.18 ***	-0.91**	-7.84**	7.26 ***	-0.59**
JS 93-05 X JS 93-37	0.03	0.23	0.19	-2.33**	6.85**	0.18 ***	0.23	0.19	2.67 ***	0.83**
JS 93-05 X VLS 59	-1.05	-0.82	-1.10*	-0.04	1.68	-0.39 ***	0.06	0.26	-2.16 ***	-1.01**
JS 93-05 X JS 88-66	-0.85	-1.82	-0.52	3.81**	-2.36*	-0.76 ***	0.36	0.69	-3.68 ***	0.47*
JS 335 X JS 2000-10	-0.51	-1.36	1.86**	1.66*	-2.36*	-0.29 ***	0.13	-2.20	0.29	-1.94**
JS 335 X JS 93-37	3.32 ***	3.35 **	-0.73	-0.34	-3.65**	-0.29 ***	-0.55*	-4.15	3.51 ***	-1.34**
JS 335 X VLS 59	-0.43	-2.36 *	0.32	-2.11	2.85*	-0.17 ***	0.04	-1.54	2.68 ***	0.72**
JS 335 X JS 88-66	-1.55	-0.02	-0.43	-1.09	4.47**	0.06	0.00	-0.44	1.65 ***	2.10**
JS 2000-10 X JS 93-37	-2.35 **	0.93	-1.89**	-1.44*	-5.53**	0.05	0.86**	-1.45	2.77 ***	2.37**
JS 2000-10 X VLS 59	-0.43	-4.44 ***	-0.18	1.03	3.30**	-0.13 **	0.16	-2.41	0.85 **	-0.94**
JS 2000-10 X JS 88-66	1.11	-4.11 ***	0.73	5.18*	-2.74*	0.1 *	-0.55*	-2.85	-2.88 ***	0.54**
JS 93-37 X VLS 59	-1.6 *	4.93 ***	-1.43**	5.56**	-1.32	-0.13 **	0.31	-0.09	1.26 ***	-2.34**
JS 93-37 X JS 88-66	0.95	-3.4 **	0.15	0.95	-0.72	0.1 *	-0.34	0.01	-1.56 ***	-0.79**
VLS 59 X JS 88-66	1.53	6.23 ***	3.19**	-0.22	-4.20**	0.22 ***	-0.24	-2.72	2.91 ***	0.00
S.E.(Sig)	.69	1.27	0.42	0.64	1.15	0.00	0.25	2.71	0.08	0.187

**Significant at 5%; **Significant at 1%*

Table 4. Components of genetic variance and related statistics for seed yield and its components in soybean

Genetic compo-nents	Days to 50% flowering	Days to maturity	Primary branches (No/plant)	Plant height (cm)	Pods (No/ plant)	Seed (No/ pods)	Seed yield plant (g/ plant)	Biological yield (g/plant)	Harvest Index (%)	100 seed weight (g)
B	0.36**	0.08	0.98	0.46	0.57	0.32*	0.11	0.67	0.35	-0.10*
t^2	46.37**	0.07	4.46*	1.60	1.50	21.39	1.15	0.01	0.03	0.22
D	-0.84	4.07	4.33*	3.63	44.58**	-0.21**	0.52*	21.67	69.33*	2.55*
H1	4.18	34.02	10.04*	37.93**	83.96*	-0.42**	0.87	48.97	66.90	9.01**
H2	4.72	27.16	7.04	28.36**	73.63*	-0.31**	0.74	37.36	54.91	7.33**
h^2	-0.55	-3.74	0.57	11.16	42.27*	0.00	0.13	36.30	-8.60	0.20
F	-1.67	7.80	6.53	9.41	27.78	-0.27**	0.51	31.55	52.25	3.07
E	1.92**	8.27*	0.23	0.52	1.71	0.23**	0.08	9.37	17.54	0.04

**, **: Significant at 5% and 1% respectively*

Table 5. Genetic parameter for seed yield and its components in soybean

Genetic components	Days to 50% flowering	Days to maturity	Primary branches (No/plant)	Plant height (cm)	Pods (No/ plant)	Seeds (No/ pod)	Seed yield (g/ plant)	Biological yield (g/ plant)	Harvest Index (%)	100 seed weight (g)
Heritability (Narrow –sense)	-6.58	6.42	49.54	10.61	41.44	-37.59	42.63	28.31	44.98	29.41
$[H_1/D]^{1/2}$	0.00	2.89	1.52	3.23	1.37	1.41	1.30	1.50	0.98	1.88
$h^2/4H_1$	0.28	0.20	0.18	0.19	0.22	0.19	0.21	0.19	0.21	0.20
$[(4DH_1)^{1/2}+F_1]/(4DH_1)^{1/2}-F_1]$	-	1.99	2.96	2.33	1.58	0.37	2.22	2.87	2.24	1.94
h^2/H_2	-0.117	-0.13	0.08	0.39	0.57	0.00	0.17	0.97	-0.15	0.02

type of gene action governing these traits. Significant values of H_1 and H_2 for plant height and number of primary branches (only in case of H_1) indicated the preponderance of non-additive genetic variance in the inheritance of these traits. The importance of both additive and non-additive type of gene-action for these characters has earlier been reported by Gravina *et al*. (2003) and Thangavel *et al*. (2004). The F value measures dominant effects were positive for most of the characters revealing an excess of dominant alleles for these traits among the parents.

The relatively greater magnitude of dominance component (H_1) than additive component (D) for most of the traits led to the phenomenon of over dominance as ratio $(H_1/D)^{1/2}$ exceeded unity, the values are presented in (Table 5) similar results were substantiated by Khattab (1998). The value of $H_2/4H_1$ was less than 0.25 for most of the characters indicating the asymmetrical distribution of positive and negative alleles in the parents. Similar kind of asymmetrical distribution of alleles in the parents was also reported by Khattab (1998). The ratio $[(4DH_1)^{1/2} + F]/ [(4DH_1)^{1/2} - F]$ was greater than unity for all the characters except number of seeds per pod indicating about the pre-ponderance of dominant genes in the parents. Low magnitude of h^2/H_2 for all the characters indicated the presence of major genes action, which inferred that traits were under polygenic control.

Diallel analysis estimated that both additive and non-additive genetic variances played a played a significant role for most of the characters studied. The SCA variance was higher than GCA variance for most of the characters, indicating predominance of non-additive gene action in the inheritance of these traits. However, additive variance played an important role in the expression of harvest index. None of the parents showed desirable GCA effects simultaneously for all the characters. The genotypes JS 335 and JS 93 05 were found to be the good general combiners, while JS 2000-10 x JS 93 37 was identified as the best cross combination for seed yield and harvest index. Preference would be given to harvest index in selection programme to isolate superior lines with genetic potentiality for higher seed yield.

REFERENCES

Anonymous. 2010. *Area and Production Estimation of Soybean, Based on Crop Survey*, conducted by SOPA, Sept. 15 to 27.

Anonymous. 2012. 4thAdavance estimates of area and production of soybean, by Directorate and economics and statistics, department of agriculture and cooperation, July, 16. 2012. (http://www.agritech.tnau.ac.in/agriculture/agri_cropscenario_india.pdf)

Gravina G de A, Sediyama C S, MartinsFilho S, Moreira M A and Baarros E G de. 2003. Diallel analysis for frogeye leaf spot resistance in soybean. *Pesquisa Agropecuaria Brasileira* **38**(6): 673-80.

Griffing B. 1956. Concepts of general and specific combining ability in relation to diallel crossing system. *Australian Journal of Biological Sciences*. **9**: 463-93.

Hayman B I. 1954. The theory and analysis of diallel crosses. *Genetics* **39**: 789-809

Khattab A B. 1998. Genetical analysis of some quantitative traits in soybean (*Glycin max* L. Merrill). *Annals of Agricultural Science* **36** (1): 133-42.

Thangavel P, Sabeson T, Sarvnan K, Vrevani N and Ganesh J. 2004. Combining ability studies in soybean (*Glycine max* L.). *Legumes Research* **27**: 216.

Soybean Research (Special Issue): 64-69: 2014

Genetic Variability, Heritability, Phenotypic and Genotypic Correlation Studies among Promising Soybean Genotypes under Manipur Condition

H NANITA DEVI[1], T SUNANDA DEVI[2] and NILIMA KARAM[3],
Directorate of Research, Central Agricultural University,
Imphal 795 004, Manipur, India
E mail: heisnamnanita@rediffmail.com

ABSTRACT

The present study was carried out at Andro Research Farm, Central Agricultural University, Imphal, Manipur during kharif 2012 to estimate genetic variability parameters for some traits such as days to 50 per cent flowering, days to maturity, plant height, 100 seed weight, seed yield per ha and oil content in thirteen soybean genotypes. Statistical analysis showed significant differences between the tested genotypes. Genotypic and phenotypic coefficients of variations were high for plant height, seed yield per ha and 100 seed weight. Heritability estimates were high for plant height, oil content and days to maturity. A high genetic advance was observed for seed yield per ha and plant height. Correlation analysis showed a significant and negative relationship between seed yields per ha and plant height. A positive and significant correlation was found between oil content and plant height, between days to 50 per cent flowering and days to maturity, between plant height and days to 50 per cent flowering and days to maturity.

Key words: Correlation coefficients, genetic advance, heritability, Soybean, genetic variability

Soybean (*Glycine max*), otherwise known as a 'miracle crop' with over 40 per cent protein and 20 per cent oil has emerged as one of the major oilseeds and revolutionized rural economy and alleviated the socio-economic status of soybean farmers. With the coverage of above 12.68 million hectares and estimated production of 12.98 million metric tons (Anonymous, 2013a), soybean has occupied important place in agriculture and oil economy of India. The result of "On Farm Research" through FLDs established an increase of about 42.0 per cent over farmer's practice in soybean productivity by adopting recommended research improved technology. The success story of soybean under rainfed cultivation in Madhya Pradesh is awaited to be repeated in other non-conventional regions like North Eastern States.

Since time immemorial, farmers of Manipur grow soybean in the vicinity of their dwellings for culinary purposes. The green/matured grains are used for making various fermented and non-fermented foods. Soybean cultivation in Manipur was confined only in kitchen garden and the total area was negligible while the area was increased up to 3,000 ha during early part of this millennium. In recent years, the area has increased up to 7,500 ha (Anonymous, 2013b). The average yearly yield of soybean is about 820 kg per ha which is below the National average yield of 1,000 kg per ha. The low rate of increase in area is may be due to the limited availability of suitable location specific high yielding

[1]*Jr Plant Breeder;* [2]*Agronomist;* [3]*Entomologist*

varieties. Thus, the need of the hour is development of location specific superior varieties.

The basic key to bring about the genetic upgrading to a crop is to utilize the available genetic variability. The variability in the population is largely due to genetic cause with least environment effect, the possibility of selecting superior genotype is a prerequisite for obtaining higher yield, which is the ultimate expression of various yield contributing characters. Therefore, direct selection for yield could be misleading (Islam and Rasul, 1998). It is difficult to judge what proportion of observed variability is heritable and not heritable i.e. environmental. The process of breeding in such population is primarily conditioned by magnitude and nature of interactions of genotypic and environmental variations in plant characters. It is imperative to partition the observed variability into its heritable and non-heritable components and to have an understanding of parameters like genetic co-efficient of variation, heritability and genetic advance (Thakur *et al.,* 2011). The objectives of the study were to assess the performance of thirteen soybean varieties under Manipur condition, and study the extent of inheritance and their relationship between yield component characters.

MATERIAL AND METHODS

The research study was conducted during *kharif,* 2012 at the CAU Research farm, Andro (Latitude 24 45′ N, Longitude 94 03′E, Altitude 810 m above MSL and average rainfall 966.2 mm during *kharif* 2012). The soil of the experimental field is clay loam having pH of 5.8 and 0.72 per cent organic carbon. The experiment was laid out in randomized complete block design in 8 row plots of 5 m long with four replications. Thirteen soybean genotypes - Dsb 19, AMS 59, SL 900, Ds 2706, MAUS 504, MACS 1340, AMS 56, PS 1499, KDS 378, KDS 701, Bragg, RKS 18, and JS 97-52 were used. Row to row and plant to plant spacing was kept at 45 and 10 cm respectively. At two weeks after emergence of seedlings, thinning was done to one seedling per hole. Normal cultural practices were adopted. The observations were recorded from five randomly selected plants in each plot in each replication on days to 50 per cent flowering, days to maturity, plant height (cm), 100 seed wt. (g), seed yield (kg/ha) and oil content (%). Seed yield was recorded on net plot basis and then converted into kg per ha. The plot mean values were subjected to analysis of variance. The genotypic and phenotypic coefficients of variation (GCV and PCV) were estimated according to the method outlined by Burton (1952). Heritability (broad sense) and genetic advance were calculated as described by Johnson *et al*. (1955). Correlation coefficients were calculated as explained by Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

Significant differences ($P<0.05$) among the genotypes tested were observed for all the traits under study (Table 1). It therefore indicated that there were wide differences among the genotypes investigated. The results in this study agree with earlier reports by Zafar *et al*. (2008) that there existed a wide range of genotypic variability in the characters. The extent of variability measured in terms of range, grand mean, phenotypic coefficients of variation (PCV), genotypic coefficients of variation (GCV), heritability (broad sense), Genetic advance (GA) are presented in table 2. For the character days to 50 per cent flowering, the study revealed that, a range of 39.50 - 50.50 days was obtained among the genotypes while a range of 69.00 -

92.00 days was obtained for maturity. Similar trends of variability in phenology were also recorded by Singh *et al.* (1996) who reported a range of 30 to 57 days for 50 per cent flowering and a range of 78.66 to 100.66 days for

Table 1. Variance mean squares of 13 soybean genotypes for six characters evaluated under Manipur condition

Source of variance	d. f.	Days to 50 % flowering	Days to maturity	Plant height (cm)	100 seed weight (g)	Seed yield (kg/ha)	Oil content (%)
Replication	4	5.28*	32.12*	12.80*	6.08*	56170.56*	0.03*
Treatments	12	39.81*	157.97*	1403.19*	16.16*	264543.18*	13.19*
Error	36	3.90	9.85	9.73	1.57	67855.05	0.03

** = Significant at P<0.05 levels*

Table 2. Estimates of genetic parameters for six characters in soybean genotype under Manipur condition

Characters	Range	Mean	PCV (%)	GCV (%)	H^2 (%) (Broad sense)	GA
Days to 50 % flowering	39.50 - 50.50	45.38	7.90	6.60	69.67	5.15
Days to maturity	69.00 - 92.00	102.57	6.67	5.93	78.98	11.13
Plant height (cm)	30.05 - 86.80	61.84	30.56	30.14	97.28	37.87
100 seed weight (g)	9.86 - 16.91	12.95	17.64	14.74	69.86	3.28
Seed yield (kg/ha)	958.33 - 1870.83	1248.82	27.39	17.75	42.01	296.06
Oil content (%)	10.17- 16.43	13.13	13.87	13.80	98.99	3.71

days to maturity. The study revealed that plant height had a range of 30.05 - 86.80 cm. Karmakar and Bhatnagar (1996) reported a range of 45.2 – 111.9 cm, while Karnwal and Singh (2009) recorded a span of 66.25 -110.75 cm for plants height in their respective studies involving various soybean genotypes. Data on 100-seed weight among varieties varied from 9.86 g - 16.91 g and these results are inaccordance with Srivastava and Jain (1994). A highest yield of 1,870 kg per ha was obtained for 'PS 1499' and lowest 958.33 kg per ha was recorded for 'Ds 2706' and similar results on yield variability were observed by

Rasaily *et al.* (1986); Karmakar and Bhatnagar (1996); Dadson (1976) and Ghatga and Kadu (1993). The data recorded in the current study showed a range of 10.17- 16.43 for oil content and variability for oil content was also reported by Dadson (1976), Maestri *et al.* (1998) and Malik *et al*. (2006). The narrow differences between phenotypic and genotypic coefficients of variation were observed for all the characters indicating the less influence of environment on expression of characters studied except for seed yield (kg/ha). The partitioning of variance components showed moderate and high heritability estimates in the broad sense for the characters (Table 2).The study revealed that high heritability was recorded for days to 50 per cent flowering, days to maturity, plant height, oil content, indicating the additive mode of gene action. On the basis of heritability, days to maturity, days to 50 per cent flowering, plant height and oil contents would respond to any intense selection exercise and would result in improvement in soybean for these characters. However, high heritability and low genetic advance was observed for seed weight and oil content indicating involvement of non-additive genes, hence heterosis breeding involving population improvement exercise may be useful for improvement of these characters. Moderate heritability (42.01) and high genetic advance was noted for yield, indicating additive gene effects. These results are comparable to the results reported by various workers including Jain and Ramgiry (2000), Jagtap and Mehetre (1994), Ghatge and Kadu (1993), Rasaily *et al.* (1986), Zhu (1992) and Rao *et al*. (1998). Correlation analysis showed a significant and negative relationship between seed yield per ha and plant height.

Table 3. Genotypic and phenotypic correlation coefficients among six characters in soybean genotype under Manipur condition

Characters	Level	Days to 50% flowering	Days to maturity	Plant height (cm)	100 seed weight (g)	Seed yield (kg/ha)	Oil content (%)
Days to 50 % flowering	G	1.000	0.782*	0.567*	-0.548*	-0.257	-0.292
	P	1.000	0.747*	0.471*	-0.384*	-0.155	-0.236
Days to maturity	G		1.000	0.229*	-0.361*	-0.560	-0.641
	P		1.000	0.209*	-0.272*	-0.263	-0.561
Plant height (cm)	G			1.000	-0.124*	-0.332*	0.314*
	P			1.000	-0.107*	-0.235*	0.312*
100 seed weight (g)	G				1.000	0.519*	0.096
	P				1.000	0.289*	0.068
Seed yield (kg/ha)	G					1.000	0.497
	P					1.000	0.309
Oil content (%)	G						1.00
	P						1.00

* = *Significant at P<0.05 levels*

The correlation study (Table 3) also showed that yield was negatively associated with both days to flowering and maturity. Similar results were obtained by and Malik *et* *al.* (2006). Seed yield also positively associated with seed weight and the positive significant results observed in this study agreed with the finding of Oz *et al*. (2009). Seed weight was negatively correlated with days to flowering, maturity, plant height, but positively with oil content. A positive and significant correlation was found between oil content and plant height, between days to 50 per cent flowering and days to maturity, between plant height and days to 50 per cent flowering and days to maturity. The genotypes studied showed wide range of variability for most of the characters. Moreover, the high positive relation between characters could be effectively exploited in soybean yield improvement program. For instance, the positive relation of days to flowering with plant height would indicate that tall plants will ordinarily produce more flowers and thus, in selecting for high grain yield, several characters should be borne in mind.

REFERENCES

Anonymous 2013a. First estimate of soybean crop survey: *kharif* 2013. Press release in 33rd Annual General Meeting of SOPA.

Anonymous 2013b. Annual report. Directorate of Agriculture, Government of Manipur.

Burton G W. 1952. Quantitative inheritance in grasses. *In: Proceedings of 6th International Grassland Congress* **1**: 277-83.

Dadson R B. 1976. Screening and evaluation of soybean cultivars at Legon. *In*: Doku E V (Ed.), *Proceedings of the Joint University of Ghana Council for Scientific and Industrial Research Symposium on Grain Legumes in Ghana,* 71–7.

Ghatge R D and Kadu R N. 1993. Genetic variability and heritability studies in soybean. *Advances in Plant Sciences* **6**: 224–8.

Islam M S and Rasul M G. 1998. Genetic parameter, correlation and path coefficient analysis in groundnut. *Bangla Journal of Scientific and Industrial Research* **33**: 250-4.

Jagtap D R and Mehetre S S. 1994. Genetic variability in some quantitative characters of soybean. *Annals of Agricultural Research* **15**: 45–9.

Jain P K and Ramgiry S R. 2000. Genetic variability of metric traits in Indian germplasm of soybean (*Glycine max* L. Merrill). *Advances in Plant Sciences* **13**: 127–31.

Johnson H W, Robinson B F and Comstock R E. 1955. Estimates of genetic and environmental variability in soybean. *Agronomy Journal* **47**: 314–8.

Karmakar P G and Bhatnagar P S. 1996. Genetic improvement of soybean varieties released in India from 1969 to 1993. *Euphytica* **90**: 95-103.

Karnwal M K and Singh K. 2009. Studies on genetic variability, character association and path coefficient for seed yield and its contributing traits in soybean [*Glycine max* (L.) Merrill]. *Legume Research* **32**(1): 70-3.

Maestri D M, Labuckas D O, Guzman C A and Giorda L M. 1998. Correlation between seed size, protein and oil contents and fatty acid composition in soybean genotypes. *Grasas Aceites* **49**: 450–3.

Malik M F A, Qureshi A S, Ashraf M and Ghafoor A. 2006. Genetic variability of the main yield related characters in soybean. *International Journal of Agriculture and Biology* **8**(6): 815-9.

Oz M, Karasu A A, Goksoy T and Turan Z M. 2009. Interrelationship of agronomical characteristics in soybean (*Glycine max)* grown in difference environments. *International Journal of Agriculture and Biology* **11**(1): 85-8.

Rao M S S, Bhagsari A S and Muhammad A I. 1998. Yield, protein and oil quality of soybean genotypes selected for tofu production. *Plant Foods for Human Nutrition* **52**: 241-51.

Rasaily S K, Desai N D and Kukadia M U. 1986. Genetic variability in soyabean (*Glycine max* L. Merrill). *Gujarat Agricultural University Research Journal* **11**: 57–60.

Singh A P, Sharma S, Sharma H K and Nema D P. 1996. Genetic variability and co-heritability estimates in soybean. *Agricultural Science Digest* **16**(3): 171-4.

Singh R K and Chaudhary B D. 1985. *Biometrical Methods in Quantitative Genetic Analysis*, Kalyani Publishers, (Third Ed., 1985), pp. 318.

Srivastava A N and Jain J K. 1994. Variability and coheritability estimates for physiological and economic attributes in soybean. *Indian Journal of Genetics* **54**(2): 179-83.

Thakur S B, Ghimire S K, Pandey M P, Shrestha S M and. Mishra B. 2011. Genic variabilty, heritabilty and genic advance of podyield component traits of groundnut (*Arachis hypogaea* L.) *Journal of the Institute of Agriculture and Animal Science* **32**: 133–41.

Zafar I, Arshad M, Ashraf M, Mahmood T and Waheed A. 2008. Evaluation of soybean (*Glycine max (L) Merrill*) germplasm for some important morphological traits using multivariate analyses *Pakistan Journal of Botany* **40**(6): 2323-8.

Zhu J C. 1992. Study on the heritability, genetic advance and correlation of primary agronomic traits of spring soybean varieties sown in spring and autumn. *Soybean Science* **11**: 322–8.

Soybean Research (Special Issue Number 2): 70-74: 2014

Phenotypic Stability for Seed Yield and its Related Traits in Soybean under Mid and Low Hill Conditions of Himachal Pradesh

G KATNA[1], JAI DEV[2], INDU BALA[3], AMAR SINGH[4] and V K SOOD[5]
Department of Crop Improvement, CSKHP Krishi Vishvavidyalaya, Palampur 176 062, Himachal Pradesh, India
E mail: gkatna@rediffmail.com

ABSTRACT

*Nine genetically diverse soybean [*Glycine max *(L.) Merr.] strains, developed from seven different crosses, along with three checks were evaluated in randomized block design with three replications for genotype x environment (G x E) interaction for seed yield and its related traits under three environments spread over different agro-climatic zones of Himachal Pradesh. The pooled analysis of variance indicated that G x E interaction and E + (G x E) components were found significant for all the traits viz., days to 50 per cent flowering, days to maturity, plant height, pods per plant, seeds per pod and seed yield suggested the linear function of the additive environment effects and allowed for evaluation of genotypes for stability across the environments. Linear and non-linear components of G x E interactions were also present. However, most of the strains showed significant deviation mean square (S^2di) implying that these were unstable and thus did not show general adaptability. For seed yield, the strain P2-11-1-1 (PK472 x H330) was responsive to better environments, while the strains P7-2-4-1 (SL 284 x Pb 1), P1-4 (SL 284 x Bragg) and checks Him Soya and Shivalik were responsive to poor environments. The strains P1 (Ankur x Bragg) and P1-2-1-1 [(SL 284 x Pb 1) x Pb 1] were most stable across the environments for seeds/pod as regression coefficient (bi) being near to unity and had least deviation from regressions coefficient (S^2di).*

Key words: G x E interaction, regression coefficient, soybean, stability

Soybean (*Glycine max* (L.) Merr.), is an important leguminous crop for feed and food products, contains about 40 per cent protein [1and 4]*Scientist;* [2]*Associate Professor;* [3]*Research Scholar;* [5]*Senior Scientist* and 20 per cent oil (Singh and Chung, 2007). In the fast changing environmental conditions the stability of crop yield over a range of environments is important and growing of genotypes over years and situations should be an integral part of a plant breeding programme. In Himachal Pradesh, soybean can be raised in all parts of the State except areas above 2,200 m amsl. It is essential to breed high yielding, early maturing and photoperiod insensitive genotypes which perform consistently better under differential environmental conditions. Selection for yield and its related traits is based on the phenotype, which is influenced considerably by G x E interaction. Therefore, present study was carried out to assess the effect of environments on performance of soybean genotypes and to identify the stable genotype(s) over the locations for cultivation in Himachal Pradesh.

MATERIAL AND METHODS

The experimental material comprised of nine genetically diverse soybean strains {P1

[1and4]*Scientist;* [2]*Associate Professor;* [3]*Research Scholar;* [5]*Senior Scientist*

(Ankur x Bragg), P12-1-1-1 (SL 284 x Pb 1), P2-11-1-1 (PK 472 x H 330), P7-2-4-1 (SL 284 x Pb 1), P1-2-1-1 (SL 284 x Pb 1) x Pb 1), P7-3-1-1 (Pb 1 x VLS 2), P 12-3-3 (SL 284 x Bragg), P1-4 (SL 284 x Bragg), P4-1-2-3-3 (Himso 333 x NRC 2)}, developed from seven different crosses, along with three checks *viz*., Bragg, Him Soya, and Shivalik were evaluated in randomized block design with three replications. The experiments were conducted under three different agro-climatic zones of Himachal Pradesh comprising mid as well as low hills namely, Palampur, Kangra and Dhaulakuan for six traits, *viz*., days to 50 per cent flowering, days to maturity, plant height (cm), pods per plant, seeds per pod and seed yield (kg /ha). The crop was raised using recommended package of practices. The observations were recorded on plot basis for days to 50 per cent flowering, days to maturity and seed yield; whereas plant height, pods per plant and seeds per pod were recorded on five randomly taken plants from each plot. The stability analysis was done as per the model suggested by Eberhart and Russell (1966).

RESULTS AND DISCUSSION

The pooled analysis of variance for stability (Table 1) revealed significant differences among environments for all the characters *viz*., days to 50 per cent flowering, days to maturity, plant height, pods per plant, seeds per pod and seed yield indicating different effect of each environment. The analysis of variance indicated that G x E interaction and E + (G x E) components were found significant for all the traits suggested the linear function of the additive environment effects and allowed for evaluation of genotypes for stability across the environments. Further, partitioning of G x E interaction into G x E (linear) and pooled deviations (non-linear) were significant when tested against pooled error mean square indicating that both linear and non-linear portions accounted for G x E interactions. Significant variance due to environments (linear) against pooled deviation for all the characters studied indicated considerable differences among the environments and their predominant effects on the characters. This could be due to the variations in weather and soil conditions over

Table1. Pooled analysis of variance for different characters in soybean

Source	df	Days to 50 % flower-ing	Days to maturity	Plant height (cm)	Pods (No/ plant)	Seeds (No/ plant)	Seed yield (kg/ha)
Environment	2	736.68*	4482.74*	1250.83*	12278.34*	0.48*	2896641.00*
Genotype	11	118.72*	19.09	1153.67*	961.93*	0.12	365848.60
Geno. x Env.	22	34.00*	16.48*	106.48*	410.14*	0.06*	428089.50*
Env. + (E x G)	24	71.79*	378.59*	136.78*	1148.47*	0.05*	372190.50*
Env. (linear)	1	1473.35*	8965.50*	2501.69*	24556.67*	0.96*	5793289.00*
G x E (linear)	11	16.19*	7.41	55.65*	246.53*	0.04*	65837.63
Pooled deviations	12	5.95*	3.26*	14.07	24.57	0.003	201255.90*
Pooled error	66	0.66	0.29	13.97	22.30	0.01	20262.83

** Significant against pooled error ms at P≤0.05; significant against pooled deviation ms at P≤0.05* different locations. Significant pooled deviations for days to 50 per cent flowering, days to maturity and seed yield suggested that the deviation from linear regression also contributed substantially towards the differences in stability of genotypes thereby indicating difficulty in predicting the performance of genotypes over environments for these traits. However, even for unpredictable traits, prediction can still be made on considering stability parameters of individual genotypes (Singh *et al*., 1991 and Pan *et al*., 2007).

According to Eberhart and Russell (1966), an ideal genotype may be characterized as having high mean (x= μ) performance with unit regression coefficient (bi=1) and minimum (non- significant) deviation from regression (s^2di=0). Accordingly, the mean (x) and deviation from regression (s^2di) are considered as measures of stability and linear regression (bi) is used for evaluating the genotypes response. The stability parameters were worked out for all the traits as G x E interaction was observed to be significant. The mean values, regression coefficient (bi) and deviation from regression (s^2di) for nine genotypes and three checks over environments are presented in table 2. The substantial magnitudes of deviation from linearity for all the characters were observed suggesting large fluctuation in the expression of all the characters over environments. However, most of the strains showed significant deviation mean square (S^2di) implying that these were unstable and thus did not show general adaptability. For seed yield strains P1 (Ankur x Bragg) (2212.81 kg/ha) and check Shivalik (1607.41 kg/ha) were the highest and lowest mean yielder. For seed yield, the strain P2-11-1-1 (PK 472 x H 330) was responsive to better environments (bi>1), while the strains P7-2-4-1 (SL 284 x Pb 1), P1-4 (SL 284 x Bragg) and checks Him Soya and Shivalik were responsive to poor environments (bi<1). The strains, P1 (Ankur x Bragg) and P1-2-1-1 [(SL 284 x Pb 1) x Pb 1] were most stable across the environments for seeds per pod as regression coefficient (bi) being near to unity and had least deviation from regressions coefficient (S^2di). The strains, P1 (Ankur x Bragg) and P12-1-1-1 (SL 284 x Pb 1) were stable for days to maturity over locations. In contrast, most of the genotypes showed regression coefficients greater than unity indicating their sensitivity to environmental changes for seed yield. Earlier workers (Sood *et al*., 1999, Jai Dev *et al*., 2009, Jai Dev *et al*., 2009) have also identified stable soybean strains for cultivation under mid-hills of Himachal Pradesh.

Summarizing, the present study on stability analysis in soybean over locations has demonstrated that the genotypes P2-11-1-1 (PK 472 x H 330), P7-2-4-1 (SL 284 x Pb 1), P1-4 (SL 284 x Bragg) and P1 (Ankur x Bragg) were found to be promising for different traits. These genotypes may be used for general cultivation in the state or used in further studies.

REFERENCES

Eberhart S A and Russell W A. 1966. Stability parameters for comparing varieties. *Crop Science* **6**: 36-40.

Jai dev, Anand D, Vedna Kumari, Sood V K, Singh A, Singh A, Kaushal R P, Jenjiha J K and Sood O P. 2009. Genotype x environment interaction for yield and maturity in soybean. *Crop Improvement* **36**: 59-63.

Jai Dev, Sood V K and Sood O P. 2009. Evaluation of G x E interaction in food grade soybean genotypes. *Soybean Research* **7**: 1-7.

Table 2. Estimated stability parameters for different characters in soybean

Genotypes	Days to 50% flowering			Days to maturity			Plant height (cm)		
	Mean	bi	s²di	Mean	bi	s²di	Mean	bi	s²di
1	2	3	4	5	6	7	8	9	10
P1 (Ankur x Bragg)	78.33	0.91*	1.49	127.67	0.93*	0.02	105.11	0.96	24.84
P 12-1-1-1 (SL-284 x Pb1)	76.67	0.73*	0.10	127.22	0.97*	0.03	88.47	0.03*	1.97
P2-11-1-1 (PK472 x H-330)	85.22	0.53*	0.22	129.56	0.91*	10.39*	71.89	1.11*	0.20
P 7-2-4-1 (SL-284 x Pb1)	77.67	0.99*	7.21*	127.67	0.94*	0.07	71.71	0.70	39.49
P1-2-1-1 (SL-284 x Pb1)x Pb1)	74.89	1.28*	0.20	127.22	0.94*	0.07	82.20	0.26*	0.35
P 7-3-1-1 (Pb1x VLS-2)	80.44	0.34	16.21*	130.11	1.01*	7.27*	95.60	1.02	34.60
P 12-3-3 (SL-284 x Bragg)	74.22	1.16*	13.96*	126.56	0.99*	7.41*	76.00	1.50*	0.84
P 1-4 (SL-284 x Bragg)	72.89	0.96	25.92*	126.00	1.09*	5.20*	80.40	1.12*	24.19
P 4-1-2-3-3 (Himso- 333x NRC-2)	75.33	1.26*	0.01	125.33	1.15*	4.38*	84.27	1.68*	0.59
Bragg (C)	73.67	1.73*	1.41	126.11	0.89*	2.25*	73.09	0.68	20.74
Him Soya (C)	73.22	1.12*	0.21	126.22	0.94*	0.30	73.47	1.65*	20.42
Shivalik (C)	73.67	0.93*	4.50*	126.00	1.21*	1.78*	65.67	1.27*	0.66
Over all mean	**76.35**			**127.14**			**80.66**		

** Significant at P≤0.05*

Table 2 Contd.

Genotypes	Pods (No/plant)			Seeds (No/pod)			Seed yield (kg/ha)		
	Mean	bi	s²di	Mean	bi	s²di	Mean	bi	s²di
11	12	13	14	15	16	17	18	19	20
P1 (Ankur x Bragg)	95.22	1.74*	18.56	2.49	0.76	0.013	2212.81	1.50	402127.60*
P 12-1-1-1 (SL-284 x Pb1)	65.89	0.86*	28.04	2.46	0.62*	0.0001	2138.52	1.69	662892.30*
P2-11-1-1	70.89	0.62*	13.16	2.20	0.58*	0.0001	2214.56	1.07*	2959.31

(PK472 x H-330)									
P 7-2-4-1 (SL-284 x Pb1)	67.89	0.61*	41.52	2.20	0.31	0.002	2201.89	0.77*	2922.25
P1-2-1-1 (SL-284 x Pb1)x Pb1)	65.78	0.85*	1.11	2.36	0.50	0.016	1758.19	0.99*	60.94
P 7-3-1-1 (Pb1x VLS-2)	76.33	0.94*	27.58	2.35	0.80*	0.0001	1986.81	1.04	808061.10*
P 12-3-3 (SL-284 x Bragg)	59.44	0.86*	1.77	2.44	2.43*	0.0002	2006.74	0.29	278210.10*
P 1-4 (SL-284 x Bragg)	61.89	0.95*	67.03	2.41	1.99*	0.0001	2082.74	0.90*	373.34
P 4-1-2-3-3 (Himso- 333x NRC-2)	77.22	1.43*	3.51	2.15	0.50*	0.002	1911.81	1.00	67636.53
Bragg (C)	58.22	0.72*	49.65	2.42	1.65*	0.004	1936.81	1.23	182445.80*
Him Soya (C)	64.22	1.02*	31.51	2.23	0.45*	0.001	1888.30	0.66*	4135.03
Shivalik (C)	61.11	1.39*	11.48	2.34	1.43*	0.0001	1607.41	0.84*	3246.03
Over all mean	**68.68**			**2.34**			**2003.80**		

Pan R S, Singh A K, Kumar S and Mathura Raj. 2007. Stability of yield and its components in vegetable soybean (Glacine max). *Indian Journal of Agricultural Science* **77**: 28-31.

Singh J V, Paroda R S, Arora R N and Saini M L. 1991. Stability analysis for green and dry fodder cluster bean. *Indian Journal of Genetics and Plant Breeding* **51**: 345-8.

Singh R J and Chung G H. 2007. Cytogenetics of soybean: Progress and perspectives. *The Nucleus* **50**: 403-25.

Sood O P, Sood V K, Daisy A and Kalia N R. 1999. Phenotypic stability for yield and maturity in soybean (Glycine max) in mid-hills of Himachal Pradesh. *Indian Journal of Agricultural Science* **69**: 536-7.

Soybean Research (Special Issue): 75-80: 2014

Genetic Divergence Studies in Soybean [*Glycine max* (L) Merrill]

L PROMIN[1*], P KHOYUMTHEM[2**], H NANITA DEVI[3**], PH R SHARMA[4**] and AMITAVA PAUL[5*]
****ViswaBharati, Sriniketan 731 236, West Bengal, India and***
*****Central Agricultural University, Imphal, Manipur 795 004, India***
Email: pramesh_kh@rediffmail.com

ABSTRACT

A total of 46 genotypes of soybean were evaluated for morphological traits to determine the genetic divergence among the introduced lines. Among the morphological character, pods per plant and seeds yield per plant showed high heritability (0.83 and 0.80, respectively) along with high genetic advance as percentage of mean (55.47 % and 30.15 %, respectively), indicating the existence of possibility for increasing seed yield by selecting the trait number of pods per plant. The clustering of genotypes based on 8 traits revealed the existence of variability among genotypes, and obtained nine clusters. Estimates of average inter-cluster distance revealed that IV and V were most divergent (D^2 = 36.07) followed by cluster I and II (D^2 = 25.96), VI and VII (D^2 = 20.15), cluster III and IV (D^2 = 18.18), hence, the genotypes grouped under these clusters could be used for crossing if superior varieties are planned in the hybrid development program.

Key words: Genetic advance, heritability, Mahalanobis's D^2 distance, soybean

The soybean (US) or soya bean (UK) (*Glycine max* (L.) Merrill) (2n = 40), is a species of legume (called "miracle legume" of the 21st century) native to East Asia, widely grown for its edible bean which has numerous uses. Soybean contains about 20 per cent oil and 38-45 per cent high quality protein (as against 7.0 % in rice, 12 % in wheat, 10 % in maize and 20-25 % in other pulses). The origin and history of soybean is not accurately known. The middle and lower yellow river basin in China has been reported to be the primary centre of origin (Verma *et al*., 1972; Chang, 1980). Unlike most of the vegetable proteins which are deficient in supplying all the essential amino acids, the soy protein stands unique by supplying all ten of them including lysine (5 %).

Specht *et al*. (1999) suggested the theoretical limit of soybean productivity to be 8 t per ha based on the amount of light energy available in the field. However, the world average yield of soybean remains at 2.27 t per ha. Even this level has not been achieved in India where the average productivity is staggering at 1.1 t per ha. This relative low productivity is mainly due to short growing period available in Indian sub-tropical conditions, limited genetic diversity and narrow genetic base of soybean cultivars (Singh and Hymowitz, 2001).

One of the major constraints in increasing the area and productivity of soybean in a state like Manipur is the lack of high yielding verities which are suitable for growing under varied agro-climatic

[1]Research Scholar, ViswaBharati; [2and3]Junior Plant Breeder, CAU; [4]Professor(Plant Breeding); [5]Associate Professor, VisvaBharati

conditions of the state. Here lies the importance of soybean breeding programmes with the main objective to develop high yielding disease resistant varieties with better seed quality and wider adaptability.

Genetic diversity is essential if higher levels of productivity are to be achieved and sustained. It is essential to preserve, assemble, develop and document the entire array of crops germplasm for planned utilization of genetic diversity for any of the economically important traits present in land races, cultivars and wild relatives aiming at pyramiding of genes for higher productivity. Proper choice of parents which can nick well to produce superior offspring is essential for rapid success in a conventional hybridization programme. Hybridization is the most potent technique for breaking yield barriers and evolving varieties having high in-built potentiality. Selection of suitable parents for hybridization is one of the most important steps in a breeding programme. The objective of this study was to determine genetic variability from the available germplasm pool and used in further hybridization programme.

MATERIAL AND METHODS

The present investigation was carried out in the experimental field of the College of Agriculture, Central Agricultural University Imphal located at 24°48′ N latitude and 93°56′ E longitude with an altitude of 790 meters above mean sea level during *kharif* 2006. The climate of Imphal is sub-tropical with an average annual rainfall of about 1,212 mm, which is distributed mainly during the five monsoon month from June to October.The mean annual maximum and minimum temperatures are 35 °C and 5 °C, respectively.

During *kharif* 2006, a total of 46 genotypes of soybean were evaluated in the field for morphological traits to determine the genetic divergence among the selected line. All the 46 genotypes were sown in randomized block design with the spacing of 10 cm x 45 cm plant to plant and row to row distance All the good agronomic practices to raise a good crop of soybean were followed.

The total variations among genotypes for different characters were tested for significance by 'F' test using analysis of variance technique. Phenotypic and genotypic variance was calculated from the total variance. The phenotypic and genotypic variances were then used to determine phenotypic and genotypic coefficient of variability**.** Heritability (h^2%) was calculated according to Burton and Devane (1953).

Genetic advance was estimated by the formula described by Allard (1960)

RESULTS AND DISCUSSION

The analysis of variance for morphological characters (Table 1) revealed highly significant difference samong 46 genotypes for all the characters studied. The variation can be exploited through adoption of suitable selection scheme for the improvement of these traits in soybean the existence of genetic variation is a paramount importance for starting a judicious plant breeding programme. Hence, the present study is justified. The significant differences between genotypes and this interaction effects warranted grouping of the genotypes to identify the genetically diverse ones to ensure success in recombination breeding. Wide range of variation in soybean was reported by Jagdish *et al*. (2000).

The estimate of PCV and GCV (Table 2) were closer for all the morphological characters except seeds per pod (24.81 and 9.66) values. Values of PCV were high for pods per plant (32.08), seed yield per plant

Table 1. Analysis of variance for 8 morphological characters in 46 soybean genotypes

Source	d.f.	Days to 50 % flowering	Days to maturity	Plant height (cm)	Pods (No/ plant)	Seeds (No/ pod	Seeds (No/ plant	100 seed weight (g)	Seed yield (g/ plant)
Replication	2	11.05	2.61	10.05	9.06	0.13	258.28	0.12	10.54
Treatment	45	61.37*	91.30*	246.39**	1062.34**	0.25*	2672.01**	4.47**	27.46**
Error	90	1.67	0.92	8.88	63.73	0.16	658.97	0.38	9.03

*, **Significant at $p = 0.05$ and 0.01, respectively*

Table 2. Phenotypic and genotypic coefficient of variability, heritability and genetic advance formorphological characters

Characters	Grand Mean	Range	GCV	PCV	Heritability (bs)	GA	GA as % of mean
Days to 50% flowering	41.92	35 – 51.00	11.09	11.55	0.92	8.82	21.95
Days to maturity	92.29	86.12 – 101.77	5.98	6.08	0.97	11.13	12.15
Plant height (cm)	61.82	51.00 – 72.66	14.99	15.81	0.89	17.38	29.29
Pods (No/plant)	47.83	19.66 – 68.00	29.39	32.08	0.83	34.43	55.47
Seeds (No/ pod)	2.09	2.00 – 2.80	9.66	24.81	0.75	0.13	7.76
Seeds (No/plant)	95.63	52.00 – 122.83	25.63	36.09	0.50	37.90	37.50
100 seed wt. (g)	9.98	8.00 – 11.08	11.81	13.39	0.77	2.10	21.45
Seed yield (g/plant)	10.24	8.00 – 13.40	28.01	36.17	0.80	31.24	30.15

(36.17) and seeds per plant (36.09) and 100 seed weight (13.39) whereas days to flowering, days to maturity and plant height showed similarity between GCV and PCV. Thus, emphasizing the existence of genetic variation, a pre-requisite for selection in these genotypic.

Bhairav *et al*. (2006), Jagdish *et al*. (2000) and Rajanna *et al*. (2000) reported that phenotypic coefficient of variation were higher than the genotypic coefficient of variation from the characters pods per plant, yield per plant and seeds per plant.

Genetic diversity among the parents is very important in selecting the parents for hybridization in any recombination breeding programme. Several methods are available to measure such diversity quantitatively. Mahalanobis's (1928) D^2 statistic is one of the widely used methods to effectively measure such genetic diversity among the genotypes in a number of crop plants (Murty and Arunachalam, 1966).

D^2 analysis was carried out separately for 8 morphological and grouping of the 46 genotypes in separate cluster was done accordingly. Following Tocher's method (Rao, 1952), all the 46 soybean genotypes were grouped in nine different clusters (Table 3). Cluster V was the largest containing of 13 genotypes followed by cluster IV and II with 8 genotypes each, cluster I with 7 genotypes, cluster VI with 6 genotypes, cluster II, VII, VIII and IX with one genotype each.

Table 3. Clustering different genotypes of soybean using Tocher'smethod (Rao, 1952)

Cluster	Genotypes	
I	RAUS 5, PK 564, PK 1399, RKS 15, DRB 9, MACS 285, NRCS 6	7
II	PS 192, VLS 69, PS 1385, JS 93-05, RKS 36, Shelajit, Ankur, PK 1042	8
III	RKS 18	1
IV	TS 25, CAUS 1, MACS 1039, PK 1420, MACS 1092, DS 2309, Himso 1608, CAUS 2	8
V	AMS 99-33, NSO 15, RKS 416, CAUS 5, JS 97-52, PK 1370, MPUS 308, JS 79-81, PK 416, Birsa soy I, PS 1024, PK 1347, PK 1092	13
VI	PS 1241, MACS 10-55, PK 327, CAUS 3, CAUS 4, PK 742	6
VII	JS 80-21	1
VIII	MAUS 308	1
IX	JS 76-205	1
Total		**46**

Table 4. Cluster mean for 46 soybean genotype in respect of eight morphological characters

Cluster	Days to 50 % flow-ering	Days to matu-rity	Plant height (cm)	Pods (No/ plant)	Seeds (No/ pod)	Seeds (No/ plant	100 seed weight (g)	Seed yield (g/ plant)
I	38.38	86.12*	53.30	64.61	2.50	105.28	9.59	11.06
II	36.12*	88.90	61.78	63.00	2.25	120.27	10.26	12.60
III	45.71	98.38	62.19	51.47	2.30	93.52	10.43	9.80
IV	42.86	87.46	51.60	62.20	2.80**	98.06	11.08**	9.76
V	42.25	90.08	63.41	68.00**	2.06	122.83**	9.42	13.40**
VI	38.44	101.77**	64.22	54.11	2.09	78.55	9.84	8.00*
VII	42.00	94.66	63.33	62.16	2.33	78.33	8.33*	9.25
VIII	46.00	98.00	51.00*	28.33*	2.00*	48.33*	9.50	7.96
IX	50.00**	92.50	72.66**	58.83	2.34	106.00	8.93	11.00
% cont-ribution	24.37	43.09	7.27	5.32	1.50	5.26	3.23	9.96

Estimates of average inter-cluster distance revealed that IV and V were most divergent (D^2 = 36.07) followed by cluster I and II (D^2 = 25.96), VI and VII (D^2 = 20.15), cluster III and IV (D^2 = 18.18).

Relative contribution of each of the 8 morphological characters (Table 4) revealed that days to maturity (43.09 %) had the highest contribution followed by days to flowering (24.37 %), seed yield (9.96 %)and plant height (7.27 %) towards the observed genetic diversity, contribution of pods per plant (5.32 %), seeds per plant (5.26 %), 100 seed weight (3.23 %) and seed per pod (1.50 %) were low. It is evident that none of the 8 morphological characters contributed very high on low compared to other to influence observed genetic diversity.

Considering genetic divergence, relative importance of characters in determining the seed yield in this particular population and *per se* performance of the genotypes as well as cluster mean seven genotypes namely RKS 15, RKS 36, DS 2309, CAUS 2, RKS 416, MPUS 308 and JS 79-81 may be used as parents (Table 5) for specific breeding objectives for combining ability keeping their inter-cluster distance in view and to provide wide spectrum of recombinants in segregating generation.

In this study pods per plant showed moderately higher heritability associated with higher genetic advance and higher genetic advance as means of percentage indicatingthe better chance of increasing seed yield per plant by selection for the trait, pods per plant. The higher genetic divergence observed in this study indicates the potential of improving yield of soybean by crossing those parents showing highest divergence which can yield heterosis.

REFERENCES

Allard R W. 1960. *Principles of Plant Breeding*, John Wiley and Sons, Inc., New York.

Bhairav Bhushan, Sharma S P and Ranwah R P. 2006. Genetic variability, heritability and genetic advance in soybean *Glycine max* (L.). Merrill. *National Journal of Plant Improvement* **8**(1): 94-5.

Burton G W and DeVane E W. 1953. Estimating heritability in tall fescue *(Festuca arundinacea)* from replicated clonal material. *Agronomy Journal* **45**: 478-81.

Chang R I. 1980. A study on the origin of *Glycine max* (L) Merrill. *Soybean Abstract* **13**(1): 3.

Jagdish Singh, Parmarand R P, Yadav H S. 2000. Assessment of genetic variability and selection parameters in early generation of soybean. *Advances in Plant Sciences* **13**(1): 227-37.

Mahalanobis P C. 1928. A statistical study of Chinese head measurement. *Journal Asiatic Society of Bengal* **25**: 301-77.

Murty B R and Arunachalam V. 1966. The nature of divergence in relation to breeding system in crop plants. *Indian Journal of Genetics and Plant Breeding* **26**A: 188-98.

Rajanna M P, Viswanatha S R, Kulkarni R S and Ramesh S. 2000. Genetic variability in soybean [*Glycine max* (L.) Merrill]. *Crop Research* Hisar **20**(1): 108-12.

Rao C R. 1952. *Advanced Statistical Methods in Biometrical Research,* John Wiley and Sons Inc., New York

Singh R J and Hymowitz T. 2001. Exploitation of the wild perennial glycine species for improving the soybean. *In*: *Proceedings of India Soy Forum, 2001*, P S Bhatnagar (Ed), pp 58-61.

Specht J E, Hume D J and Kumidini S V. 1999. Soybean yield potential – A genetic and physiological perspective. *Crop Science* **39**: 1560-70.

Verma M. M, Murty B R and Singh Harbhajan. 1972. Adaptation and genetic diversity in soybean. *Indian Journal of Genetics and Plant Breeding* **32**(2): 266-75.

Table 5. Average intra and inter - cluster D^2 and $\sqrt{D^2}$ values of 46 soybean genotype

Cluster	I	II	III	IV	V	VI	VII	VIII	IX
I	254.899	268.351	128.899	139.840	191.770	165.342	151.62	172.88	190.770
	(23.535)	(25.968)	(11.353)	(20.323)	(13.848)	(15.141)	(12.626)	(12.525)	(10.323)
II		175.660	159.603	142.730	121.220	121.225	124.330	206.430	218.202
		(18.698)	(12.633)	(12.854)	(22.924)	(10.535)	(12.624)	(18.522)	(10.510)
III			122.630	130.628	199.640	151.605	220.520	123.620	135.521
			(11.074)	(18.183)	(19.990)	(18.933)	(15.125)	(18.182)	(17.172)
IV				543.450	430.628	221.120	150.400	220.420	255.430
				(32.848)	(36.072)	(22.052)	(13.042)	(12.051)	(12.040)
V					135.020	125.022	122.044	123.055	130.551
					(10.053)	(11.551)	(12.541)	(13.512)	(13.851)
VI						160.511	140.511	170.531	181.224
						(10.583)	(20.151)	(18.955)	(19.425)
VII							170.351	180.051	142.553
							(10.521)	(10.522)	(11.510)
VIII								0.00	151.625
								(0.00)	(12.535)
IX									0.00
									(0.00)

The values in the parenthesis are $D=\sqrt{D^2}$ *values*

Soybean Research (Special Issue Number 2): 81-92: 2014

Genetic Diversity and Association Studies in Soybean [*Glycine max* (L.) Merrill]

J POORNIMA JENCY[1] and T KALAIMAGAL[2],
Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India
E mail: poornimajames@gmail.com

ABSTRACT

*An investigation was conducted during the year 2011-2012 with fifty genotypes of soybean (*Glycine max *(L.) Merrill) germplasms to identify the diverse genetic stocks for the use in hybridization programme through genetic diversity based on Mahalanobis's D² statistics, genetic variability, heritability, genetic advance, association studies and also to identify lines with low phytic acid content. The data were recorded on ten yield and yield contributing traits on genotypes raised in randomized block design in two replications. Analysis of variance showed significant differences for all the characters. On the basis of mean performance the genotypes BIOLOXI 3, NSO 111, IC 18733, Co 1, VLS 41, Co (Soy)3, CSB 0808, NSO 15, CSB 0903 were found to be superior for seed yield. With regard to phytic acid content, the genotypes Co 1, VLS 41, Co (Soy)3, CSB 0808, NSO 15, CSB 0903 recorded very low phytic acid content coupled with high seed yield. The fifty genotypes were grouped into six clusters. The cluster III comprised of 21 genotypes. The cluster V possessed the highest mean values for many of the traits studied. With respect to single plant yield, clusters V and VI contributed more towards the genetic diversity. The entries of cluster V *viz.*, Co 1, Co (Soy)3, CSB 0903 and twenty entries of the cluster VI can be used in crossing programme for the development of good recombinants. Based on the variability, heritability and genetic advance estimates of eleven characters studied, plant height and number of primary branches showed high heritability and high genetic advance, while the character viz., number of pods per cluster, number of pods per plant, number of seeds per plant, single plant yield and phytic acid content showed low heritability and high genetic advance as a per cent of mean. The character association studies revealed that the traits *viz.*, plant height, number of pods per cluster, number of pods per plant and number of seeds per plant can be improved and simultaneous selection would offer scope for yield improvement.*

Key words: Association studies, genotypes, genetic diversity, phytic acid, soybean, yield improvement

Soybean *Glycine max* (L.) is a marvellous world's leading economic oilseed crop and ranks first among the oilseeds in the world. Soybean tops in the world production of both oilseeds and edible oil. Hence, it is called as the 'Miracle Golden Bean' of the 21st century. The economic importance of soybean is mainly due to its chemical constituents primarily oil and protein. A logical way to start any breeding programme for crop improvement is to survey the variations present in the germplasm. Precise information on the nature and degree of genetic divergence helps the plant breeder in

[1] *M.Sc (Ag)Student;* [2] *Soybean Breeder*

choosing the diverse parents for purposeful hybridization. The development of new varieties is mainly governed by the magnitude of genetic variability present in the base material. In breeding programme, progenies derived from diverse crosses which are selected based on genetic divergence analysis are expected to show a broad spectrum of genetic variability. Therefore under the present investigation, an effort was made to understand the quantum and nature of genetic variability present in a set of 50 elite soybean accessions.

MATERIAL AND METHODS

The Experiment was conducted during *rabi* 2011-12. Fifty soybean genotypes (Table 1) maintained in the Department of Pulses, Centre for Plant Breeding and Genetics, Tamil Nadu Agriculture University, Coimbatore were utilized for analysing the morphological diversity. Morphological characters *viz.*, days to 50 per cent flowering, days to maturity, plant height, number of primary branches per plant, number of pod per cluster, number of pods per plant, pod length, number of seeds per plant, hundred seed weight and single plant yield were recorded on five randomly selected plants for each genotype in all the three replications. The replicated data were subjected to genetic divergence analysis using Mahalanobis's D^2 – statistic (Mahalanobis, 1936) as suggested by Rao (1952). All the soybean accessions were grouped into respective clusters on the basis of values following Tocher's method. Phenotypic and genotypic coefficient of variation (PCV and GCV) was estimated using the formula suggested by Burton (1952) and expressed in percentage. Heritability in broad sense (H^2) was calculated according to Lush (1940) and expressed in percentage. Genetic advance was categorized as suggested by Johnson *et al.*, (1955). The variance and covariance components were utilized to calculate correlation coefficient (Weber and Murthy, 1952) and path co-efficient analysis was calculated according to Dewey and Lu (1959).

RESULTS AND DISCUSSION

Diversity

Analysis of variance showed significant differences among the genotypes for all the ten characters studied. The calculated D^2 values ranged from 26.85 to 720.92 indicating the existence of considerable amount of genetic diversity among the genotypes studied. The fifty genotypes were grouped into 6 clusters revealing the presence of wide genetic diversity. The present study indicated that the distribution of genotypes into different clusters was at random and the absence of relationship between genetic diversity and geographical origin suggests a similarity in their genetic constitution, free exchange of breeding material over places (Sharma, 2005). The genotypes developed from different geographical regions were included in the same clusters (Table 2).

Among 6 clusters, cluster III was the largest with 21 genotypes followed by cluster VI with 20 genotypes, cluster V with 3 genotypes. Cluster I, II and IV had 2 genotypes each. Intra cluster D^2 values and distance values are given in table 3. Maximum difference among the genotypes within the same cluster (intra cluster) was shown by cluster VI (720.92) with a distance of 26.85, followed by clusters III (535.13) with a distance of 23.13, V (308.29) with a distance of 17.55, IV (27.35) with a intra cluster distance of 5.23, II (17.25) with a distance of 4.15. Cluster I had the lowest value of 15.23 which showed the least distance of 3.90.

Table 1. Details of 50 soybean accessions used in the study

S. No.	Accessions/ Genotypes	S. No.	Accessions/ Genotypes	S. No.	Accessions/ Genotypes
1	IC I41431	18	LU 51	35	WC 35
2	AMSS 34-A	19	OS 612	36	NSO 29
3	BIOLOXI-3	20	MAUS 285	37	CSB 0808
4	WC 03	21	HIMSO 1608	38	MAUS 2
5	LU 98	22	NSO 78	39	BRAGG
6	JS 98-62	23	LU 89	40	LU 70
7	SL 710	24	JS 56	41	NSO 15
8	NRC 2007-L-1-5	25	Co 1	42	JS (SH) 2002-11
9	IC 15088	26	RKS 48	43	CSB 0903
10	SL 64-A	27	VLS 41	44	WC 31
11	EC 13056	28	IC 39250	45	LU 100
12	TAS 40	29	JS 395	46	STB-2
13	EC 2514	30	IC 18733	47	LU 133
14	LU 90	31	Co (Soy)3	48	Co 2
15	TS 5	32	IC 151515	49	LU 106
16	LSB 23	33	IC 25166	50	NSO 383
17	NSO 111	34	IC 10808		

Table 2. Clustering pattern of 50 soybean germplasm accessions

Clusters No.	Number of accessions	Accessions/Genotypes
I	2	EC 2514, OS 612
II	2	JS 98-62, LU 89
III	21	IC 141431, AMSS 34-A, BIOLOXI-3, WC 03, LU 98, SL 710, NRC 2007-L-1-5, IC 15088, SL 64-A, EC 13056, TAS 40, LU 90, TS 5, LSB 23, NSO 111, LU 51, MAUS 285, HIMSO 1608, NSO 78, JS 56, IC 151515
IV	2	LU 100, LU133
V	3	Co 1, Co (Soy)3,CSB 0903
VI	20	RKS 48, VLS 41, IC 39250, JS 395, IC 18733, IC 25166, IC 10808, WC 35, NSO 29, CSB 0808, MAUS 2, BRAGG, LU 70, NSO 15, JS (SH) 2002-11, WC 31, STB-2, Co 2, LU 106, NSO 383

Diversity among clusters varied with inter-cluster D square values of 53.01 to 1730.46. The cluster V and IV showed maximum inter cluster D^2 values (1730.46) with a distance of 41.59 followed by clusters V and II (1690.77) with a D value of 41.11, clusters V and I (1638.87) with a inter cluster distance of 40.48, clusters VI and IV (975.50) and clusters VI and I (897.03). The lowest inter cluster values was noticed between cluster I and II (53.01) which showed the lowest inter cluster distance of 7.28 (Table 3).

Table 3. Inter and Intra cluster D^2 values and distance D of soybean

Cluster	1	2	3	4	5	6
1	15.23 (3.90)*	53.01 (7.28)	569.52 (23.86)	79.04 (8.89)	1638.87 (40.48)	897.03 (29.95)
2		17.25 (4.15)	613.39 (24.76)	64.52 (8.03)	1690.77 (41.11)	927.98 (30.46)
3			535.13 (23.13)	661.90 (25.72)	843.23 (29.03)	641.05 (25.31)
4				27.35 (5.23)	1730.46 (41.59)	975.50 (31.23)
5					308.29 (17.55)	706.91 (26.58)
6						720.92 (26.85)

**Values in parenthesis are distance values (D)*

In the present study, it can be observed that out of the ten characters studied, single plant yield and number of seeds per plant contributed for more than 89 per cent of genetic diversity (Table 4) among the 50 germplasm accessions. The cluster means of ten characters (Table 5) showed an interesting picture of the nature of genetic diversity. Cluster V recorded highest mean values for six traits *viz.*, single plant yield, number of seeds per plant, number of pods per plant, number of pods per cluster, number of primary branches and plant height. While the clusters I and II possessed very low mean values for many of the traits studied. It is inferred that with respect to single plant yield and number of seeds per plant (the characters which contributed more to genetic diversity among 50 genotypes), cluster V and cluster VI were the superior clusters. The genotypes in these clusters could be widely used in crossing programme for generation of wide spectrum of variability for yield.

Variability and heritability

The estimates of genotypic and phenotypic coefficient of variation are necessary to understand the role of environmental influence on different traits. The differences between the GCV and PCV indicated the level of environmental variations that contribute a major part in the expression of traits (Majumdar *et al.*, 1974).

Table 4. Relative contribution of yield and yield components to genetic diversity

Characters	Number of first rank	Percentage contribution
Days 50 % flowering	11	0.89
Days to maturity	68	0.55
Plant height (cm)	10	0.81
Number of primary branches	3	0.24
Number of pods per cluster	2	0.16
Number of pods per plant	5	0.40
Pod length (cm)	0	0.00
Number of seeds per plant	161	13.14
Hundred seed weight (g)	32	2.61
Single plant yield (g)	933	76.16
Total	**1225.00**	**100.00**

Table 5. Cluster means of the 10 characters used in the study

Character/ Cluster	Days to 50 % flowering	Days to maturity	Plant height (cm)	Primary branches (No/plant)	Pods (No/ cluster)
	1	**2**	**3**	**4**	**5**
1	33.50	88.50	31.81	4.00	3.83
2	33.66	90.50	29.88	3.00	2.66
3	36.14	91.77	44.80	4.39	4.31
4	33.50	89.50	24.30	4.33	4.16
5	37.66	90.22	69.83	5.11	4.66
6	36.51	91.50	56.04	4.98	4.56

Table 5-contd.

Character/ Cluster	Pods (No/ plant)	Pod length (cm)	Seeds (No/ plant)	100 seed weight (g)	Single plant yield (g)
	6	7	8	9	10
1	41.16	4.34	115.50	11.66	10.25
2	51.33	4.36	150.50	11.00	10.10
3	73.87	4.19	225.22	12.02	17.76
4	46.50	4.22	151.00	13.58	8.50
5	121.66	4.23	372.33	12.77	24.16
6	93.10	4.07	274.01	11.63	18.78

In the present investigation, the genotypes exhibited considerable amount of variability for all eleven traits studied (Table 6). The estimates of genotypic coefficient of variation were lesser than the estimates of phenotypic coefficient of variation indicating the environmental influence over the characters studied. All the 50 genotypes showed wide range of variation for the traits *viz.,* days to 50 per cent flowering, days to maturity, plant height, number of primary branches per plant, number of pods per cluster, number of pods per plant, pod length, number of seeds per plant, hundred seed weight, single plant yield and phytic acid content. This variation indicated the scope for selection of these traits for further breeding work.

From the present study, the characters plant height, number of pods per plant, number of seeds per plant and single plant yield showed higher values of PCV and GCV. The results indicated a greater scope for selection to improve these characters. Moderate values of PCV and GCV were noticed for characters *viz.,* number of pods per cluster, hundred seed weight. The characters *viz.,* days to 50 per cent flowering, days to maturity and pod length showed lower values of PCV and GCV. The coefficient of variation indicates only the extent of variability existing for various characters, but does not give any information regarding heritable proportion of it. Hence, amount of heritability permits greater effectiveness of selection by separating out the environmental influence from the total variability and to indicate accuracy with which a genotype can be identified phenotypically. In the present study, broad sense heritability, which includes both additive and non-additive gene effects (Hanson *et al.,* 1956), was estimated. The results indicated that estimates of heritability were high for the following characters under study *i.e.,* days to 50 per cent flowering, days to maturity, plant height, number of primary branches per plant and hundred seed weight.

Yield being a complex character is influenced by many factors. In the present study, high heritability coupled with high genetic advance as per cent of mean was observed for plant height, number of primary branches per plant, number of pods per cluster, number of pods per plant, number of seeds per plant, hundred seed weight and single plant yield. This indicated the lesser influence of environment in expression of these characters and prevalence of additive gene action in their inheritance, since are amenable for simple selection. High heritability accompanied with low genetic advance as per cent of mean was recorded for days to 50 per cent flowering, days to maturity and hundred seed weight. The results indicated that these characters were governed by non-additive gene action and selection for such traits may not be rewarding. The characters number of pods per cluster, number of pods per plant, number of seeds per plant and single plant yield showed low heritability but high genetic advance as per cent of mean which reveals that the characters were governed by additive gene action. The low heritability was due to high environmental effects. Selection may be effective in such cases. The character pod length showed low heritability accompanied with low genetic advance as per cent of mean, thereby indicating that the character was highly influenced by environment and selection would be ineffective. For phytic acid content low heritability accompanied with high genetic advance as a per cent of mean revealed that the character is governed by additive gene effects. The low heritability was due to high environmental effects. Selection may be effective. Reduction of phytic acid in

Table 6. Coefficient of variation, heritability (broad sense), genetic advance (GA) and genetic advance as per cent of mean of yield and yield components of soybean

Characters	Variance		PCV	GCV	Heritability	Genetic	GA as per cent
	σ^2p	σ^2g	(%)	(%)	H^2 (%)	advance	of mean
Days 50 per % flowering	9.22	5.84	8.42	6.69	63.34	3.95	10.95
Days to maturity	12.31	8.97	3.84	3.28	72.89	5.28	5.78
Plant height (cm)	377.29	281.80	39.75	34.36	74.69	30.00	61.40
Primary branches (No/plant)	0.90	0.54	20.62	15.97	60.00	1.17	25.44
Pods (No/cluster)	0.74	0.38	19.82	14.20	51.35	0.90	20.73
Pods (No/plant)	900.05	512.04	36.98	27.89	56.89	35.23	43.43
Pod length (cm)	0.17	0.09	9.94	7.23	52.94	0.45	10.84
Seeds (No/plant)	9155.94	5401.09	39.34	30.22	58.99	116.30	47.82
Hundred seed weight (g)	2.13	1.46	12.23	10.13	68.54	2.08	17.44
Single plant yield (g)	48.13	28.52	39.28	30.24	59.26	8.43	47.74
Phytic acid content (mg/100g)	1.44	0.86	33.33	25.76	59.72	1.23	34.17

Table 7. Genotypic (rG) and phenotypic (rP) correlation coefficient among the 10 characters

		Days to 50 % flower-ing	Days to maturity	Plant height (cm)	Primary branches (No./plant)	Pods (No/ cluster)	Pods (No/ plant)	Pod length (cm)	Seeds (No/ plant)	100 seed weight (g)	Single plant yield (g)
Days to 50 % flowering	rG	**1.000**	0.002	0.619**	0.343**	0.327*	0.400**	0.042	0.361**	-0.325*	0.205
	rP	**1.000**	0.002	0.541	0.286	0.237	0.351	0.030	0.329	-0.270	0.179
Days to maturity	rG		**1.000**	0.185	-0.020	-0.081	0.115	-0.168	0.097	0.160	0.012
	rP		**1.000**	0.167	-0.002	-0.061	0.110	-0.091	0.094	0.155	0.008
Plant height (cm)	rG			**1.000**	0.605**	0.436**	0.800**	0.031	0.770**	-0.262*	0.405**
	rP			**1.000**	0.510	0.368	0.752	0.024	0.736	-0.243	0.385
Primary branches	rG				**1.000**	0.889**	0.580**	-0.268*	0.603**	-0.074	0.401**
(No./plant)	rP				**1.000**	0.718	0.517	-0.090	0.542	-0.049	0.357
Pods (No./ cluster)	rG					**1.000**	0.581**	-0.170	0.632**	-0.074	0.519**
	rP					**1.000**	0.475	-0.070	0.528	-0.048	0.436
Pods (No./ plants)	rG						**1.000**	-0.074	0.981**	-0.361**	0.543**
	rP						**1.000**	-0.042	0.962	-0.336	0.535
Pod length (cm)	rG							**1.000**	-0.134	0.052	-0.335**
	rP							**1.000**	-0.074	0.056	-0.194
Seeds (No./plant)	rG								**1.000**	-0.312*	0.569**
	rP								**1.000**	-0.298	0.564
100 seed weight (g)	rG									**1.000**	-0.254*
	rP									**1.000**	-0.245
Single plant yield (g)	rG										**1.000**
	rP										**1.000**

*** Significant at 1% level * Significant at 5% level*

Table 8. Direct and indirect effect of different characters on single plant yield at genotypic level

	Days to 50 % Flowering	Days to maturity	Plant height (cm)	Primary branches (No/plant)	Pods (No/ cluster)	Pods (No/ plant)	Pod length (cm)	Seeds (No/ plant)	100 seed weight (g)	Correlation with single plant yield
Days to 50 % flowering	**-0.572**	-0.000	0.962	-0.744	0.745	0.506	-0.031	-0.695	0.035	0.205
Days to maturity	-0.001	**-0.204**	-0.292	0.042	-0.184	0.146	0.126	-0.187	-0.017	0.012
Plant height (cm)	-0.349	-0.038	**1.578**	-1.314	0.993	1.012	-0.023	-1.483	0.028	0.405**
Primary branches (No/plant)	-0.196	0.004	0.955	**-2.172**	2.028	0.733	0.201	-1.161	0.008	0.401**
Pods (No/cluster)	-0.187	0.017	0.688	-1.931	**2.281**	0.734	0.127	-1.217	0.007	0.519**
Pods (No/ plants)	-0.229	-0.024	1.263	-1.261	1.325	**1.264**	0.056	-1.890	0.389	0.543**
Pod length (cm)	-0.024	0.034	0.049	0.583	-0.388	-0.094	**-0.748**	0.259	-0.006	-0.335**
Seeds (No/plant)	-0.207	-0.020	1.215	-1.309	1.442	1.240	0.101	**-1.926**	0.034	0.569**
100 seed weight (g)	0.186	-0.033	-0.413	0.161	-0.152	-0.456	-0.039	0.600	**-0.108**	-0.254*

Residual effect=0.201

soybean seeds has the potential to improve the nutritional value of soybean meal and lessen phosphorus pollution in large scale animal farming.

From the above, it can be concluded that high genotypic coefficient of variability and phenotypic coefficient of variability coupled with high heritability were observed for plant height. This indicates that there is a lesser influence of environment in the expression of character which is amenable for selection. The character *viz.*, days to 50 per cent flowering, days to maturity, number of primary branches per plant, hundred seed weight showed high heritability but low level of variability. Hence, these characters are not amenable for selection.

Correlation studies

Yield is a complex quantitative character governed by large number of genes and is highly influenced by environment. Hence, the selection of superior genotypes based on yield as such is not effective. For a rational approach towards improvement of yield, selection has to be made for the components of yield. Association of yield components and yield thus assumes special importance as the basis for indirect selection. Genetic correlation between different characters of plant often arises because of linkage or pleiotrophy.

In the present study, phenotypic and genotypic correlation of single plant yield was positive and significant with plant height, number of primary branches, number of pods per cluster, number of pods per plant, number of seeds per plant (Table 7). Positive association of yield with these characters illustrated that simultaneous selection for plant height, number of primary branches, number of pods per cluster, pods per plant and seeds per plant can increase the plant yield. However, seed yield showed significant and negative association with pod length and 100 seed weight. Hence, these traits need not be emphasized while selecting for improvement of yield.

Correlations among component traits

Days to 50 per cent flowering had positive and significant association with plant height, number of primary branches, number of pods per cluster, number of pods per plant and number of seeds per plant. While, number of primary branches per plant recorded significant and positive correlation values for number of pods per cluster, number of pods per plant and number of seeds per plant, it also recorded significant negative correlation with pod length. Number of pods per cluster showed positive and significant correlation with number of pods per plant and number of seeds per plant. Number of pods per plant showed positive and significant correlation with number of seeds per plant. Hundred seed weight recorded significant and negative correlation with pods per plant and number of seeds per plant inferring that increase in seed size decrease the grain yield.

There were significant correlations between the dependent variable yield and independent variables, the yield components. Also there were significant correlations among the yield components, the independent variables. In the present study it was noted that the genotypic correlation values was greater than the phenotypic correlation values which implies the dilution of the characters by the effect of environment. Also, it was observed that all the phenotypic correlations are in the same direction of the genotypic correlation. Hence, selection for component characters having positive correlation with yield may indirectly help in increasing the yield.

Path analysis

Path analysis is a statistical technique that helps in partitioning the total effect into direct and indirect effects (Wright, 1921). In view of this correlation among the characters were subjected for analysing the direct and indirect effects (Table 8). The correlation coefficient between days to 50 per cent flowering and grain yield was positive but the direct effect was negative which was mainly because of the high negative indirect effect via number of primary branches per plant and pod length. Similarly days to maturity also recorded negative effect for grain yield. This negative direct effect of days to 50 per cent flowering and days to maturity on grain yield implies that the high yielding genotypes would be late in their maturity period.

Plant height and grain yield were positive and significantly correlated and the direct effect of plant height on grain yield was also positive and high. This relationship can be fruitfully exploited to breed for taller plants which will be highly productive. This is evident from the tallest plant among the germplasm EC 18733 with 85 cm height which recorded 26 g single plant yield, while the shortest genotype JS (SH) 2002-11 recorded half the yield (13.0 g). Number of primary branches and single plant yield showed positive and significant correlation while the direct effect of number of primary branches per plant was negative and high. The correlation co-efficient value between number of pods per cluster and single plant yield was positive and significant and similar was the case with number of pods per plant and single plant yield. The direct effect of pods per cluster and number of pods per plant on single plant yield was also positive and very high showing that there is scope for yield improvement by improving these traits. The correlation co-efficient values between pod length and seed yield was significant and negative. Similarly the direct effect of pod length on yield was also negative and high thus showing that pod length need not be considered for yield improvement.

Number of seeds per plant and yield were significantly and positively correlated whereas the direct effect of seeds per plant and yield was negative and high but the positive correlation was brought out via the positive indirect effects of plant height, pods per cluster and number of pods per plant. Hundred seed weight was negatively correlated with yield and the direct effect of hundred seed weight on yield was also negative. This signifies that there is no scope for yield improvement by improving the seed size.

REFERENCES

Burton G W. 1952. Quantitative inheritance in grasses. *In*: *Proceedings of 6th International Grassland Congress* **1**: 277-83.

Dewey D R and Lu K N. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal* **51**: 515-8.

Hanson C H, Robinson H F and Comstock, R E. 1956. Biometrical studies of yield in segregating populations of Korean Lespedeza. *Agronomy Journal* **48:** 268-72.

Johnson H W, Robinson H F and Comstock, R E. 1955. Estimation of genetic variability and environmental variability in soybean. *Agronomy Journal* **47**: 314-8.

Lush J L. 1940. Intra-site correlation and regression of offspring on dams as a method of estimating heritability of characters. *In*: *Procceedings of American Society of Animal Production* **32**: 293-301.

Mahalanobis P C. 1936). On the generalized distance in statistics. *Proceedings of National Academy of Science*, India **2:** 49-55.

Majumdhar M **K,** Chatterjee **S D**, Bose P and Bhattacharya **G.** 1974. Variability inter-relationships and coefficient analysis for some quantitative characters in okra (*Abelmoschus esculentus* (L.) Moench). *Indian Agriculture* **18**(1): 13-20.

Rao C R. 1952. *Advanced Statistical Methods in Biometrical Research*. *John Willey and Sons Inc*., New York, pp 390.

Sharma S S. 2005. Genetic divergence in Indian varieties of soybean. *Soybean Research* **3**: 9-16.

Weber C R and Murthy B R. 1952. Heritable and non-heritable relationships and variability for oil content and agronomic characters in the F_2 generation of soybean crosses. *Agronomy Journal* **44:** 202-9.

Wright S. 1921. Correlation and causation. *Journal of Agricultural Research* **20:** 202-9.

Soybean Research (Special Issue Number 2): 93-98: 2014

Oil Quality of Some Elite Soybean Varieties of India

PHILIPS VARGHESE[1], S P TAWARE[2], S A JAYBHAY[3]
and MANOJ OAK[4],
Department of Genetics and Plant Breeding, Agharkar Research Institute,
Pune 411 004, Maharashtra, India
E mail: philipsv@gmail.com

ABSTRACT

Soybean has become the leading oil seed crop in India. It contributes about 43 per cent of the oilseed crops and 25 per cent of the edible oil production in the country. Soybean in India occupies an area of 10.33 million hectares with a production of 11.6 million tonnes. As the oil production increases, the demand for better quality oil will also increase. Soybean oil contains five fatty acids, which are palmatic, stearic, oleic, linoleic and linolenic. Saturated fatty acids compose of about 15 per cent and the remaining 85 per cent is unsaturated fatty acids. The present study was undertaken to find the variability of fatty acid composition in 41 elite soybean varieties of the country. These varieties were developed through breeding at various research centers in India and were evaluated in the year 2012, in a replicated trial with three replications and harvested seeds were analyzed for variability for the above mentioned five fatty acids. Palmatic acid varied from 9.24 to 10.33 per cent, while for stearic acid from 1.89 to 2.41 per cent, oleic acid from 16.87 to 35.23 per cent, linoleic acid from 47 to 63 per cent and linolenic acid from 5.42 to 6.98 per cent. Varieties showing better oil stability index and with better nutritional quality index could be identified. The total oil content and its significance with yield of the varieties are discussed further.

Key words: Fatty acid composition, oil quality, soybean, variability

Soybean [*Glycine max* (L.) Merrill] has become the leading *kharif* season oilseed crop in India. It contributes about 43 per cent of the oilseed crops and 25 per cent of the edible oil production in the country. The cultivation of the crop in India has shown a tremendous growth during the last fourty years. At present, soybean in India occupies an area of 10.33 million hectares with a production of 11.6 million tonnes. As the cultivation increases gradually there will be a demand for better quality oil from the crop.

Soybean oil contains five major fatty acids, both saturated and unsaturated types. Many genes have been reported to control the fatty acid levels in soybean and conventional breeding, mutation breeding and transgenic approaches have been attempted to improve the oil quality in soybean. There is a need to evaluate the variability in the existing varieties for the desired characters so as to use the variability for further improvement through breeding. Hence, a study was undertaken to find the variability of fatty acid composition in 41 elite soybean varieties developed at various breeding centers of the country.

MATERIAL AND METHODS

Forty one elite soybean varieties developed through breeding at various

Soybean Breeder; [2]Entomologist; [3]Agronomist: [4]Biochemist research centers in India were evaluated in *kharif* 2012, in a replicated trial with three replications at research farm of Agharkar Research Institute. Each plot had three rows of 3 meter length with 45 cm distance between rows and 5 cm between plants. Uniform basal dose of NPK fertilizers was applied and all recommended package of practices were followed. From the harvested seeds 100 seeds randomly selected were screened replication-wise for variability for five fatty acids along with total oil content on Near Infra Red Transmitance method (Patil *et al.,* 2010) and the data on yield was also recorded. The nutritional quality index, which is a ratio of polyunsaturated to saturated fatty acids and oil stability index, a ratio of mono-saturated to poly-unsaturated fatty acids was calculated for the varieties from the fatty acid composition using the method suggested by Carpenter *et al.* (1976). Data was statistically analysed using Agrobase99.

RESULTS AND DISCUSSION

Oil content in the seeds varied fro m 16.8 to 20.6 per cent with maximum being in variety SL 982. MACS 1394 showed the highest seed yield of 3,928 kg per ha followed by MACS 1416 (3,829 kg/ha). Variability for seed yield in the varieties studied was also high. The minimum was recorded in KBS 11-2007 (637 kg/ha). Ten varieties showed significantly higher yield than mean, while 8 showed significantly lower yield than mean yield (2,975 (kg/ha) (Table 1).

Among the fatty acid components, palmatic acid showed less variation and it ranged from 9.24 to 10.33 per cent (Table 2). Only two varieties had significantly lower values than mean while none had significantly higher values. In case of linolenic acid also, the range of variation was less even though seven varieties each showed higher and lower values than the mean. A lower value for linolenic acid is a desirable character (Primomo *et al.,* 2002) as this leads to improvement of quality of soybean oil. Variety SL 979 had the significantly lowest value of 5.42 per cent. Kinney (1994) successfully developed low linolenic lines in soybean using transgenic approach. The narrow range of variability may be due to the narrow genetic base from which these varieties have been developed and this has been the case for Indian soybean varieties as reported by Tarasatyavathi *et al.* (2003) and Rani *et al.* (2007). Variability for stearic acid was moderate with 5 varieties showing significantly higher values and 4 varieties significantly lower values than mean. It was the least in VLS 85 (1.89 %) and the highest in RVS 2006-1 (2.41 %). Jaureguy *et al.* (2013) showed that early planting of soybean increased oleic acid and decreased linolenic acid in seeds. Stojsin *et al.* (1998) and Bilyeu *et al.* (2011) showed that low linolenic acid is controlled by *Fan* gene which had three alleles. They showed additive gene action and which when combined together can produce seeds with as low as 1 per cent linolenic acid in soybean.

High oleic acid content in the oil is known to impart better oxidative stability to soybean oil. Rani *et al.* (2007) showed that linoleic acid and linolenic acid oxidize 10 and 21 times faster than oleic acid and higher the oleic acid content better the stability of the oil. In the present varieties studied, oleic acid was as low as 16 per cent in HIMSO 1684 and was highest in RVS 2006-1 (35.26 %). Seven varieties namely, RVS 2006-1, AMS 358, SL 979, AMS 475, JS 20 69, SL 925 and DSb 22 showed significantly higher oleic acid content than mean. Similarly seven varieties showed significantly higher linoleic acid content than mean with a highest of 63.59 per cent in HIMSO 1684. Also seven varieties showed

Table 1. Fatty acid composition in soybean varieties

Variety	Palmatic acid	Stearic acid	Oleic Acid	Linoleic Acid	Linolenic Acid	Nutri-tional quality Index	Oil stability Index	Oil content (%)	Yield (kg/ha)
1	2	3	4	5	6	7	8	9	10
RVS 2006-1	10.07	2.41*	35.26*	46.74#	6.26	4.50#	0.57*	17.64#	2191#
MACS 1407	9.90	2.19	22.28	58.03	6.47	5.34	0.34	19.45	3503*
RSC 10-01	9.39	2.09	25.69	55.32	6.51	5.39	0.42	18.92	3133*
NRC 94	9.76	2.20	25.06	55.64	6.40	5.19	0.40	19.68*	3484*
DS 2705	9.92	2.01#	22.37	58.73*	6.42	5.48	0.34	20.41*	3636*
RKS 115	9.87	2.13	22.83	57.95	5.93#	5.33	0.36	19.87*	2454#
DSb 22	10.05	2.29	28.40*	52.28#	6.23	4.74#	0.49	18.38	2943
AMS 475	9.88	2.25	30.93*	50.40#	5.89#	4.64#	0.55*	17.76#	2422#
SL 982	9.58	2.09	26.64	54.66	5.56#	5.17	0.44	20.62*	3502*
HIMSO 1684	9.87	2.13	16.87#	63.59*	6.68	5.59*	0.31#	19.20	2472#
VLS 84	9.25#	2.13	20.35#	60.29*	6.86*	5.90*	0.30	18.14#	2952
JS 20 71	9.84	2.20	27.50	53.85	6.14	4.98	0.46	19.90*	3505*
KDS 705	10.05	2.32*	26.16	55.08	6.93*	5.02	0.42	17.30#	3373*
MAUS 614	9.64	2.17	26.48	54.88	6.45	5.20	0.43	17.63#	3232
KBS 11-2007	9.89	2.09	24.94	56.15	6.43	5.22	0.40	20.53*	637#
RSC 01-05	9.57	1.99#	25.86	55.65	6.59	5.39	0.42	18.88	2757
NRC 93	10.11	2.21	22.05#	58.49	6.49	5.27	0.34	20.40*	3231
PS 1518	10.17	2.18	22.58	57.81	6.17	5.18	0.35	20.01*	3157
MACS 1416	10.18	2.24	19.63#	60.17*	6.81*	5.39	0.30#	19.08	3829*
PS 1521	10.04	1.99#	17.75#	62.95*	6.98*	5.82*	0.25#	20.23*	3100

Table 1 contd.

1	2	3	4	5	6	7	8	9	10
SL 979	9.61	2.09	31.91*	51.01#	5.42#	4.82	0.56*	20.20*	2738
KDS 693	10.19	2.35*	25.15	55.46	6.71*	4.96	0.40	17.15#	3298
NRC 92	10.32	2.21	19.37#	60.90*	6.45	5.37	0.29#	19.42	2871
VLS 85	9.24#	1.89#	27.16	54.73	6.36	5.49	0.44	18.55	2795
DSb 22	9.99	2.12	23.72	56.96	6.44	5.23	0.38	19.51	2784
AMS 358	10.01	2.22	32.62*	48.94#	6.03	4.50#	0.59*	16.86#	2270#
KDS 708	10.16	2.32*	26.89	53.71	6.69	4.84	0.45	17.55#	3091
MAUS 612	9.82	2.21	27.55	52.62#	6.36	4.90	0.47	18.24#	3033
KBS 22-2009	9.64	2.09	26.26	55.03	6.38	5.23	0.43	19.55	3221
JS20-69	9.92	2.22	29.49*	52.46#	6.32	4.84	0.50*	17.83#	2976
NRC 91	9.86	2.15	20.03#	61.02*	6.58	5.63*	0.30#	19.92*	3133
PS 1520	9.81	2.04	22.57	57.92	6.78*	5.46	0.35	18.91	3093
MACS 1394	9.93	2.25	26.59	54.14	6.61	4.99	0.44	18.21#	3928*
SL 925	9.77	2.19	28.63*	53.21	5.44#	4.90	0.49	19.50	2406#
CSB 904	9.79	2.20	27.32	53.83	6.42	5.02	0.45	17.93#	3470*
AMS 77	9.85	2.15	25.00	55.31	6.51	5.15	0.40	18.32#	3186
RKS 133	10.33	2.30	27.58	54.09	5.66#	4.74#	0.46	19.50	3100
BRAGG	9.65	2.01#	23.73	57.74	5.84#	5.47	0.37	20.07*	2420#
RKS 18	9.82	2.18	26.45	54.27	6.13	5.03	0.44	18.82	2939
JS 335	9.44	2.11	24.23	56.98	6.57	5.53	0.39	18.51	2983
MAUS 61	9.68	2.04	22.68	57.97	6.80*	5.53	0.35	18.75	2711

** Significantly superior over the mean # significantly inferior over mean.*

Table 2. Variability for oil components

Oil Component	Range	Mean
Palmatic acid (%)	09.24 to 10.33	09.85
Stearic acid (%)	01.89 to 02.41	02.16
Oleic acid (%)	16.87 to 35.26	25.23
Linoleic acid (%)	46.74 to 63.59	55.78
Linolenic acid (%)	05.42 to 06.98	06.36
Oil content (%)	16.86 to 20.62	18.98
Nutritional quality index	04.50 to 05.90	05.18
Oil stability index	00.25 to 00.59	00.41
Yield (kg/ha)	637 to 3928	2975

significantly lower linoleic acid content than mean with a lowest of 46.74 per cent in the variety RVS 2006-1. Plants grown in shade away from sunlight were also shown by Bellaloui *et al.* (2012) to reduce oleic acid content and increase linoleic and linolenic acid as well as the total oil content in seed. Warner and Fehr (2008) studied different types of soybean oil and concluded that oil with medium levels of oleic and very low linolenic acid was the best for health. Ahire (2012a) showed that mutation can be used to create variability for fatty acids, and he developed low linolenic acid (1 %) lines and high oleic acid lines (80 %). Soybean oil is considered to be better oil for its nutritional value for dietary purpose as per the recommendation of World Health Organisation (Ghafoor-unissa and Krishnaswamy, 2000). Variability for nutritional quality index in the varieties studied was less and ranged from 4.50 to of 5.90 (Table 2). Maximum 5.90 in the variety VLS 84 followed by PS 1521 (5.82). Four varieties showed significantly higher values than mean, while 5 varieties showed significantly lower values. There was wide range of variability for oil stability index (OSI) ranging from 0.25 in the variety PS 1521 to 0.59 in the variety AMS 358. Six varieties showed significantly higher values than mean for oil stability. Warner and Gupta, (2003) tested soybean lines with 2 per cent linolenic acid for oil stability and concluded that there is a need to reduce it to 0.8 per cent for better oil stability. Ahire (2012b) suggested the need for high oleic acid and low linolenic acid for better oil stability in soybean and concluded that oil stability index above 0.50 indicates better quality soybean oil. In the present studies 4 varieties showed values above 0.50 but all of them are poor in seed yield. Among the varieties MACS 1394 with oil stability index of 0.44 and with highest yield of 3,928 kg per ha was found to be better for the character.

Among the varieties in the pipeline tested for variability for oil components the amount of variability is low. Different varieties have different desirable characters showing the possibility of different genes being involved. There is a need to select the varieties and pyramid the genes for different oil characters through hybridization and selection for obtaining better soybean varieties. Moongkanna *et al.* (2011) studied QTLs associated with all the five fatty acids and found 10 QTL located on 6 linkage groups which can be used for molecular marker based breeding to improve soybean oil composition.

ACKNOWLEDGEMENTS

Authors are thankful to ICAR, New Delhi, DSR, Indore for funding and Director, ARI, Pune for facilities provided.

REFERENCES

Ahire D D. 2012a. Induced mutations for elevated oleic acid and reduced linolenic acid content in soybean seeds. *Bioremediation, Biodiversity and Bioavailability* **6**: 46-52.

Ahire D D. 2012b. Correlation studies and coefficient of variation among fatty acids and oil quality parameters in soybean mutants. *Bioremediation, Biodiversity and Bioavailability* **6**: 107-12.

Bellaloui N, J R Smith, A M Gillen, D K Fisher and Mengistu A. 2012. Effect of shade on seed protein, oil, fatty acids, and minerals in soybean lines varying in seed germinability in the early soybean production system. *American Journal of Plant Sciences* **3(**1): 84-95.

Bilyeu K, Gillman J D and LeRoy A R. 2011. Novel *FAD3* mutant allele combinations produce soybeans containing 1 % linolenic acid in the seed oil. *Crop Science* **51**(1): 259-64.

Carpenter D L, J Lehman, D S Manon and Slover H T. 1976. Lipid composition of selected vegetable oils. *Journal of American Oil Chemist Society* **53**: 713-8.

Ghafoorunissa and Krishnaswamy Kamala. 2000. *Dietary Prescriptions, Diet and Heart Disease*, National Institute of Nutrition, Hyderabad 23-41.

Jaureguy L M, F L Rodriguez, L L Zhang, P Y Chen, K Brye, D Oosterhuis, A Mauromoustakos and Clark J R. 2013. Planting date and delayed harvest effects on soybean seed composition. *Crop Science* **53**(5): 2162-75.

Kinney A J. 1994. Genetic modification of the storage lipids of plants. *Current Opinion in Biotechnology* **5**: 144-51.

Moongkanna J, V R Pantalone, J W Burton, T Toojinda, S Nakasathien and Srinives P. 2011. Identification of QTLS controlling major fatty acid contents in soybean seed. *SABRAO Journal of Breeding and Genetics* **43**(2): 226-40.

Patil A G, Oak M D, Taware S P, Tamhankar S A and Rao V S. 2010. Nondestructive estimation of fatty acid composition in soybean [*Glycine max* (L.) Merrill] seeds using Near-Infrared Transmittance Spectroscopy. *Food Chemistry* **120**: 1210-7.

Primomo V S, E D Falk, G R Ablett, J W Tanner and Rajcan I. 2002. Inheritance and intraction of low palmitic and low lenolenic soybean. *Crop Science* **42**: 31-6.

Rani Anita, Kumar Vineet, Verma Sandeep K, Shakya Arvind and Chauhan G S. 2007. Oil content and fatty acid composition of cultivars/strains of Indian soybean: an interrelationship study. *Indian Journal of Agricultural Sciences* **77**: 59-62.

Rani Anita, Kumar Vineet, Verma Sandeep K, Shakya Arvind, Husain S M and Chauhan G S. 2007. Tocopherol content and profile in soybean: Genotypic variability and correlation studies. *Journal of American Oil Chemist's Society* **84**(4): 377-83.

Stojšin D, Luzzi B M, Ablett G R and Tanner J W. 1998. Inheritance of low linolenic acid level in the soybean line RG10. *Crop Science* **38**(6): 1441-4.

Tarasatyavathi C, Karmakar P G, Bharswaj Ch and Tiwari S P. 2003. Ancestral analysis of soybean varieties. *Indian Journal of Genetics* **63**: 87-8.

Warner K and Fehr W. 2008. Mid-oleic/ultra low linolenic acid soybean oil: a healthful new alternative to hydrogenated oil for frying. *Journal of the American Oil Chemists' Society* **85(**10): 945-51.

Warner K and Gupta M. 2003. Frying quality and stability of low- and ultra-low-linolenic acid soybean oils. *Journal of the American Oil Chemists' Society* **80(**3): 275-80.

Soybean Research (Special Issue Number 2): 99-107: 2014

Screening of Soybean (*Glycine max*) Germplasm for Multiple Disease Resistance

AMAR SINGH [1], JAI DEV [2], D K BANYAL[3] and G KATNA[4]
CSK Himachal Pradesh Krishi Vishvavidyalaya,
Palampur, 176 062, India
E mail: singhamar008@gmail.com

ABSTRACT

Soybean, one of the important oilseed crops, is attacked by many fungal, bacterial and viral diseases that cause huge yield losses. Realising the importance of host resistance as most effective and pro-ecological component of plant disease management, soybean germplasm comprising 337 lines were screened during kharif *2011 and 2012 under field natural epiphytotic conditions for identifying multiple disease resistance against major prevalent fungal, bacterial and viral diseases. Germplasm lines namely, Himso 222a, Himso 263a and Himso 334a were found highly resistant while Himso 91a, Himso 136a, Himso 164a, Himso 267a and Himso 293a were resistant to all the six diseases* viz., *frog eye leaf spot (*Cercospora sojina*), pod blight (*Colletotrichum truncatum*), brown spot (*Septoria glycines*), powdery mildew (*Microsphaera diffusa*), bacterial pustule (*Xanthomonas axonopodis *pv. glycines) and soybean mosaic virus. Out of total tested lines, 43 lines showed multiple disease resistance against at least three diseases. Thirty-six, thirty-four, eighteen, twelve, and four lines were found highly resistant against powdery mildew, pod blight, bacterial pustule, frogeye leaf spot and brown spot diseases, respectively. After characterizing these genetic sources, these lines can be used in future breeding programme for developing resistant cultivars.*

Key words: Germplasm, multiple disease resistance, soybean

Soybean is an important oil seed which owing to its nutritional value, industrial and medicinal purposes is regarded as miracle crop of the world. In India, soybean is also one of the oilseed crops grown over an area of about 10.2 million ha with a production of 12.2 million tonnes and productivity of about 1190 kg per ha (FAO, 2011). The national average productivity is less than other major soybean growing countries. Several factors accounts for its low productivity. Among them weather vagaries, erratic rainfall pattern, outbreak of diseases and pests are important. Soybean crop is attacked by fungi, bacteria, viruses and nematodes which cause several root rots, seedling blights, stem blights, pod rot/blights, rust, wilt, powdery and downy mildews and leaf spots diseases (Sinclair, 1978). Among these, foliar diseases directly affect the crop by reducing the photosynthetic area thus causing quantitative as well as qualitative losses. More than seven million tonnes loss of soybean has been reported in the world caused by diseases (Sinclair, 1988). Wrather *et al*. (2010) have reported that 14 major

[1]*Scientist (Plant Pathology);* [2]*Professor (Plant Breeding and Genetics);* [3]*Professor (Plant Pathology);* [4]*Scientist (Plant Breeding)*

diseases out of about 35 diseases identified on soybean in India were important based on the magnitude of yield loss. The yield losses were reported mainly due to viruses, Sclerotium blight, anthracnose, rust, charcoal rot, and Rhizoctonia aerial blight, whereas Myrothecium leaf spot, frogeye leaf spot, target spot, and brown spot causes losses in specific locations. Frogeye leaf spot and anthracnose diseases have been reported to cause 23.7 to 32.5 per cent seed yield loss of soybean *var*. VL Soya 2 in Almora hills (Mittal, 2001). In Himachal Pradesh pod blight (*Colletotrichum truncatum*), frogeye leaf spot (*Cercospora sojina*), brown spot (*Septoria glycines*), bacterial pustule (*Xanthomonas axonopodis* pv. *glycines*) and soybean mosaic virus are commonly occurring diseases of soybean while powdery mildew (*Microsphaera diffusa*) occurs occasionally in mild to severe form depending on the environmental conditions (Anonymous, 2013).

For the disease management there are different methods such as adoption of cultural practices, use of biological control agents, chemicals and resistant varieties. Use of resistant cultivar of crop plays an important role in combating the losses caused by diseases as it is an eco-friendly, easy and cost effective disease management strategy. Plant host resistance against many diseases *i.e.*, multiple disease resistance is preferred in order to avoid risk of yield loss, and ecological concern. Identification of multiple disease resistant sources is pre-requisite to breed genotype having multiple disease resistance. Keeping in view the importance of crop and diseases, the present study was carried out with the aim to screen the soybean germplasm to identify resistant sources against prevalent diseases under field conditions.

METERIAL AND METHODS

Field experiments were conducted during the *kharif* 2011 and 2012 to evaluate 337 lines of soybean germplasm available with the Department of Crop Improvement, CSKHPKV, Palampur for multiple disease resistance under natural epiphtotic conditions. Each germplasm line was sown in two rows of two meter length with a row spacing of 45 cm. Checks comprising Bragg, JS 335, Punjab 1 and Shivalik were also included along with 337germplasm lines *i.e.*, Himso1a to Himso 337a in the experiment conducted during *kharif* 2011. Forty four lines *viz*., Himso 23a, Himso 88a, Himso 91a, Himso 96a, Himso 106a, Himso 110a, Himso 111a, Himso 115a, Himso 118a, Himso 136a, Himso 141a, Himso 164a, Himso 169a, Himso 173a, Himso 187a, Himso 190a, Himso 192a, Himso 205a, Himso 210a, Himso 212a, Himso 219a, Himso 222a, Himso 228a, Himso 239a, Himso 254a, Himso 257a, Himso 267a, Himso 296a, Himso 297a, Himso 311a, Himso 263a, Himso 265a, Himso 280a, Himso 283a, Himso 287a, Himso 293a, Himso 298a, Himso 320a, Himso 321a, Himso 329a, Himso 330, Himso 330a and Himso 334a found resistant against more than three diseases were also screened in field condition during *kharif* 2012. Recommended package of practices was followed at the different stages of crop growth except disease management. Data on disease severity of brown spot, frog eye leaf spot, pod blight, bacterial pustules, powdery mildew and soybean mosaic virus on genotypes was scored on the basis of per cent leaf area infected by using the scale given by Mayee and Datar (1986) and adopted by AICRP on soybean for recording disease score (Directorate of Soybean Research, Indore) and slightly modified is given as below.

The maximum disease score recorded during the crop season was taken to categorise the disease reaction and the data recorded on disease severity as score rating periodically after 45, 60 and 90 days of sowing.

a) Disease rating scale for brown spot, frogeye leaf spot, powdery mildew, pod blight and bacterial pustule

Rating	Description	Disease reaction category
0	No lesions/spots	Highly resistant
1	1 % leaf area covered with disease lesions/spot	
3	1.1-10 % leaf area covered with disease lesions/spots	Resistant
5	10.1-25 % leaf area covered with disease	Susceptible
7	25.1-50 % leaf area covered with disease lesions/spots	Highly susceptible
9	More than 50 % area covered with disease lesions/spots	

b) Disease rating scale for soybean mosaic virus

Rating	Description	Disease reaction category
0	No symptoms on any plant	Highly resistant
1	1 % plants sowing mosaic/rough and curled leaf	
3	1.1-10 % plants sowing mosaic/rough and curled leaf	Resistant
5	10.1-25 % mosaic/rough, curled leaf and dwarfing	Susceptible
7	25.1-50 % mosaic/rough, curled leaf and dwarfing	Highly susceptible
9	More than 50 % mosaic/rough, curled leaf and sever reduction in leaf and plant growth	

RESULTS AND DISCUSSION

Out of 337 tested lines, 43 lines showed multiple disease resistance against at least three diseases during 2011 under field conditions. The maximum disease score of different diseases was recorded on these lines sown during *kharif* 2012 (Table 1). Highest disease scores recorded 9 (Shivalik check *cv*.), 7 (Himso 141a, Himso 173a and Himso 187), 7 (JS 335 check *cv*.), 9 (Himso 173a), 9 (Himso 96a) and 7 (Himso 296a) for frogeye leaf spot, brown spot, pod blight, bacterial pustule, powdery mildew and soybean mosaic virus, respectively and thus there was sufficient natural disease pressure except for pod blight and soybean mosaic virus. Germplasm lines Himso222a, Himso 263a and Himso 334a were found highly resistant while Himso 91a, Himso 136a, Himso 164a, Himso 267a

Table 1. Disease score of different diseases on germplasm lines (0-9 scale)

Entry/Line	Frogeye leaf spot	Brown spot	Pod blight	Bacterial pustule	Powdery mildew	Soybean mosaic virus
1	**2**	**3**	**4**	**5**	**6**	**7**
Himso 23a	3	3	0	3	0	0
Himso 88a	3	3	1	1	3	0
Himso 91a	3	1	0	1	0	0
Himso 96a	1	3	1	3	9	0
Himso 106a	5	3	1	3	0	0
Himso 110a	3	5	1	1	3	0
Himso 111a	5	5	5	1	0	1
Himso 115a	3	3	0	3	0	0
Himso 118a	5	3	0	1	0	1
Himso 136a	1	3	1	3	0	0
Himso 141a	1	7	1	3	0	0
Himso 164a	3	3	1	1	0	0
Himso 169a	0	5	5	1	0	0
Himso 173a	3	7	3	9	0	0
Himso 187a	3	7	3	3	0	0
Himso 190a	3	3	5	3	0	0
Himso 192a	5	3	1	1	0	0
Himso 205a	1	3	1	5	0	0
Himso 210a	3	1	1	3	0	0
Himso 212a	3	3	1	3	0	0
Himso 219a	3	3	1	3	0	0

Table 1. contd.

Entry/Line	Frogeye leaf spot	Brown spot	Pod blight	Bacterial pustule	Powdery mildew	Soybean mosaic virus
1	2	3	4	5	6	7
Himso 222a	1	1	1	1	0	0
Himso 228a	1	3	1	5	0	0
Himso 239a	0	3	1	5	0	0
Himso 254a	3	3	1	3	5	3
Himso 257a	3	3	1	3	0	3
Himso 263a	1	1	1	1	0	0
Himso 265a	5	3	1	3	3	0
Himso 267a	0	3	3	3	0	0
Himso 280a	7	3	1	3	3	0
Himso 283a	5	3	3	1	0	0
Himso 287a	3	3	5	1	0	0
Himso 293a	3	3	1	1	0	0
Himso 296a	0	5	3	5	0	7
Himso 297a	1	3	1	5	0	0
Himso 298a	0	5	1	5	0	0
Himso 311a	7	3	1	3	0	0
Himso 320a	5	3	1	1	0	0
Himso 321a	5	3	5	0	0	0
Himso 329a	3	5	1	0	0	0
Himso 330	3	3	1	0	7	0
Himso 330a	3	3	0	5	3	1
Himso 334a	1	1	1	1	0	0
Bragg (Check)	3	5	5	3	1	5
JS 335 (Check)	3	3	7	0	1	3
Punjab 1 (Check)	3	5	1	3	9	1
Shivalik (Check)	9	5	1	0	3	0

and Himso 293a were resistant to all the six diseases *viz*., frogeye leaf spot (*Cercospora sojina*), pod blight (*Colletotrichum truncatum*), brown spot (*Septoria glycines*), powdery mildew (*Microsphaera diffusa*), bacterial pustule (*Xanthomonas axonopodis* pv. *glycines*) and soybean mosaic virus. Thirty-six, 34, 18, 12, and 4 lines were observed highly resistant against powdery mildew, pod blight, bacterial pustule, frogeye leaf spot and brown spot diseases, respectively during 2012. Himso 23a, Himso 91a, Himso 115a, Himso 136a, HImso 164a, Himso 210a, Himso 212a, Himso 219a, Himso 222a, Himso 239a, Himso 257a, Himso 267a, Himso 297a, Himso 311a and Himso 334a were found having multiple disease resistance against frogeye leaf spot, pod blight, brown spot and powdery mildew (Table 2). However six lines *viz*,. Himso 136a, Himso 173a, Himso 205a, Himso 212a, Himso 228a, Himso 297a and Himso 330a showed multiple disease resistance against soybean mosaic virus and four fungal diseases (Table 3).

Chandra *et al*. (1987) evaluated 722 soybean entries at Umiam in Megalaya under natural infection conditions against rust (*Phakopsora pachyrhizi*) and frogeye leaf spot (*Cercospora sojina*), only two entries were found resistant for both the diseases. Shehzad *et al.* (2006) also conducted similar preliminary studies on screening 99 soybean entries against bacterial pustule, anthracnose and yellow mosaic virus under natural condition and observed disease intensity of varying degrees. Mahesa *et al*. (2009) screened 204 soybean genotypes both under field and laboratory conditions against rust, powdery

Table 2. Resistant sources of soybean against different fungal diseases

Disease score	Disease reaction	Soybean entry/lines			
		Frogeye leaf spot (*Cercospora sojina*)	Pod blight (*Colletotricum truncatum*)	Brown spot (*Septoria glycines*)	Powdery mildew (*Microsphaera diffusa*)
1	**2**	**3**	**4**	**5**	**6**
0-1	Highly resistant	Himso 96a, Himso 136a, Himso 141a, Himso 169a, Himso 205a, Himso 222a′ Himso 239a, Himso 263a, Himso 267a, Himso 296a, Himso 297a, Himso 311a and Himso 334a	Himso 23a, Himso 88a, Himso 91a, Himso 96a, Himso 106a, Himso 110a, Himso 115a, Himso 118a, Himso 136a, Himso 141a, Himso 164a, Himso 192a, Himso 205a, Himso 210a, Himso 212a, Himso 219a, Himso 222a′ Himso 228a, Himso 239a, Himso 254a, Himso 257a, 263a, Himso 265a, Himso 280a, Himso 293a, Himso 297a, Himso Himso 298a, Himso 311a, Himso 320a, Himso 329a, Himso 330, Himso 330a and Himso 334a	Himso 91a, Himso 210a, Himso 222a, Himso 263a, Himso 334a	Himso 23a, Himso 91a, Himso 106a, Himso 111a, Himso 115a, Himso 118a, Himso 136a, Himso 141a, Himso 164a, Himso 169a, Himso 173a, Himso 187a, Himso 190a, Himso 192a, Himso 205a, Himso 210a, Himso 212a, Himso 219a, Himso 222a′ Himso 228a, Himso 239a, Himso 257a, Himso 263a, Himso 267a, Himso 283a, Himso 287a′ Himso 293a, Himso 296a, Himso 297a, Himso 311a, Himso 298a, Himso 320a, Himso 321a, Himso 329a, and Himso 334a

Table 2. Contd.

Disease score	Disease reaction	Soybean entry/lines			
		Frogeye leaf spot (*Cercospora sojina*)	**Pod blight (*Colletotricum truncatum*)**	**Brown spot (*Septoria glycines*)**	**Powdery mildew (*Microsphaera diffusa*)**
1	**2**	**3**	**4**	**5**	**6**
>1-3	Resistant	Himso 23a, Himso 88a, Himso 91a, Himso 110a, Himso 115a, Himso 164a, Himso 187a, Himso 190a, Himso 210a, Himso 212a, Himso 219a, Himso 254a, Himso 257a, Himso 287a' Himso 293a, Himso 298a, Himso 329a, Himso 330, Himso 330a	Himso 173a, Himso 187a, Himso 265a, Himso 267a, Himso 280a, Himso 283a, Himso 287a, Himso 293a, Himso 297a, Himso 298a, Himso 311a, Himso 320a, Himso 330, Himso 330a	Himso 23a, Himso 91a, Himso 96a, Himso 106a, Himso 115a, Himso 136a, Himso 164a, Himso 190a, Himso 192a, Himso 205a, Himso 212a, Himso 219a, Himso 228a, Himso 239a, Himso 254a, Himso 257a, Himso 267a, Himso 297a, Himso 311a,	Himso 88a, Himso 110a, Himso 265a, Himso 280a, Himso 330a

mildew, anthracnose, purple seed stain, bud blight and bacterial pustule and reported several genotypes having multiple disease resistant sources. Shrirao *et al*. (2009) evaluated 16 genotypes and reported that four and 15 entries were absolutely resistant while 13 and one entry were found highly resistant against anthracnose and Cercospora leaf spot diseases. They also reported that 10 and 14 entries were found absolutely resistant against bacterial pustule and soybean mosaic virus and two each also showed highly resistant reaction against both the disease, respectively. Recently, Parameshwar *et al*. (2012) screened 84 genotypes under natural condition for indenting resistant source for rust and yellow mosaic virus disease. The multiple disease sources indentified under natural field condition in the present studies is a preliminary work and require further studies to confirm the resistance through artificial inoculation and field evaluation at different location. Study on the genetics of resistance and agronomical desires traits of the genotype will be helpful for their exploitation in future to breed the multiple disease resistant varieties.

Table 3. Multiple disease sources against fungal and virus diseases

Entry	Disease score (0-9 scale)					
	Frogeye leaf spot	Pod blight	Brown spot	Powdery mildew	Bacterial pustule	Soybean mosaic virus
Himso 136a	0	0	3	0	3	0
Himso 173a	0	0	3	0	9	0
Himso 205a	1	0	3	0	5	0
Himso 212a	1	3	3	0	3	0
Himso 228a	1	0	3	0	7	0
Himso 297a	1	0	1	0	5	0
Himso 330a	3	0	1	1	7	1
Bragg (Check)	3	5	5	3	1	5
JS 335	3	7	3	0	1	3
Punjab 1	3	1	5	3	9	1
Shivalik	9	1	5	0	3	0

REFERENCES

Anonymous 2013. Director`s Report and Summary Tables of Experiments (2012-2013), AICRP on Soybean, Directorate of Soybean Research (ICAR) Indore 452 001, Madhya Pradesh.

Chandra S, Kumar S, Verma R N and Sharma B K. 1987. Soybean cultivars resistant to rust and frog eye leaf spot diseases. *Soybean Rust Newslette* **8**: 11-2.

FAO. 2012. FAOSTAT, online. Fao.org

Mahesha B, Patil P V and Nandini B. 2009. Identification of multiple disease resistance sources in soybean. *Crop Research* (Hisar) **37**: 213-6.

Mayee C D and Datar V V. 1986. Phytopathometry, *Technical bulletin-1 (Special bulletin-3)* Marathwada Agricultural University, Parbhani.

Mittal R K. 2001. Yield losses by frog-eye leaf spot and anthracnose diseases in soybean under different sowing dates in the hills. *Indian Phytopathology* **54**: 32-34.

Parameshwar G, Basavaraja G T and Bhat Sujata. 2012. Screening of genotypes against rust and yellow mosaic diseases in soybean (*Glycine max* (L.) Merrill). *Environment and Ecology* **30**: 306-9.

Shehzad Asad, Fauzia Sohail, Mansab Ali, Hussain Shah and Nazir Ali. 2006. Screening of soybean entries against various diseases under natural conditions during autumn 2001 at NARC. *Pakistan Journal of Agricultural Research* **19**(4): 78-80.

Shrirao A V, Gawade D B, Shrirao R A, Patil, S P and Khote A C. 2009. Evaluation of soybean genotypes against the major diseases. *Journal of Plant Disease Sciences* **4**: 92-4.

Sinclair J B. 1978. The seed-borne nature of some soybean pathogens, the effect of *Phomopsis* spp. and *Bacillus subtilis* on germination, and their occurrence in soybean produced in Illinois. *Seed Science and Technology* **6**: 957-64.

Sinclair J B. 1988. Anthracnose of soybean. *In*: *Soybean Diseases of North Central Region*, American Phytopathological Society, St. Paul, Minnesota, USA, P. 104

Wrather A, Shannon G, Balardin R, Carregal L, Escoba R, Gupta G K, Ma Z, Morel W, Ploper D and Tenuta A. 2010. Effect of diseases on soybean yield in the top eight producing countries in 2006. On line, *Plant Health Progress* doi: 10.1094/PHP-2010-0125-01-RS).

Soybean Research (Special Issue Number 2): 108-119: 2014

Influence of Tillage and Integrated Nutrient Management on Carbon Sequestration in Vertisols under Soybean Based Cropping Systems in Central India

NAMRATA YADAV*[1], A RAMESH**[2], SUSHIL K SHARMA**[3], IQBAL SANJEEDA*[4] and O P JOSHI[5]**

Holkar Science College (Davi Ahilya Vishwa Vidyalaya), Indore 452 001, and **Directorate of Soybean Research (ICAR), Indore 452 001, Madhya Pradesh, India

E mail: namratayadav87@gmail.com

ABSTRACT

A total of 213 representative rhizosphere surface soil samples from different agro-ecological zones covering the states of Madhya Pradesh, Maharashtra, Rajasthan and Andhra Pradesh, that are under soybean based cropping systems, were collected to elucidate the effect of different agricultural management practices on SOC pools. The analysis of soil samples drawn from 14 different agricultural management systems followed for past 10 years or more under , conventional or conservation tillage and different nutrient management revealed that the content of total organic carbon varied between 0.36 per cent (conservation tillage, soybean-wheat, fertilizer) and 0.95 per cent (conservation tillage, poultry manure, soybean–wheat). Similarly, particulate organic carbon was also found to be higher (1.6 g/kg C and 3.2 g/kg C) in soil samples collected from locations under conservation tillage, soybean-wheat system with application of FYM and poultry manure, respectively. The particulate organic carbon content was found be lower in soils under conventional tillage irrespective of cropping system and nutrient management. Similar trend was also observed with regards to light fraction organic carbon content. Highest soil organic carbon storage was observed in soils under conservation tillage, soybean-wheat system with FYM (18.5 Mg/ha), and poultry manure (17.14 Mg/ha). We conclude that adoption of conservation tillage and application of FYM/poultry manure under soybean–wheat system can improve carbon storage and may have the most benefits to soil quality in soybean growing areas of India.

Key words: Carbon sequestration, carbon fractions, nutrient management, tillage

Soil organic carbon (SOC) is recognized as a primary soil fertility constituent and a key factor in sustainable soil use (Roose and Barthes, 2001; Zaujec, 2001). Maintaining high level of SOC translates into good soil physical properties, high soil fertility, and high yields. In addition to agronomical benefits SOC is an important component of the global carbon (C) cycle. Increasing concerns about global climate change, driven by rising atmospheric concentrations of greenhouse gases, have enhanced the interest in soil C sequestration as one of the strategies to offset anthropogenic CO_2 emissions. Soils can function either as a source or a sink for atmospheric greenhouse gases depending on land use and soil management. Appropriate management can enable agricultural soils to be a net sink for

[1]PhD Scholar; [3]Senior Scientist; [3]Principal Scientist; [4]Professor: [5]Ex-Emeritus Scientist

sequestering atmospheric CO_2 and other greenhouse gases (Lal and Kimble, 1997; Paustian *et al*., 1997; West and Post, 2002).

Carbon sequestration in agricultural soils is frequently promoted as a practical solution for slowing down the rate of increase of CO_2 in the atmosphere. Consequently, there is a need to improve our understanding of how land management practices may affect the net removal of greenhouse gases from the atmosphere (Desjardins *et al*., 2005). Carbon sequestration by agricultural land has generated international interest because of its potential impact on and benefits for agriculture and climate change. Agricultural ecosystems represent an estimated 11 per cent of the earth's land surface and include some of the most productive and carbon-rich soils. As a result, they play a significant role in the storage and release of C within the terrestrial carbon cycle (Lal *et al*., 1998). Optimum levels of soil organic carbon can be managed through crop rotation, fertility maintenance including use of inorganic fertilizers and organic manures, tillage methods, and other cropping system components (Swarup, 1998; Purakayastha *et al*., 2008). Among these, management practices like proper cropping systems and balanced fertilization are believed to offer the greatest potential for increasing SOC storage in agricultural soils (Swarup *et al*., 2000; Lal, 2002).

Tillage and residue management play an important role in SOC turnover, aggregate formation and microbial abundance in soil (Lagomarsino *et al*., 2009). No-till and crop residue retention tend to decrease the turnover rate of macro-aggregate (Six *et al*., 2000), resulting in SOC sequestration in the surface soil (Six *et al*., 2002; Pacala and Socolow, 2004). Compared to traditional tillage techniques, conservation tillage can play a key role in decreasing CO_2 emissions and in increasing the pool of C sequestered in the soil (Deen and Kataki, 2003; Freibauer *et al*., 2004; Lal, 2004; Baker *et al*., 2007). In a long-term perspective, (>10 years) SOC storage in the soil may increase by implementing conservation tillage practices such as no-tillage (West and Post, 2002; Franzluebbers, 2005; Liebig *et al*., 2005; Martens *et al*., 2005, Giacomo De Sanctis *et al*., 2012). Conservation tillage is one of the recommended management practices for increasing soil organic carbon pool in agricultural ecosystems (Lal and Kimble, 1997; Lal *et al*., 1998). Conservation tillage systems retain more crop residues on the soil surface and have a higher SOC concentration in surface layer than conventional tillage (Hutchinson *et al*., 2007). Joao Carlos de Moraes Sá *et al*. (2014) also emphasized the role of labile fractions in the overall SOC accumulation processes in soils managed under continuous no-till cropping systems and their positive impacts on the soil resilience restoration and on agronomic productivity.

The results of Campbell *et al*. (2001) indicate that without adequate fertilization the adoption of no-tillage will not necessarily increase soil C. Recent studies on long-term fertilizer experiments in India indicated that integrated use of FYM with chemical fertilizers (100 % NPK+FYM) over 30 years showed significant increase in SOC content than 100 per cent NPK in rice–jute–rice cropping system in humid tropical climate (Manna *et al*., 2006). Brar *et al*., (2013) also observed that 100 per cent NPK with FYM significantly increased carbon sequestration rate from 9.19 to 9.99 Mg C per ha, 3.30 to 4.10 Mg C per ha and 0.37 to 0.46 Mg C per ha per year, respectively. Organic carbon levels increased with continuous cropping particularly when legumes were included in the improved systems (Wani *et al*., 1994).

Continuous application of FYM and green manure substantially improved the organic carbon under different soils and cropping systems (Manna *et al.*, 1997, Swarup 1998, Wani *et al.*, 2003).

So, the monitoring CO_2 emissions and changes in SOC for different tillage and nutrient treatments is important to identifying the management practices that maintain soil productivity, increase C storage, and contribute to mitigate the greenhouse effects. Therefore the objective of this research was to assess the effects of different tillage and nutrient management on carbon sequestration and soil organic carbon (SOC) under soybean crop rotation in Central India.

MATERIALS AND METHODS

The present study was confined to the major command area of soybean in the states of Madhya Pradesh, Maharashtra, Rajasthan and Andhra Pradesh, which falls under semi-arid tropics and receives an average annual rainfall between 800 to 1000 mm; the bulk of which is received in the months from June to October. Maximum temperature in April and May ranges from 38°C to 44°C and the minimum temperature during December and January from 7°C to 13°C. Majority of soybean command area is covered with Vertisols and associated soils. Since soybean-wheat (irrigated regime), soybean-chickpea (rainfed regime) and soybean-potato or garlic or onion constituted major cropping systems of Central India, were included in the study.

A total of 213 surface (0-15 cm) soil samples from the rhizosphere of soybean at growth stage close to flowering (R2+ stage) from farmers' field covering contrasting agro-management systems were collected from major soybean growing regions of Madhya Pradesh, Maharashtra, Rajasthan and Andhra Pradesh. The contrasting management practices included either reduced (two passes of cultivators followed by planking) or conventional tillage (deep tillage once in 3-4 years followed by two passes of cultivator and planking), nutrient management through integrated approach or inorganics in cropping systems, namely soybean-wheat, soybean-chickpea, soybean-potato/garlic/onion. Thus, total management systems considered were 14 (Table 1). These management systems were followed by the farmers for minimum 10 years. In case of integrated nutrient management, the farmers used organic manures once in 3 years. These soil samples were collected during the *kharif* of 2009 and 2010 and refrigerated at 4°C and subsequently analysed for bulk density (Piper, 1966), soil reaction (Jackson, 1973), organic carbon and its fractions. The organic carbon in soil was analysed using Walkley and Black (1934) method as described by Yeomans and Bremner (1988), particulate organic carbon by the method of Cambardella and Elliot (1992) and light fraction carbon by the method of by Janzen *et al*. (1992).

The analytical results were analyzed by using SAS statistical software (ver.9.2; SAS Institute, Cary, NC). One way analysis of variance (ANOVA) was carried out with the ANOVA procedure in SAS enterprise guide 4.2 and the Fisher least significant differences (LSD).

RESULTS AND DISCUSSION

Effect of tillage and nutrient management on bulk density and soil reaction

Considerable variation (1.07 to 1.55 g/cc) in bulk density values was observed in soils under contrasting cropping systems under different tillage and nutrient management (Table 2). The variation in

Table 1. Treatment description of the different agricultural management systems

Management System	Treatment description		
	Cropping system	Tillage	Nutrient management
1	2	3	4
ConsT, SFYM – WF	Soybean (S)-wheat (W)	Conservation (ConsT)	FYM to soybean and fertilizer (F) to Wheat
ConsT, SFYM + F– WF	Soybean (S)-wheat (W)	Conservation (ConsT)	FYM and fertilizer (F) to soybean, and fertilizer (F) to wheat
ConsT, SPM – WF	Soybean (S)-wheat (W)	Conservation (ConsT)	Poultry manure (PM) to soybean and fertilizer (F) to wheat
ConsT, S – WF	Soybean (S)-wheat (W)	Conservation (ConsT)	No fertilization to soybean and fertilizer (F) to wheat
ConsT, SF – WF	Soybean (S)-wheat (W)	Conservation (ConsT)	Fertilizer (F) to soybean, fertilizer (F) to wheat
ConsT, SFYM +F – CF	Soybean (S) – chickpea (C)	Conservation (ConsT)	FYM and fertilizer (F) to soybean, and fertilizer (F) to chickpea
ConsT, SFYM – P/Ga/OF	Soybean (S)-potato (P) or garlic (G) or onion(O)	Conservation (ConsT)	FYM to soybean and fertilizer (F) to potato/garlic/onion
ConsT, SPM – P/Ga/OF	Soybean (S)-potato (P) or garlic (G) or onion(O)	Conservation (ConsT)	Poultry manure (PM) to soybean and fertilizer (F) to potato/garlic/ onion
ConvT, SFYM – WF	Soybean (S)-wheat (W)	Conventional (ConvT)	FYM to soybean and fertilizer (F) to wheat
ConvT, SFYM +F – WF	Soybean (S)-wheat (W)	Conventional (ConvT)	FYM and fertilizer (F) to soybean and fertilizer (F) to wheat
ConvT, SF – WF	Soybean (S)-wheat (W)	Conventional (ConvT)	Fertilizer (F) to soybean and fertilizer (F) to wheat
ConvT, S FYM +F – CF	Soybean (S) – chickpea (C)	Conventional (ConvT)	FYM and fertilizer (F) to soybean, and fertilizer (F) to chickpea

Table 1. Contd.

1	2	3	4
ConvT, SF – CF	Soybean (S) – chickpea (C)	Conventional (ConvT)	Fertilizer (F) to soybean and fertilizer (F) to chickpea
ConvT, SFYM +F – P/GA/OF	Soybean (S) –potato (P) or garlic (G) or onion (C)	Conventional (ConvT)	FYM and fertilizer (F) to soybean, and fertilizer (F) to potato/garlic/onion

values for bulk density under conservation tillage (1.07 to 1.55 g/cc) and conventional tillage (1.43 to 1.50 g/ cc) observed in different cropping systems might be on account of integrated use of organic manures with fertilizers or fertilizers alone. Application of poultry manure along with fertilizers irrespective of cropping systems showed comparatively lower bulk density values (1.07 and 1.21 g/cc). In general, integrating FYM with fertilizers in different cropping systems as well led to lower bulk density as

Table 2. Effect of different agricultural management practices on bulk density (g/cc) and soil pH

Treatment	Bulk density (g/cc)	pH
ConsT, SFYM – WF	1.46±0.13[ab]	7.51±0.26[bc]
ConsT, SFYM + F– WF	1.44 0.07[ab]	7.67±0.09[ab]
ConsT, SPM – WF	1.21±0.14[c]	7.70±0.27[ab]
ConsT, S – WF	1.55±10[a]	7.32±0.27[c]
ConsT, SF – WF	1.49± 0.13[ab]	7.66±0.21[ab]
ConsT, SFYM +F – CF	1.48± 0.19[ab]	7.76±0.09[ab]
ConsT, SFYM – P/Ga/OF	1.15±0.06[cd]	7.81±0.43[a]
ConsT, SPM – P/Ga/OF	1.07± 0.06[d]	7.67±0.34[ab]
ConvT, SFYM – WF	1.43± 0.07[ab]	7.89±0.20[a]
ConvT,SFYM +F – WF	1.48±0.11[ab]	7.71±0.24[ab]
ConvT, SF – WF	1.48±0.13[ab]	7.70±0.21[ab]
ConvT, S FYM +F – CF	1.38±0.12[b]	7.67±0.13[ab]
ConvT, SF – CF	1.42±0.04[b]	7.75±0.25[ab]
ConvT, SFYM +F – P/GA/OF	1.50±0.11[ab]	7.74±0.14[ab]
SEm (±)	0.01	0.06
LSD (P = 0.05)	**0.13**	**0.28**

Data are mean values of six replicates ± SD; means with different letters in the same row differ significantly at P = 0.05 according to Fisher LSD.

compared to cropping systems receiving only fertilizers for nutrient management. A reduction in bulk density is very commonly observed on incorporation of crop residues organic amendments as compared to fertilizers alone (Herrick and Lal, 1995;

Sharma *et al.,* 2000; Srikanth, 2000; Bellakki and Badanur, 1994; Itnal, 1997). In general, irrespective of cropping systems and nutrient management, the average bulk density was lower by 10 per cent indicating better soil physical conditions in conservation tillage over conventional tillage. Irrespective of cropping system and tillage, the integrated nutrient management revealed lower values of bulk density by 9 per cent (Table 2). This brought out that the reduction in extent of tillage as well integrated use of organics and inorganics in long-term reduces the bulk density of soil.

Cropping systems under contrasting management showed significant differences with respect to pH which varied from 7.32 to 7.81 in conservation tillage and from 7.67 to 7.89 in conventional tillage. Although, soil reaction is inherent property of soil, the variation might be the combined effect of varying management. However, the lowest value of pH (7.32) was associated with soybean- wheat system with conservation tillage, wherein no organics were used and wheat received only fertilizers (Table 2).

Effect of tillage and nutrient management on total organic carbon content

Cropping systems under contrasting management showed significant variation in organic carbon content (0.36-0.95 %). In general, irrespective of nutrient management followed, the organic carbon content was higher in soils under conservation tillage (0.54 to 0.95 %) as compared to conventional tillage (0.41 to 0.84 %). The variation in organic carbon content with in systems under conventional or conservation tillage might be on account of nutrient management systems indicating the role of organic matter recycling in use of organics in conjunction with inorganics (Table 3). The maximum build up of organic carbon (0.95 %) was noticed in soybean-wheat cropping system under conservation tillage wherein soybean received poultry manure followed by wheat receiving fertilizers only. In case of conventional tillage as well soybean receiving FYM plus fertilizers followed by wheat fertilized showed maximum value of organic carbon (0.84 %). Comparison of high intensity cropping system soybean followed by potato/onion/garlic under different tillage system revealed that soybean receiving FYM followed by fertilized subsequent crops had higher contents of organic carbon (0.74 %) than the same system under conventional tillage wherein soybean receiving FYM plus fertilizer followed by fertilized subsequent crops (0.55 %) indicating the importance of conservation tillage in building up of organic carbon in soil. On an average basis, irrespective of cropping systems and nutrient management practices, organic carbon content was 19.64 per cent higher in conservation tillage over conventional tillage. Similarly integrated nutrient management over cropping systems and tillage systems revealed higher organic content by 41 per cent.

Apart from other agricultural management practices, conversion from conventional to conservation and no tillage has potentials to sequester more soil carbon stock in soil (Martel and Paul, 1974.; Dick *et al*., 1998), which is obvious in the present studies. The rates of organic C sequestration in soil under no till or conservation practices reported in the literature (West and Post, 2002; Luo *et al*., 2010).

In case of the two agricultural management systems under conservation tillage where soybean receiving FYM followed by potato/garlic/onion and soybean receiving poultry manure followed by potato/garlic/onion as well the organic source influenced the organic carbon content. Replacement of FYM with poultry manure reduced bulk density and increased the organic carbon remained comparable (Table 3).

In case of soybean–chickpea system under conventional tillage, soybean receiving FYM with fertilizer followed by chickpea fertilized showed slight improvement in bulk density but there was reduction in content of organic carbon (Table 3).

Effect of tillage and nutrient management on soil organic carbon stock and their fractions

Significant differences in soil organic carbon stock (8.38 to 18.77 Mg/ha) were noticed due to different management systems. An examination of data (Table 3) showed increased carbon sequestrations as represented by soil organic carbon. It is noteworthy that conservation tillage could not help in higher carbon sequestration if the soybean-wheat system was not adequately

Table 3. Effect of different agricultural management practices on total organic content, soil organic carbon and their fractions

Treatment	**Organic carbon (%)**	**SOC (Mg/ha)**	**Particulate C (g/ kg)**	**Light fraction C (g/kg)**
ConsT, SFYM – WF	0.87±0.55[ab]	18.50±9.82[a]	1.60±0.41[bc]	0.91±0.33[cdef]
ConsT, SFYM + F– WF	0.59±0.13[cd]	12.64±2.89[cd]	0.56±0.28[def]	0.94±0.19[cdef]
ConsT, SPM – WF	0.95±0.12[e]	17.14±2.35[ab]	3.12±0.64[a]	1.90±0.59[a]
ConsT, S – WF	0.36±0.05[cd]	8.38±0.93[d]	0.51±0.13[def]	0.19±0.05[g]
ConsT, SF – WF	0.59±0.13[cde]	13.34±3.60[bc]	0.68±0.53[def]	0.95±0.18[bcdef]
ConsT, SFYM +F – CF	0.54±0.08[abc]	11.53±1.22[cd]	0.95±1.01[de]	1.08±0.43[bcd]
ConsT, SFYM – P/Ga/OF	0.74±0.08[abc]	12.66±1.14[cd]	2.05±0.32[b]	0.99±0.22[bcde]
ConsT, SPM – P/Ga/OF	0.73±0.13[abc]	11.68±2.52[cd]	2.65±0.36[a]	1.31±0.40[b]
ConvT, SFYM – WF	0.53±0.09[cde]	11.48±1.87[cd]	1.07±0.42[cd]	0.66±0.25[ef]
ConvT,SFYM +F – WF	0.84±0.27[ab]	18.77±6.30[a]	0.47±0.43[ef]	1.15±0.59[bc]
ConvT, SF – WF	0.41±0.13[de]	8.94±3.47[d]	0.43±0.45[ef]	0.60±0.13[f]
ConvT, S FYM +F – CF	0.49±0.10[de]	10.13±2.84[cd]	0.35±0.50[f]	0.77±0.24[def]
ConvT, SF – CF	0.54±0.62[cde]	11.49±1.60[cd]	0.54±0.52[def]	0.79±0.10[cdef]
ConvT,SFYM+F-P/GA/OF	0.55±0.05[cde]	12.33±1.94[cd]	0.22±0.10[f]	0.87±0.08[cdef]
SEm (±)	0.04	14.50	0.24	0.10
LSD (P = 0.05)	**0.22**	**4.38**	**0.56**	**0.37**

Data are mean values of six replicates ± SD; means with different letters in the same row differ significantly at P = 0.05 according to Fisher LSD.

managed with respect to nutrition, and thereby agricultural management system conservation tillage, soybean followed by wheat with fertilization recorded lowest values of SOC. Reasonably good amount of carbon was sequestered when poultry manure was used in place of farmyard manure in an integrated approach with inorganic in the agricultural management systems irrespective of the type of tillage (Table 2). Similar trend was observed when organic manure incorporated with 100 per cent NPK in long-term experiment (Manna *et al*., 2006, Purakayastha *et al*., 2008, Brar *et al*., 2013). The highest content of soil organic carbon (18.77 Mg/ha) was associated with the management regimes include soybean wheat cropping system with the incorporation of farmyard manure with fertilizer under conventional tillage fallowed by conservation tillage with soybean farmyard- wheat fertilized (18.50 Mg/ha). Application of inorganic fertilizer alone could not maintain organic carbon content in rhizosphere soil. Integrated nutrient management with conservation tillage play vital role in increasing SOC (Guo-ChengWang *et al*., 2013). Conservation tillage significantly increased the soil organic carbon from 11.53 to 18.50 Mg per ha as compared to conventional tillage. Giacomo De Sanctis *et al*., (2012) also observed SOC content following 8 and 12 years of continuous treatment application was significantly higher in the top 10 cm of the soil under no till than conventional tillage, but it was similar in the 10–40 cm layer and soil C increased by 0.3 t per ha per year over 50 years, under no-till with N fertilizer. Similarly Shang-Qi XU *et al*. (2013) showed in his research, after four years of experiment, the no till treatment sequestrated more SOC than the other treatments. The SOC stocks in the 0–80 cm layer under no till (on an ESM basis) was as high as 129.32 Mg C per ha, significantly higher than those under PT and RT ($P < 0.05$).

Particulate organic carbon (POC) was significantly increased 0.22 to 3.12 g per kg under contrasting management. It was observed that application of poultry manure triggered higher value of particulate carbon (2.65 to 3.12 g /kg) in rhizosphere soil. The system include conservation tillage with soybean poultry manure fallowed by wheat fertilized and conservation till under soybean poultry manure – paotao/garlic/ onion fertilized system had higher particulate carbon content 3.12 g per kg and 2.65 g per kg in soil, respectively. Incorporation of farmyard manure with inorganic carbon also enhanced particulate organic carbon in soil irrespective of tillage and cropping systems (Table 2). However, conservation tillage had more impact on particulate carbon as compared to conventional tillage practices. The use of inorganic fertilizer alone reduced particulate organic carbon in soil. The particulate organic matter C (POM-C), dissolved organic C (DOC), and microbial biomass C (MBC) levels in the 0–5 cm layer under NT treatment were 155 per cent, 232 per cent, and 63 per cent greater, respectively, compared to the conventional tillage treatment. (Enke Liu *et al*., 2014).

It is evident from the data that contrasting management practices signify-cantly influenced light fraction carbon content (Table 3). The management system that included poultry manure had higher light fraction carbon content (1.90 and 1.31 g/kg) and significantly higher as compared to other management systems included in the study. The system with inorganic fertilization / no fertilization and conventional tillage decreased light fraction carbon content. The lowest value (0.60 g/kg) was associated under conventional tillage with soybean fertilized fallowed by wheat fertilized. Although incorporation of farmyard manure with inorganic fertilizer under conventional tillage also maintained quit increase in light fraction carbon under soybean - wheat cropping system. So this indicated that soybean wheat cropping system helps in maintaining biological soil properties (Table 2).

Amongst soybean–wheat cropping systems (irrigated regime) under conservation tillage and varying nutrient management practices, the carbon sequestered from environment represented by organic carbon stock, soybean receiving poultry manure followed by wheat fertilized showed comparable values and excelled in particulate and light fraction carbon as compared to soybean receiving FYM followed by wheat fertilized. Soybean receiving FYM plus fertilizer followed by wheat fertilized showed intermediate values for these indicators and was comparable with soybean fertilized followed by wheat fertilized. Soybean without fertilization followed by wheat showed lowest values for these indicators. Under conventional tillage, the trend visualized in conservation tillage was not seen. However, as compared to soybean fertilized followed by wheat fertilized showed lowest values for these indicators (Table 3).

Soybean receiving FYM plus fertilizer followed by chickpea fertilized (rainfed regime) under conservation tillage showed invariably higher values for soil organic carbon stock, particulate carbon and light fraction carbon over same system under conventional tillage. Soybean fertilized followed by chickpea fertilized was marginally better than soybean receiving FYM plus fertilizer followed chickpea fertilized. The reason being conventional tillage does not permit expression of organic manure being applied due to disturbances up to deeper layers of soil.

Comparable values for organic carbon stock were noticed between soybean with poultry manure followed by potato/ garlic/onion fertilized and soybean with FYM plus fertilizer followed by potato/garlic/onion fertilized under conservation tillage and also soybean receiving FYM plus fertilizer followed by potato/garlic/onion fertilized under conventional tillage, but the first system with incorporation of poultry manure showed higher values for particulate and light fraction carbon. The result indicated that use of conservation tillage with organic amendment improves these indicators. Application of organic sources has been reported to enhance organic carbon stock and particularly labile fractions in the soil (Wander *et al.*, 1994). Accumulation of organic carbon and improvement in soil quality indices as a result of crop management with organic components has been documented in the past (Liebig and Doran, 1999).

With increasing concern over the effect of intensive agricultural practices on soil and environmental quality, there is a movement towards adoption of cropping systems that maintain and/or improve soil health and quality. The level of organic matter in soil is a function of the net input of organic residues by rotation practices with in cropping systems. Crop rotation allows return of crop residues of varying quality to the soil, which, in turn, affects the level and quality of soil organic matter retained over time (Campbell *et al.*, 1991; 1992).

Mean values for tillage practices showed that conservation tillage invariably led to higher build up of organic carbon stock, particulate organic carbon and light fraction carbon in soil over conventional tillage. The use of deep ploughing (conventional tillage) and abandonment of traditional crop rotation has led to a strong reduction in organic matter content, with consequences affecting also its quality and composition (Wander *et al*, 1994). Therefore, replacing deep tillage with less-disruptive systems could prevent soil degradation and improve its functionality. Studies on a number of soils in an array of climatic conditions demonstrated that conservation tillage improves soil biological properties by increasing C sequestration (Kern and Johnson, 1993; Franzluebbers, 2002; Hernanz *et al*., 2002).

Similar was the effect of integrated nutrient management practices over inorganic nutrient management for these quality indicators. Important land uses and practices with the potential to sequester SOC include conversion of crop land to pastoral and forest lands, conventional tillage to conservation and no tillage, no manure use to regular addition of manure, and to soil-specific fertilization rate have been reported earlier (Martel and Paul, 1974; Jenkinson and Rayner, 1977) and provides the support to the presented findings.

Application of integrated nutrient management showed better results as compared to use of inorganic management and organic manure alone, both in combination maintained soil organic carbon pool and helps in sequestration of carbon. Even under conventional practices with integrated use of chemical nutrients with organic manure revealed increase in soil carbon storage. Adoption of conservation tillage enhanced microbial activity in soil which in turn increase soil carbon content and helps in maintaining environment balance as compared to conventional tillage. Among all fourteen agricultural management soybean-wheat cropping systems under conservation tillage and poultry manure, showed good increase in soil organic carbon and their fractions.

ACKNOWLEDGMENT

The authors are thankful to Director, Directorate of Soybean Research, Indore and ICAR for provision funding for the research.

REFERENCES

Baker J M, Ochsner T E, Venterea R T and Griffis T J. 2007. Tillage and soil carbon sequestration -What do we really know? *Agriculture Ecosystems and Environment* **118**: 1-5.

Bellakki M A and Badanur V P. 1994, Effect of crop residues incorporation on physical and chemical properties of a Vertisol and yield of sorghum. *Journal of the Indian Society of Soil Science* **42(**2): 533-5.

Brar B S, Singh Kamalbir, Dheri G S and Kumar Balwinder. 2013. Carbon sequestration and soil carbon pools in a rice–wheat cropping system: Effect of long-term use of inorganic fertilizers and organic manure. *Soil and Tillage Research* **128**: 30-6.

Cambardella A A and Elliot E T. 1992. Particulate soil organic matter changes across a grass land cultivation sequence. *Soil Science Society of America Journal* **63**: 186-91.

Campbell C A, Biederbeck V O, Zentner R P and Lafond G P. 1991. Effect of crop rotation and cultural practices on soil organic matter, microbial biomass and respiration in thin black Chernozem. *Canadian Journal of Soil Science* **71**: 363-76.

Campbell C A, Moulin A P, Bowren K E, Janzen H H, Townleysmith L and Biederbeck V O. 1992. Effect of crop rotation on microbial biomass, specific respiratory activity and mineralisable nitrogen in a black chernozem soil. *Canadian Journal of Soil Science* **72**: 417-27.

Campbell C A, Selles F, Lafond G P and Zentner R P. 2001. Adopting zero tillage management: Impact on soil C and N under long-term crop rotations in a thin Black Chernozem. *Canadian Journal of Soil Science* **81**: 39–148.

Deen W and Kataki P K. 2003. Carbon sequestration in a long-term conventional versus conservation tillage experiment. *Soil and Tillage Research* **74**: 143–50.

Desjardins R, Smith W, Grant B, Campbell C and Riznek R. 2005. Management strategies to sequester carbon in agricultural soils and to mitigate greenhouse gas emissions. *Climatic Change* **70**: 283-97.

Dick W A and Durkalski J T. 1998. No-tillage production agriculture and carbon sequestration in a Typic Fragiudalf soil of north-easter Ohio. pp. 59-71. *In*: Lal R, Kimble J M, Follett R F and Stewart B A (Eds.), *Management of Carbon Sequestration in Soil*, CRC Press, Boca Raton, FL.

Enke Liu, Saba Ghirmai Teclemariam, Changrong Yan, Jianmin Yu, Runsheng Gu, Shuang Liu, Wenqing He and Qin Liu. 2014. Long-term effects of no-tillage management practice on soil organic carbon and its fractions in the northern China. *Geoderma* **213:** 379–84

Franzluebbers A J. 2002. Soil organic matter stratification ratio as an indicator of soil quality. *Soil and Tillage Research* **66**: 95-106.

Franzluebbers A J. 2005. Soil organic carbon sequestration and agricultural green house gas emissions in the south-eastern US. *Soil and Tillage Research* **83**: 120-47.

Freibauer A, Rounsevell M D A, Smith P and Verhagen J. 2004. Carbon sequestration in the agricultural soils of Europe. *Geoderma* **122:** 1–23.

Giacomo De Sanctis, Pier Paolo Roggero, Giovanna Seddaiu, Roberto Orsini, Cheryl H Porter and James Jones W. 2012. Long-term no tillage increased soil organic carbon content of rain-fed cereal systems in a Mediterranean area. *European Journal of Agronomy* **40**: 18–27

Guo-Cheng Wang, Zhong-Kui Luo, En-Li Wang and Yao Huang. 2013. Contrasting effects of agricultural management on soil organic carbon balance in different agricultural regions of China. *Pedosphere* **23**(6): 717–28

Hernanz J L, Lopez R, Navarrete L and Sanchez-Giron V. 2002. Long-term effects of tillage systems and rotations on soil structural stability and organic carbon straitification in semi-arid central Spain. *Soil and Tillage Research* **66**: 129-41.

Herrick J E and Lal R. 1995. Soil physical property changes during dung decomposition in a tropical pasture. *Soil Science Society of America Journal* **59**: 908–12.

Hutchinson J J, Campbell C A and Desjardins R L. 2007. Some perspectives on carbon sequestration in agriculture. *Agriculture Meteorology* **142:** 288–302.

Itnal C J. 1997. Fertility management in dryland agriculture - Principles and practices. *In*: *Proceedings of Short Summer Course on Role of Organics in Sustaining Soil Fertility and Crop Productivity*, June 9-18, Directorate of Research, University of Agricultural Sciences, Dharwad, pp. 274-90.

Jenkinson D S and Rayner J H. 1977. The turnover of soil organic matter in some of the Rothamsted classical experiments. *Soil Science* **123**: 298-305.

Janzen, H. H., Campbell, C. A., Brandt, S. A., Lafond, G. P. and Smith, L. T. 1992. Light fraction organic matter in soils from long term crop rotation. *Soil Science Society of America Journal* **56**: 1799-1806.

João Carlos de Moraes Sá, Florent Tivet, Rattan Lal, Clever Briedis, Daiani Cruz Hartman, Juliane Zuffo dos Santos and Josiane Burkner dos Santos. 2014. Long-term tillage systems impacts on soil C dynamics, soil resilience and agronomic productivity of a Brazilian Oxisol. *Soil and Tillage Research* **136**: 38-50

Kern I S and Johnson M G. 1993. Conservation tillage impacts on national soil and atmospheric carbon levels. *Soil Science Society of America Journal* **57**: 200-10.

Lagomarsino A, Grego S, Marhan S, Moscatelli M C and Kandeler E. 2009. Soil management modifies micro-scale abundance and function of soil microorganisms in a Mediterranean ecosystem. *European Journal of Soil Sci*ence **60**: 2–12.

Lal R. 2002. Why carbon sequestration in soils. *In*: Kimble J *et al*. (Eds), *Agricultural Practices and Policies for Carbon Sequestration in Soil*, CRC Press, Boca Raton, FL., pp. 21–30.

Lal R. 2004. Soil carbon sequestration impacts on global climate change and food security. *Science* **304**: 1623–27.

Lal R., Kimble J M, Follett R F and Cole C V. 1998. *The Potential of U S Cropland to Sequester Carbon and Mitigate the Greenhouse Effect*, Chelsea, Mich.: Ann Arbor Press, Chelsea, MI, pp 108.

Lal R and Kimble J M. 1997. Conservation tillage for carbon sequestration. *Nutrient Cycling in Agro-ecosystems* **49**(1–3): 243–53.

Liebig M and Doran J W. 1999. Impact of organic production practices on soil quality indicators. *Journal of Environmental Quality* **28**: 1601-9.

Liebig M A, Morgan J A, Reeder J D, Ellert B H, Gollany H T and Schuman G E. 2005. Greenhouse gas contributions and mitigation potential of agricultural practices in northwestern USA and western Canada. *Soil and Tillage Re*search **83**: 25–52.

Luo Z K, Wang E L and Sun O J. 2010. Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments. *Agriculture Ecosystems and Environment* **139**: 224–31.

Manna M C, Hajra J N, Sinha N B and Ganguly T K. 1997. Enrichment of compost by bio- inoculants and minerals amendments. *Journal of Indian Society Soil Science* **45:** 831-3.

Manna M C, Swarup A, Wanjari R H, Singh V V, Ghosh, P K, Singh K N, Tripathi A K and Saha M N. 2006. Soil organic matter in a West Bengal Inceptisol after 30 years of multiple cropping and fertilization. *Soil Science Society of American* Journal **70**: 121–9.

Martens D A, Emmerich W, McLain J E T and Johnsen T N. 2005. Atmospheric carbon mitigation potential of agricultural management in the southwestern USA. *Soil and Tillage Res*earch **83**: 95–119.

Martel Y A and Paul E A. 1974. Effects of cultivation on the organic matter of grassland soils as determined by fractionation and radiocarbon dating. *Canadian Journal of Soil Science* **54**: 419-26.

Pacala S and Socolow R. 2004. Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science* **305:** 968–72.

Paustian K, Collins H P and Paul E A. 1997. Management controls on soil carbon. *In*: Paul E A, Paustian K, Elliott E A and Cole C V (Eds), *Soil Organic Matter in Temperate Agroecosystems: Long-term Experiments in North America*, CRC Press, Boca Raton, pp 15-49.

Piper C S. 1966. *Soil and Plant Analysis*. Hans publishing house, Bombay, India.

Purakayastha T J, Huggins D R and Smith J L. 2008. Carbon sequestration in native prairie, perennial grass, no-tilled and cultivated Palouse silt loam. *Soil Science Society of American Journal* **72**(2): 534-40.

Roose E and Barthes B. 2001. Organic matter management for soil conservation and productivity restoration in Africa: a contribution from Francophone research. *Nutrient Cycling in Agroecosystems* **61**: 159–70.

Sharma M P, Bali S V and Gupta D K. 2000. Crop yield and properties of Inceptisol as influenced by residual management under rice-wheat cropping sequence. *Journal of Indian society of Soil Science* **48**: 506-9

Shang-Qi XU, Ming-Yuan Zhang, Hai-Lin Zhang, Fu Chen, Guang-Li Yang and Xiao-Ping XIao. 2013. Soil organic carbon stocks as affected by tillage systems in a double-cropped rice field. *Pedosphere* **23**: 696-704.

Six J, Conant R T, Paul E A and Paustian K. 2002. Stabilization mechanisms of soil organic matter: implications for C-saturation of soils. *Plant and Soil* **241**: 155–76.

Six J, Elliott E T and Paustian K. 2000. Soil macroaggregate turnover and microaggregate formation: a mechanism for C sequestration under no-tillage agriculture. *Soil Biology and Biochem*istry **32**: 2099–2103.

Srikanth K, Srinivasamurthy C A, Siddaramappa R and Ramakrishna Parama V R. 2000. Direct and residual effect of enriched composts, FYM, vermicompost and fertilizers on properties of an Alfisol. *Journal of the Indian Society of Soil Science* **48**(3): 496-9.

Swarup A. 1998. Emerging soil fertility management issues for sustainable crop production in irrigated systems. *In*: Swarup *et al*. (Eds), *Long-term Soil Fertility Management through Integrated Plant Nutrient Supply*, Indian Institute of Soil Science, Bhopal, India, pp. 54–68.

Swarup A, Manna M C and Singh G B. 2000. Impact of land use and management practiced on organic carbon dynamics in soils of India. *In*: Lal *et al*. (Eds), *Advances in Soil Science Global Climate Change and Tropical Ecosystem*, CRC-Lewis Publishers, Boca Raton, FL, pp 261–281.

Walkley A and Black I A. 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Science* **47**: 29-38.

Wander M M, Trania S J, Stinner B R and Peters S E. 1994. Organic and conventional management effects on biologically active soil organic matter pools. *Soil Science Society of America Journal* 58: 1130-9.

Wani S P, McGill W B, Haugen-Koyzra K L, Robertson J A and Thurstson J J. 1994. Improved soil quality and barley yields with faba beans, manure, forages and crop rotation on a gray Luvisol. *Canadian Journal of Soil Science* **74:** 75-84.

Wani S P, Pathak P, Jangawad L S, Eswaran H and Singh P A. 2003. Improved management of Vertisols in the semi-arid tropics for increased productivity and soil carbon sequestration. *Soil Use Management* **19**: 217–22.

West T O and Post W M. 2002. Soil organic carbon sequestration rate by tillage and crop rotation: A global data analysis. *Soil Science Society of America Journal* **66**: 1930-46.

Yeomans J C and Bremner J M. 1988. A rapid and precise method for routine determination of organic carbon in soils. *Communication in Soil science and Plant Analysis* **19**: 1467-76.

Zaujec A. 2001. Soil organic matter as indicator of soil quality and human influences on agroecosystem and natural forest ecosystem. *Ekologia-Bratislava* **20**: 133–9.

Soybean Research (Special Issue Number 2): 120-125: 2014

Effects of Different Levels of Phosphorus and Phosphate Solubilising Fungi on Soil Nutrient Availability and Yield of Soybean

B M KAMBLE[1] and D K KATHMALE[2],
Agricultural Research Station (Mahatma Phule Krishi Vidyapeeth), K. Digraj, Sangli 416 305, Maharashtra, India
Email: bmkamble2007@rediffmail.com

ABSTRACT

A field experiment was conducted during kharif *2011 at Agricultural Research Station, K. Digraj, Sangli to study the effect of different levels of phosphorus and phosphate solubilising fungi (PSF) on nutrient availability and yield of soybean. The experiment was laid down in randomized block design with eight treatments replicated thrice. The treatments consisted of 50 and 100 per cent recommended dose of phosphorus (RDP) with three different consortium of* Penicillium bilaji *along with recommended dose of N and K fertilizers. The results revealed that the highest 100 seed weight (12.20 g), seed yield (2,919 kg/ha) and straw yield (3,874 kg/ha) of soybean were recorded in 100 per cent RDP and inoculation with consortium of* Penicillium bilaji *x 10^4 over rest of the treatments and it was at par 50 per cent RDP + inoculation with consortium of* Penicillium bilaji *x 10^4 and 100 per cent RDP + inoculation with consortium of* Penicillium bilaji *x 10^3 and 10^5 for seed and straw yields of soybean. The seed inoculation with phosphate solubilising fungi and different levels of phosphorus showed non-significant effect on soil pH and EC after harvest of soybean. Significantly highest available N, P and K in soil after harvest of soybean were recorded in treatment inoculation with consortium of* Penicillium bilaji *x 10^4 + 100 per cent RDP over the rest of the treatments. The lowest 100 seed weight, seed and straw yields of soybean as well as available N, P and K were observed in treatment without seed inoculation + 50 per cent RDP.*

Key words: Available N P K, fungi, soybean, yield

Globally, soybean [*Glycine max* (L.) Merrill] continues to rank first amongst various oilseed crops, contributing approximately 25 per cent to the world's total oil and fat production, which is next only to palm oil, having 26 per cent share. Thus, soybean is expected to play a pivotal role in meeting the continuously increasing demand of the edible oil across the world. The world soybean area, production and productivity for 2012-13 are 108.89 million ha, 268.02 million tonnes and 2.47 t per ha (Anonymous, 2013). Five countries, *viz;* United State of America, Brazil, Argentina, China and India account for 90 per cent of world production. Soybean continues to rank number one oilseed crop of India and is followed by rapeseed, mustard, groundnut and sunflower. The country has seen an unprecedented growth in soybean area which was just 0.03 m ha in 1970 and has reached to 9.30 million ha in 2010 and production reaching to 10.13 million tons in 2010 from 0.014 million tons in 1970. The average national productivity of the crop has increased from 0.43 t per ha in 1970 to 1.09 t

[1]*Associate Professor (Soil Science);* [2]*Officer Incharge*

per ha in 2010 (Anonymous, 2011).

Soybean being a legume, requires high quantity of phosphorus as it plays an important role in energy transformation and biochemical reactions including biological nitrogen fixation. When phosphatic fertilizers added to soil, a part of phosphorus is utilized by the plants (15-20 %) and remainining is (80-85 %) fixed in the form of insoluble phosphate in the soil in less available form. Due to poor solubility of native soil phosphorus, sometimes there is a buildup of insoluble phosphorus as a result of chemical phosphorus application (Dubey, 1997). The calcareous soils contain relatively large amount of insoluble phosphorus but because of phosphorus fixation relatively little is available for crop use. This is true in case of water soluble phosphorus added to the calcareous soil in the form of single superphosphate. Therefore mobilization of such insoluble phosphorus accumulated in soil is of practical importance. Various types of microorganisms are known to inhabit soil, especially rhizosphere and play an important role in plant growth and development. Gerretsen (1948) initially demonstrated that microbiological activity in the rhizosphere could dissolve sparingly soluble inorganic P and increase plant growth. Phosphorus in different forms might be taken up by the plants, but by far, the major form absorbed either is HPO_4^{2-} or $H_2PO_4^-$ (Beever and Burns, 1981). High amount of applied single super phosphate enters in to the immobile pools through precipitation reaction with highly reactive calcium in calcareous or normal soils (Gyaneshwar *et al.,* 2002). Efficiency of P fertilizer throughout the world is around 10 - 25 per cent (Isherword, 1998). Soil microorganisms play a key role in soil P dynamics and subsequent availability of phosphate to plants (Richardson, 2001). It is well known that more than two-third of phosphatic fertilizers are rendered unavailable within a very short period of time after its application due to fixation in soil complex as di- and tri-calcium phosphate. Several soil fungi, particularly those belonging to the genera *Penicillium* and *Aspergillus* possess ability to bring insoluble native soil phosphates into soluble forms by secreting weak organic acids such as formic, acetic, propionic, lactic, glucolic, fumaric and succinic. No information is available on the use of different levels of phosphorus and consortium of *Penicillium bilaji* on nutrient availability and yield of soybean. The present investigation was undertaken to study the effect of different levels of phosphorus and consortium of *Penicillium bilaji* on nutrient availability and yield of soybean.

MATERIAL AND METHODS

The field experiment was conducted during *kharif* 2011 at Agricultural Research Station, K. Digraj, Sangli to study the effect of different levels of phosphorus and phosphate solubilising fungi on nutrient availability and yield of soybean. The experiment was laid down in randomized block design with eight treatments (Table 1) replicated three times. The pre-experimental soil status analysed, pH 8.33, EC 0.15 dS per m, N 180 kg per ha, P 10.78 kg per ha and K 418 kg per ha. The soil was calcareous in nature and medium deep black clay. The treatments consisted of 0, 50, 100 per cent RDP with three different consortium of *Penicillium bilaji* (10^3,10^4 and10^5) of phosphate solubilising fungi. The uniform dose of N @ 50 kg per ha through urea as per recommendation and 75 kg P_2O_5 kg per ha through single super phosphate (SSP) as per treatment was applied at the time of sowing.

Soybean seeds (JS 335) were inoculated with PSF during sowing as per treatments. PSF (Jump start 1+2; *Penicillium bilaji*) inoculum was supplied by Novozymes India Pvt. Ltd, Bangalore. The 1,000 g seeds were taken in large zip-lock bags and added 3 ml PSF (Jump start 1+2 *Penicillium bilaji*) as per consortium *i.e.* 10^{-3},10^{-4} and 10^{-5} separately into the different bags (3ml/kg of seed). The bags were sealed and hand manipulated to mix the seed well and placed in the shade. Spread the inoculated seed into a flat layer within the bags and opened one end of the bags to allow the seed to dry prior to sowing and sown within 2 to 3 h of inoculation. The net plot size was 2.70 m x 4.80 m and dibbling of seed was done at a distance of 45 cm X 5 cm. The regular management practice and need base plant protection measures were carried out. The soil samples (0-15 cm depth) from each plot after harvest of soybean were collected, air dried and passed through 2 mm sieve and used for estimation of available N by modified alkaline $KMnO_4$ method (Sahrawat and Burdford, 1982), P by 0.5 M $NaHCO_3$ at pH 8.5 ascorbic acid method (Watanbe and Olsen, 1965) and K by 1 N NH_4OAc at pH 7.0 method (Jackson, 1973). The seed, straw yield and 100 seed weight were recorded. The statistical analysis was carried out by procedure suggested by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Effect of phosphate solubilising fungi (PSF) *Penicillium bilaji* and phosphorus levels on yield and yield contributing parameters of soybean

The results revealed that the different levels of phosphorus along with *Penicillium bilaji* seed inoculation showed significant effect on seed and straw yields of soybean, whereas non-significant effect on 100 seed weight (Table 1). The highest 100 seed weight (12.20 g), seed yield (2,919 kg/ha) and straw yield (3,874 kg/ha) were recorded in treatment 100 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^4, which was at par with treatments of 50 per cent RDP with inoculation with consortium of *Penicillium bilaji* x 10^4 and100 per cent RDP with inoculation with consortium of *Penicillium bilaji* x 10^3 and 10^5 for seed and straw yields of soybean. The inoculation of *Penicillium bilaji* to seed along with single superphosphate increased the efficiency of single superphosphate and ultimately improved yield. This might be due to readily available phosphorus from single super phosphate resulting in better absorption and utilization of phosphorus by plant and presence of other important plant nutrient (sulphur). Sulphur, besides increasing phosphorus availability (Sacchidanand *et al*., 1980) also increases its assimilation rate. The P-solubilizers increase the amount of available major and minor nutrients besides certain growth promoters which might have provided a suitable medium for the enhanced growth (Patil *et al,* 2012). Tiwari *et al*. (1989), who recorded increase in nodulation and grain yield of chickpea due to inoculation of *A. awamori* in combination with application of rock phosphate and super phosphate as P sources. Phosphate solubilising fungi with various P_2O_5 levels showed positive effect on grain yield of maize (Patil *et al*., 2012). The lowest 100 seed weight (11.30 g), seed (2,415 kg/ha) and straw (3,260 kg/ha) yields of soybean were recorded in treatment without seed inoculation + 50 per cent RDP. Lower yield in treatments receiving 50 per cent RDP was due to the slow rate of release of phosphorus from applied P fertilizer to meet the P requirement of crops at its critical growth stages, low availability of phosphorus to

Table 1. Effect of PSF and phosphorus levels on yield and yield contributing parameters of soybean

Treatment	Yield (kg/ha)		100 seed weight (g)
	Seed	Straw	
50 % RDP+ inoculation with consortium of *Penicillium bilaji* x 10^3	2523	3340	11.53
50 % RDP + inoculation with consortium of *Penicillium bilaji* x 10^4	2716	3633	12.00
50 % RDP+ inoculation with consortium of *Penicillium bilaji* x 10^5	2521	3303	11.57
100 % RDP+ inoculation with consortium of *Penicillium bilaji* x 10^3	2734	3691	11.97
100% RDP + inoculation with consortium of *Penicillium bilaji* x 10^4	2919	38.74	12.20
100% RDP+ inoculation with consortium of *Penicillium bilaji* x 10^5	2770	3707	11.70
Un-inoculated seed and 50 % RDP	2415	3260	11.30
Un-inoculated and 100 % RDP	2541	3434	11.67
Mean	2642	3530	11.74
SEm (±)	98	118	0.35
C D (P = 0.05)	**298**	**359**	**NS**

soybean crop and more fixation of P in soil ultimately affected yield as compared to P with PSF. The application of single super phosphate was applied alone without PSF, the phosphorus become unavailable to plant at later growth stages of soybean. The PSF inoculation or phosphorus application alone did not improve grain yield of maize over control (Patil *et al*., 2012).

Effect of PSF *Penicillium bilaji* and phosphorus on soil properties and available nutrient status after harvest of soybean

Seed treatment with PSF and different levels of phosphorus showed a significant effect on available nitrogen, phosphorus and potassium contents of soil (Table 2). The non-significant effect noticed in soil pH and EC after harvest of soybean might be due to high buffering capacity of soil. The numerical reduction in pH of soil was noticed in treatment of application of 100 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^4 over rest of the treatments. This might due to the inorganic P is solubilized by the action of organic acid (low molecular weight) secreted by phosphate solubilising microorganisms in which hydroxyl and carboxyl groups of acids chelate cations (Ca, Al and Fe) and decrease the pH in basic soils (Kpomblekou and Tabatabai, 1994). The organic acids produced by phosphate solubilising microorganisms solubilize insoluble (inorganic) phosphates by lowering the pH, chelation of cations and competing with phosphate for adsorption sites in the soil (Nahas, 1996) and increased calcium P solubility.

The significantly highest available N, P and K after harvest of soybean were recorded in seed inoculation with PSF and 100 per cent RDP over rest of the treatments. The treatment 100 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^4 was at par with treatments 50 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^4, 100 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^3 and 100 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^5 for available N, 50 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^4 for available P and 100 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^3, 100 per cent RDP + inoculation with consortium of *Penicillium bilaji* x 10^5 for available K. It indicated that inoculation of *Penicillium bilaji* to seed alongwith single superphosphate increased the efficiency of single superphosphate. This might be due to mineralization and solubilization of inorganic fixed soil nutrients by organism (Gerretsen, 1948; Sundara Rao and Sinha, 1963). Mineralisation of soil organic-P to

Table 2. Effect of PSF and phosphorus levels on soil properties and available nutrient status after harvest of soybean

Treatment	Soil properties		Available nutrient status (kg/ha)		
	pH	EC (dS/m)	N	P	K
50 % RDP+ inoculation with consortium of *Penicillium bilaji* x 10^3	8.33	0.19	174	9.68	404
50 % RDP + inoculation with consortium of *Penicillium bilaji* x 10^4	8.31	0.20	187	12.63	434
50 % RDP+ inoculation with consortium of *Penicillium bilaji* x 10^5	8.39	0.19	178	10.24	441
100 % RDP+ inoculation with consortium of *Penicillium bilaji* x 10^3	8.30	0.22	181	11.76	448
100% RDP +inoculation with consortium of *Penicillium bilaji* x 10^4	8.26	0.21	200	15.20	487
100% RDP+ inoculation with consortium of *Penicillium bilaji* x 10^5	8.30	0.21	191	11.25	456
Un-inoculated seed and 50 % RDP	8.41	0.20	166	9.41	403
Un-inoculated and 100 % RDP	8.37	0.20	174	10.21	425
Mean	8.33	0.20	181	11.30	437
S.Em (±)	0.04	0.03	6.32	1.03	13.54
C D (P = 0.05)	**NS**	**NS**	**19.18**	**3.11**	**41.07**

inorganic P by phosphatase enzyme (Hilda and Fraga, 2000) and native inorganic P solubilization by microbes has been attributed to process involving acidification, chelation and exchange reactions in the growth environment (Sperber 1958, Molla and chowdhury, 1984). Wani *et al.* (1979) studied the effect of phosphate solubilising microorganism on availability of phosphorus in soil and found significant increase available P in the soil over control. Shukla and Namdeo (1981) reported that the maximum amount of residual available N and P in soil was left over the mung bean and residual available K by yellow soybean. With the increasing levels of applied phosphorus, the residual available P was increased. The lowest available N, P and K were recorded in without seed inoculation + 50 per cent RDP.

The results of present investigation suggests that seed inoculation with phosphate solubilising fungi consortium of *Penicillium bilaji* x 10^4 + 100 per cent RDP leads to highest 100 seed weight, seed and straw yields of soybean with increased contents of available N, P and K in soil.

REFERENCES

Anonymous. 2011. Indian council Agricultural Research, Data Book.

Anonymous. 2013. *United States Department of Agriculture, Foreign Agricultural Service Circular Series WAP 12-13 World Agricultural Production* : December 2013

Beever R E and Burns D J. 1981. Phosphorus uptake, storage and utilization by fungi. *Advances in Botanical Research* **8**: 127-219.

Dubey S K. 1997. Co-inoculation of phosphorus bacteria with *Bradyrhizobium japonicum* to increase phosphate availability to rainfed soybean in Vertisol. *Journal of Indian Society of Soil Science* **45**: 506-9.

Gerretsen F C. 1948. The influence of micro organisms on the phosphate uptake by the plant. *Plant and Soil* **1**: 51-81.

Gyaneshwar P, Kumar G N, Parekh L J and Poole P S. 2002. Role of soil microorganisms in improving P nutrition of plants. *Plant and Soil* **245**: 83-93.

Hilda R and Fraga R. 2000. Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotechnology Advances* **17**: 319-59.

Isherword K F. 1998. Fertilizer use and environment. *In*: N. Ahmed and A. Hamid (eds.), Proceedings of symposium on *Plant Nutrition Management for Sustainable Agricultural Growth*. NFDC, Islamabad, pp 57-76.

Jackson M L. 1973. *Soil Chemical Analysis*, Prentice Hall of India, Pvt (Ltd), New Delhi.

Kpomblekou K and Tabatabai M A. 1994. Effect of organic acids on release of phosphorous from phosphate rocks. *Soil Science* **158**: 442-53.

Molla M A and Chowdhury A A. 1984. Microbial mineralization or organic phosphate in soil. *Plant and Soil* **78**: 393-99.

Nahas E. 1999. Factors determining rock phosphate solubilization by micro-organisms. *World Journal of Microbiology and Biotechnology* **12**: 567-72.

Panse V G and Sukhatme P V. 1985. *Statistical Methods for Agricultural Workers*, ICAR, New Delhi.

Patil Praveen M, Kuligod V B, Hebsur N S, Patil C R and Kulkarni G N. 2012. Effect of phosphate solubilizing fungi and phosphorus levels on growth, yield and nutrient content in maize (*Zea mays*). *Karnataka Journal of Agricultural Sciences* **25**: 58-62.

Richardson A E. 2001. Prospect for using soil microorganisms to improve the acquisition of phosphorus by plants. *Australian Journal of Plant Physiology* **28**: 897-907.

Sacchidanand B, Sawarkar N J, Ghurayya R S, Shinde D A and Sinha S B. 1980. Response of soybean (*Glycine max*) to sulphur and phosphorus. *Journal of Indian Society of Soil Science* **28**: 189-92.

Sahrawat K L and Burdford J R. 1982. Modification of the alkaline permagnate method for assessing the availability of soil nitrgen in upland soils. *Soil Science* **133**: 53-7.

Shukla R and Namdeo K N. 1981. Performance of *kharif* pulses under different levels of phosphorus and residual nutrients in soil. *JNKVV Research Journal* **15**: 43-5.

Sperber J I. 1958.Solution of apatite by soil microorganisms producing organic acids. *Australian Journal of Agricultural Research* **9:** 778-81.

Sundara Rao W V B and Sinha M K. 1963. Phosphate dissolving micro-organisms in the soil and rhizosphere. *Indian Journal of Agricultural Sciences* **33**: 272-8.

Tiwari V N, Lehri L K and Pathak A H. 1989. Effect of inoculating crop with phosphomicrobes. *Experimental Agriculture* **25**: 47-50.

Wani P V, More B B and Patil P L. 1979. Physiological studies on the activity of phosphate solubilizing microorganisms. *Indian Journal of Microbiology* **19**: 23-5.

Watanbe F C and Olsen S R. 1965. Test of ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. *Proceedings of Soil Science Society of America* **29**: 677-8.

Soybean Research (Special Issue Number 2): 126-135: 2014

Influence of Integrated Nutrient Management Practices on Yield Attributes, Yield and Quality Parameters of Soybean [*Glycine max* (L.) Merrill} under Pigeonpea [*Cajanus cajan* (L.)] based Intercropping System

M SENTHIVELU[1], P SUBBIAN[2] and A C SURYA PRABHA[3]
Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam 641 301 and FLUCC Division, Institute of Forest Genetics & Tree Breeding, Coimbatore 641 002, Tamil Nadu, India
E mail: senthivelu.m@gmail.com

ABSTRACT

Field experiments were conducted at Department of Pulses, Tamil Nadu Agricultural University, Coimbatore during kharif *2006 and 2007 to study the influence of integrated nutrient management practices on yield attributes, yield and quality parameters of soybean in soybean + pigeonpea intercropping system at 2:1 row ratio as replacement series under irrigated condition. The experiments were laid out in factorial randomized block design with three replications. Three levels of inorganic fertilizer application to base crop of soybean* viz., *50, 75 and 100 per cent recommended dose of fertilizer were assigned as factor I and two levels and combinations of farmyard manure (0 and 5 t/ha) and zinc (0 and 5 kg/ha) were assigned as factor II, and a total of twelve treatments were implemented in intercropping system. In addition sole crop of both soybean and pigeonpea with recommended dose of fertilizer (RDF) were raised as control. In intercropping system, application of 100 per cent RDF (20:80:40 kg $NP_2O_5K_2O$/ha) to soybean registered the higher number of pods per plant (71.48 and 61.76), pod setting percentage (83.67 and 80.70), number of seeds per pod (3.24 and 3.17), test weight (12.33 and 12.05 g), seed yield (1,298 and1,284 kg/ha), protein yield (489 and 475 kg/ha) and oil yield (271 and 269 kg/ha) in soybean thanapplication of 75 and 50 per cent RDF during 2006 and 2007, respectively. Combined application of FYM @ 5 t per ha + zinc @ 5 per ha to intercropping system also improved the number of pods per plant (70.38 and 62.00), pod setting percentage (82.79 and 79.78), number of seeds per pod (3.09 and 3.04), test weight (11.88 and 11.65 g), seed yield (1,240 and 1,229 kg/ha), protein yield (462 and 450 kg/ha) and oil yield (256 and 254 kg/ha) during 2006 and 2007, respectively than no organic and micronutrient application and application of zinc alone @ 5 kg per ha. Among the levels of inorganic fertilizer, FYM and zinc, no significant interaction were observed in yield attributes, yield and quality parameters of soybean.*

Key words: Intercropping system, integrated nutrient management, quality parameters, yield, yield attributes

Pulses are important crops in terms of the daily diet, it provides both protein and fat in human nutrition for majority of the population in South Asia generally and in India specifically and also in terms of their contribution to farmers income and to the national economy. Proteins are essential for human health and better living and hence

[1]*Assistant Professor;* [2]*Ex-Professor (Agronomy);* [3]*Scientist C*

pulses consumption is very important in human daily diet. Pulses in India have long been considered as poor man's major source of protein. In India, grain legumes contribute significant sources of nutrition and out of the total food consumption, 8.4 per cent calories, 14.6 per cent proteins and 18.6 per cent fats are from grain legumes. Pulses are grown on 22-23 million hectare of area with an annual production of 13.17 million tonnes. India accounts for 33 per cent of world area and 22 per cent of the world production of pulses (FAOSTAT, 2011). Projected pulses demand is 42.5 million tonnes by 2021 and 57.7 million tonnes by 2026. Due to the stagnant production, net availability of pulses cames down from 70.13 g per day per person in 1951 to 31 g per dayperperson in 2008 (Reddy, 2013).

Since 1966, pulse crops have been neglected with agricultural policy environment favouring spread of green revolution technology in few cereal crops like paddy and wheat at the cost of pulses and oilseeds for food security reason in many developing countries including India. This input intensive technology further widened already existing yield gap between major cereal and pulses. Due to prolonged neglect for several decades, yield levels of pulse crops are stagnant and increased only by 12.2 per cent from 1966 to 2009. Another important reason for decreased preference for pulses by farmers is continued high instability in yield (16.5 %) of pulse crops (Reddy, 2013). In addition, pulse crops are shifted to marginalised lands with no/little inputs and cultivated as mixed crop/catch crop between cereal crops and consequently low yields. Though pulse crops are being raised under marginal lands with low input and poor management practices leading to low productivity level, there is no significant technological breakthrough until now, due to peculiar problems like indeterminate plant type, low response to fertilizers and irrigation (Gangwar and Prasad, 2005). Therefore, the need for introducing new and advanced technologies for increasing and sustaining the yields in irrigated and rainfed areas can hardly be over emphasized.

Intercropping of pulse crop is one such method which offers great scope for pulses productivity and system sustainability besides significant soil fertility improvement through its nitrogen fixation ability and there by sustenance of soil productivity. The legume based inter cropping system are also environmentally sustainable and increase the productivity and profitability of cropping system by increasing the yield of component crops without jeopardizing the natural resource base and environment (Reddy and Reddy, 2010). Intercropping system not only helps to solve the problem of pulses production but also helps to bring additional income to farmers and to get higher benefits with lower cost of cultivation and helps to utilize natural resource base and environment on time and space dimension very efficiently and numerically land use efficiency can be maximized.

Intensive cropping system which promotes productivity per unit area per unit input is well recognized to meet out the growing demands of ever increasing population. Pulses are receiving more attention owing to higher price due to increased demand. Inclusion of these crops in cropping system was found more beneficial than cereal crops alone. A pulse based intensive cropping system which is not only highly productive and profitable but also stable over times and maintains soil fertility is of great importance in present condition (Gangwar and Prasad, 2005; Sarawgi *et al*., 2012). Monetary benefits based intensive cropping systems are exhaustive feeders of plant nutrients and lead to depletion of soil fertility when a balanced and adequate replenishment of nutrients are continuously ignored. However, there is a need to maintain soil productivity and there by sustainability. Under these circumstances, integrated nutrient management is a viable option in intensive agriculture to preserve, promote and sustain soil health and productivity. Balanced nutrition is indispensable for achieving higher productivity under intensive intercropping system. At the same time, increasing nutrient demand, escalating price of industrial inorganic fertilizers and their possible degradation of cultivable soil health and hazardous to environment, warrant the need for judicious use of chemical fertilizers With this background, the present field investigation was conducted to study the influence of integrated nutrient management practices on yield attributes, yield and quality parameters of soybean+ pigeonpea intercropping system under integrated nutrient management practices.

MATERIAL AND METHODS

Field experiments under irrigated condition were conducted to study the productivity and efficiency of soybean + pigeonpea intercropping system at 2:1 row ratio as replacement series under integrated nutrient management practices during *kharif* 2006 and *kharif* 2007 at experimental farm of Department of Pulses, Tamil Nadu Agricultural University, Coimbatore situated in Southern India at 11^o N latitude and 77^o E longitude with an altitude of 426.72 m above mean sea level. The experimental farm extends over an area of 78.4 ha with Alfisol (red soil) as major soil type and the experimental area falls under Southern agro-climatic zone of India and Western agro-climatic zone of Tamil Nadu, respectively. The mean annual rainfall of TNAU, Coimbatore is 670 mm in 40 rainy days distributed at 209.4 mm (31.25 %) and 305.4 mm (45.58 %), respectively during south-west monsoon period (June- September) and north-east monsoon (October-December). The mean maximum and minimum temperature are 32.12 ^{o}C and 21.51 ^{o}C, respectively. The relative humidity ranges from 61 to 91 per cent during forenoon and 14 to 68 per cent during afternoon. Wind velocity is 5.8 km per h, the mean daily sunshine is 7.4 h per day with mean solar radiation of 400 Cal. cm^{-2} day^{-1} and pan evaporation of 5.4 mm per day. The soil of experimental field was sandy loam type (15.0 % coarse sand, 30.5 % fine sand, 35.8 % silt and 18.7 % clay) in texture and classified as Typic Ustivertept belonging to Periya Nayakkan Palayam (P.N. Palayam) series and had 8.2 pH (1:2 soil : water), 0.46 dS per m EC, 0.34 per cent organic carbon (Chromic acid wet oxidation method), 254.0 kg per ha available nitrogen (by Alkaline permanganate method), 10.2 kg per ha available phosphorus (Olsen method) and 496.0 kg per ha of 1 N neutral ammonium-acetate-extractable potassium (by flame photometry) with bulk density of 1.48 Mg per m^3.

The experiments were laid out in factorial randomized block design with two treatment factors comprising of (i) inorganic fertilizer at three levels *viz.,* 50 per cent RDF, 75 per cent RDFand 100 per cent RDF (20:80:40 kg $NP_2O_5K_2O$/ha) to the base crop were assigned as factor I, and (ii) two levels and combinations of organic manure (FYM @ 0 and 5 t/ha) and micronutrient (zinc @ 0 and 5 kg/ha) were assigned as factor II and a total of twelve treatments were implemented in soybean + pigeonpea intercropping (2:1 replacement series) system. In addition, sole crop of both soybean with RDF (20:80:40 kg $NP_2O_5K_2O$/ha) and pigeonpea with RDF (25:

50: 00 kg $NP_2O_5K_2O$/ha) were raised as control and replicated thrice. In sole cropping system, chemically and biologically treated seeds of soybean and pigeonpea were sown at 30 cm x 10 cm and 60 cm x 30 cm spacing respectively, while in intercropping system, treated pigeonpea seeds were dibbled in appropriate lines (2:1 ratio of soybean and pigeonpea) adopting a row spacing of 60 cm and 30 cm between plant to plant within the lines. Soybean and pigeonpea were harvested in 95 days after sowing (DAS) and 140 DAS respectively, in both the years of field experimentation. The border rows in each plot were harvested first and then the plants in the net plots were harvested separately. Seeds were separated through manual threshing. The cleaned seeds were dried and the yield was recorded at 12 per cent moisture level. From these values, oil yield and protein yield were worked out for each treatment. After threshing the pod, the stalk left in the net plot area were sun dried for three days. The dry weight of stalk of each treatment was computed and expressed in kg per ha.

Protein yield

Seed samples of each treatment were analyzed for total nitrogen (N) by Microkjeldahl's method. Nitrogen content of the seeds was multiplied by the factor 5.71 (Alikhan and Youngs, 1973) to get crude protein content of seeds and expressed as per cent and the protein yield in pulse grains was calculated by the formula enumerated by Kushwaha and Chandel (1997) and was projected as kg per ha.

Protein yield = Seed yield (kg/ha) x Protein content (%)/100

Oil yield

Oil content of seed samples was estimated by using Oxford 4000 Nuclear Magnetic Resonance (NMR) spectra and expressed as per cent (Sadasivam and Manickam, 1996). Oil yield was calculated by multiplying the oil content in the seed with the corresponding seed yield and expressed as kg per ha.

The data on various characters studied in the experiment were statistically analyzed using the standard analysis of variance suggested by Gomez and Gomez (1984). The significance of the treatment effect was determined using the *f*-test. To determine the significance of the difference between the means of two treatments, least significance difference was computed at 5 per cent probability and values were furnished. The treatment differences that are non-significant were indicated as non-significant (NS).

RESULTS AND DISCUSSION

Yield attributes

Application of inorganic fertilizer, organic manure and micronutrient at different levels in intercropping system had significant effect on yield attributes of soybean (base crop) during both the years of experiment (Table 1).In intercropping system, application of inorganic fertilizer at 100 per cent RDF (20:80:40 kg $NP_2O_5K_2O$/ha) significantly registered higher pod setting percentage (83.67 and 80.70), seeds per pod (3.24 and 3.17) and test weight (12.33 and 12.05 g) during *kharif* 2006 and *kharif* 2007, respectively than application of 75 per cent RDF and 50 per cent RDF. However in terms of number of pods per plant, application of 100 per cent RDF (71.48 and 61.76) and 75 per cent RDF (67.79 and 57.84) recorded on par value in both years but significantly higher than 50 per cent RDF. Synthetic fertilizer application favourably affects cell-elongation, turgidity and promotes various physiological processes including the absorption of nutrients leading to improvement in plant growth and ultimately better development of yield attributes of soybean (Menaria and Singh, 2004; Sarawgi *et al*., 2012). Higher level inorganic fertilizer application also improves the availability of nutrients, nutrient uptake and nutrient use efficiency throughout the cropping period which might be enhanced the translocation of photosynthates from source to sink and thereby yield attributes.

In intercropping system, combined application of farmyard manure @ 5 t per ha and zinc @ 5kg per ha recorded significantly higher number of pods per plant (70.38 and 62.00), pod setting percentage (82.79 and 79.78), seeds per pod (3.09 and 3.04) and test weight (11.88 and 11.65 g) during *kharif* 2006 and *kharif* 2007 respectively than application of zinc alone and control. However, it was on par with the application of farmyard manure alone @ 5 t per ha, which recorded 67.98 and 59.36 number of pods per plant, 81.59 and 78.16 per cent pod setting, 3.09 and 3.02 number of seeds per pod and 11.80 and 11.59 g of test weight in *kharif* 2006 and *kharif* 2007, respectively. This might be due to the application of organic manure either alone or along with inorganic fertilizer which enhanced the organic carbon and other plant nutrients availability through mineralization process and consequently it increased growth attributes and yield determinants of soybean (Singh et al., 2003; Thakur *et al*., 2011). Balanced nutrition by way of symbiotically fixed nitrogen together with phosphorus, potassium and other trace elements provided by farmyard manure could have improved the photosynthetic rate of soybean and thereby facilitates better source-sink relationship and higher level of yield attributes. Cropping systems, inorganic fertilizer, farmyard manure and zinc application had significant influence on number of seeds per pod and test weight of soybean seeds, whereas no significant differences were observed in number of pods per plant and seed setting percentage. Among the cropping systems, sole soybean with RDF (20:80:40 kg $NP_2O_5K_2O$/ha) recorded 3.28 and 3.22 number of seeds per pod and 12.56 and 12.47 g of test weight during *kharif* 2006 and *kharif* 2007 respectively which were significantly higher than intercropping system with integrated nutrient management practices. This was mainly due to higher availability of space, light and nutrients for growth and development and there was no competitive influence from adjacent plants within and between rows throughout crop growing period. In general, sole cropping system with required quantum of nutrients have ample opportunity for better crop growth and development and in turn production of maximum yield attributes. Similar findings were reported by Wanjari *et al*. (2005) and Ghosh *et al*. (2006).

Seed and straw yield

Seed and straw yield of soybean were significantly influenced by cropping systems as well as integrated nutrient management practices (Table 2). In intercropping system application of 100 per cent RDF (20:80:40 kg $NP_2O_5K_2O$/ha) produced significantly higher seed yield of 1,298 and 1,284 kg per ha than 75 per cent and 50 per cent RDF in *kharif* 2006 and *kharif* 2007, however it recorded on par straw yield (2,080 and 2,046 kg/ha) with 75 per cent RDF (1,960 and 1,975 kg per ha) which was significantly higher than 50 per cent RDF. The increase in seed and straw yield are due to the fact that, higher levels of inorganic fertilizer showed the optimum values of various physiological determinants of growth attributes, which leads to realization of maximum level of yield attributes and yield

Table 1. Effect of integrated nutrient management practices on yield attributes of soybean under soybean + pigeonpea intercropping system

Treatments	Pods (No/plant)		Pod setting (%)		Seeds (No/pod)		Test weight (g)	
	Kharif 2006	*Kharif* 2007	*Kharif* 2006	*Kharif* 2007	*Kharif* 2006	*Kharif* 2007	*Kharif* 2006	*Kharif* 2007
Factor I-NPK levels of the base crop								
50 % RDF (10:40:20 kg $NP_2O_5K_2O$/ha)	56.46	51.79	75.15	72.90	2.69	2.60	10.94	10.74
75 % RDF (15:60:30 kg $NP_2O_5K_2O$/ha)	67.79	57.84	79.75	76.26	2.94	2.88	11.43	11.22
100 % RDF (20:80:40 kg $NP_2O_5K_2O$/ha	71.48	61.76	83.67	80.70	3.24	3.17	12.33	12.05
SEd (±)	1.97	1.91	1.34	1.29	0.09	0.10	0.20	0.19
C D (P = 0.05)	**4.07**	**3.93**	**2.76**	**2.66**	**0.19**	**0.20**	**0.41**	**0.40**
Factor II - FYM and Zinc levels								
Control	60.26	52.62	76.38	73.82	2.81	2.73	11.24	11.03
FYM @ 5 t/ha	67.98	59.36	81.59	78.16	3.09	3.02	11.80	11.59
Zinc @ 5 kg/ha	62.36	54.55	77.34	74.72	2.83	2.74	11.33	11.09
FYM @ 5 t/ha + zinc @ 5 kg/ha	70.38	62.00	82.79	79.78	3.09	3.04	11.88	11.65
SEd (±)	2.27	2.20	1.55	1.49	0.10	0.11	0.23	0.22
C D (P = 0.05)	**4.67**	**4.54**	**3.19**	**3.07**	**0.22**	**0.24**	**0.47**	**0.46**
Cropping Systems								
Soybean + pigeonpea (2:1 ratio)	65.24	57.13	79.53	76.62	2.96	2.88	11.57	11.34
Soybean (Sole crop)	60.56	52.44	78.56	75.50	3.28	3.22	12.56	12.47
SEd (±)	2.90	2.81	1.97	1.90	0.13	0.15	0.29	0.28
C D (P = 0.05)	**NS**	**NS**	**NS**	**NS**	**0.28**	**0.30**	**0.60**	**0.59**

of soybean (Chaturvedi and Chandel, 2005; Thakur *et al*., 2011). Major nutrients are essential for soybean production which promote growth and development, assimilate production, translocation and its efficient portioning to biological and economical traits.

Application of farmyard manure @ 5 t per ha either alone or in combination with zinc @ 5 kg per ha in intercropping system had also significantly increased seed yield of soybean but no effect on straw yield. Integrated application of FYM and zinc recorded 10.22 per cent, 11.22 per cent, 9.35 per cent and 10.62 per cent higher seed yield than control and application of zinc alone in *kharif* 2006 and *kharif 2007*, respectively. This could be attributed to improvement in yield attributes through adequate availability nutrients which in turn favourably influenced the number of physiological and biochemical process and build up of food materials in the form of economic yield (Padmavathi *et al*., 2003; Khutate *et al*., 2005). The supplementary and complementary use of organic manures and inorganic fertilizers augment the efficiency of both the substances to sustain soil productivity which attributed continuous supply of nutrients along with favourable environment for higher nutrient absorption which resulted better plant growth, superior yield attributes and higher yield of soybean.

Sole cropping system with 100 per cent RDF (20:80:40 kg $NP_2O_5K_2O$/ha) registered 33.61 per cent, 34.10 per cent, 30.16 per cent and 31.02 per cent higher seed yield and straw yield during *kharif* 2006 and *kharif* 2007 respectively than intercropping system with integrated nutrient management practices. Higher dry matter production, nutrient uptake and ultimately higher seed yield of soybean in the present investigation was due to normal planting with 100 per cent population than intercropped soybean. Higher availability of natural resources and less competitive effect within and between rows favoured higher grain yield (Jat and Ahlawat, 2003). This is due to significant and progressive effect of higher levels of inorganic fertilization which improved the symbiotic nitrogen fixation of legumes and current transfer of nitrogen to the associated plants and simultaneously increased concentration of available nutrients in soil and ultimately influenced the formation of root nodules, vigorous root development, better nitrogen fixation and overall development of plant. These ultimately resulted in maximum yield attributing characters and thereby higher yield of soybean.

Protein and oil yield

Protein and oil yield of soybean under pure and intercropping system was significantly improved by different levels of inorganic fertilizer, farmyard manure and zinc (Table 2). In intercropping system, application of inorganic fertilizer @ 100 per cent RDF level significantly registered higher protein yield of 489 and 475 kg per ha and oil yield of 271 and 269 kg per ha in *kharif* 2006 and *kharif* 2007 respectively than 75 per cent and 50 per cent RDF level. The response to inorganic fertilizer application in improving the seed quality should be attributed to its significant role in regulating photosynthesis and better physio-bio-chemical activities. In addition, nitrogen is the important element in the synthesis of protein. Phosphorus along with other nutrients like sulphur, are very essential for energy transformation process and it might have increased the conversion of phosphorylated plant constituents into fatty acids and ultimately the oil content and oil yield of soybean (Majumdar *et al*., 2001; Singh *et al*., 2003).

Table 2. Soybean yield and quality parameters influenced by integrated nutrient management practices under soybean+pigeonpea intercropping system

Treatments	Seed yield (kg/ha)		Straw yield (kg/ha)		Protein yield (kg/ha)		Oil yield (kg/ha)	
	Kharif 2006	*Kharif* 2007	*Kharif* 2006	*Kharif* 2007	*Kharif* 2006	*Kharif* 2007	*Kharif* 2006	*Kharif* 2007
Factor I-NPK levels of the base crop								
50 % RDF (10:40:20 kg $NP_2O_5K_2O$/ha)	1077	1053	1859	1850	375	359	212	206
75 % RDF (15:60:30 kg $NP_2O_5K_2O$/ha)	1177	1165	1960	1975	429	415	235	234
100 % RDF (20:80:40 kg $NP_2O_5K_2O$/ha	1298	1284	2080	2046	489	475	271	269
SEd (±)	37	42	62	71	14	15	8	8
CD (P = 0.05)	**77**	**86**	**127**	**146**	**28**	**31**	**16**	**17**
Factor II - FYM and Zinc levels								
Control	1125	1105	1922	1905	398	383	216	213
FYM @ 5 t/ha	1238	1223	2013	2013	460	446	253	250
Zinc @ 5 kg/ha	1134	1111	1925	1904	403	386	233	228
FYM @ 5 t/ha + zinc @ 5 kg/ha	1240	1229	2004	2006	462	450	256	254
SEd (±)	43	48	71	82	16	17	9	10
C D (P = 0.05)	**89**	**99**	**NS**	**NS**	**32**	**35**	**18**	**20**
Cropping Systems								
Soybean + pigeonpea (2:1 ratio)	1184	1167	1966	1957	431	416	239	236
Soybean (Sole crop)	1582	1565	2559	2564	581	570	317	313
SEd (±)	55	61	91	104	20	22	11	12
C D (P = 0.05)	**113**	**127**	**187**	**215**	**41**	**45**	**23**	**25**

Integrated application of farmyard manure (5 t/ha) + zinc (5 kg/ha) or farmyard manure alone (5 t/ha) to intercropped soybean also registered higher protein yield and oil yield in both the years. Combined use of organic manures and inorganic fertilizers helped in maintaining nutrient stability by correcting the marginal deficiencies of primary and secondary nutrients throughout cropping period resulting in increased supply and uptake of nitrogen by crop plants under direct effect or organic sources and fertilizer at higher dose which ultimately was converted into higher amounts of amino acids consequently higher protein and oil content in soybean and protein and oil yield (Wandile *et al.*, 2005).

Among the cropping system, sole soybean with 100 per cent recommended inorganic fertilizer (20:80:40 kg $NP_2O_5K_2O$/ha) application recorded 34.75 per cent, 36.84 per cent, 32.64 per cent and 32.63 per cent higher protein yield and oil yield during *kharif* 2006 and *kharif* 2007 respectively than intercropping system with integrated nutrient management practices. Maintaining higher levels of population in pure cropping system with competition free environment for natural resources utilization facilitated higher yield attributes, grain yield, oil and protein content and consequently higher oil and protein yield of soybean (Singh *et al.*, 2003; Wandile *et al.*, 2005). Application of higher levels of inorganic fertilizers enhanced the availability of nutrients in the soil and nutrient uptake by soybean crop; it consequently improved the metabolic activity essential for protein synthesis and carbohydrate metabolism and in turn it increased the protein and oil yield.

The results of the present investigation suggested that sole cropping system with 100 per cent RDF (20:80:40 kg $NP_2O_5K_2O$/ha) recorded higher yield attributes, yield and quality parameters than soybean+pigeonpea intercropping system at 2:1 row ratio as replacement series under integrated nutrient management practices. Intensive intercropping systems are well recognized to meet out the growing demands of ever growing population. Inclusion of pulse crops in intercropping/sequential cropping was found more beneficial than sole cropping. In intercropping system, adoption of integrated nutrient management practices, which comprising of 100 per cent RDF and FYM @ 5 t per ha+ zinc @ 5 kg per ha can be successfully practiced than application of either 100% RDF alone or farmyard manure @ 5 t per haalone. The effects of organic and inorganic fertilizers are complementary to each other in terms of soil fertility improvement and sustainable agriculture. Therefore it is necessary to make their judicious use in right proportion for harvesting better yield component crops in cropping system and for sustaining soil fertility.

REFERENCES

Alikhan S T and Youngs C G. 1973. Variation in protein content of field peas. *Canadian Journal of Plant Science* **53**: 36-7.

Chaturvedi S and Chandel A S. 2005. Influence of organic and inorganic fertilization on soil fertility and productivity of soybean (*Glycine max*). *Indian Journal of Agronomy* **50**: 311-3.

FAOSTAT. 2011. Statistical Data Base of Food and Agriculture Organisation.

Gangwar B and Prasad K. 2005. Cropping system management for mitigation of second-generation problems in agriculture. *Indian Journal of Agricultural Sciences* **75**: 65-78.

Ghosh P K, M Mohanty, K Bandyopadhyay, D K Painuli and Misra A K. 2006. Effect of nutrient management on growth, competition, yield advantage and economics in soybean/pigeonpea inter-cropping system in semi-arid tropics of India. *Field Crops Research* **96**: 90-7

.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*, 2nd edn. John Wiley and Sons, New York, pp 680.

Jat H S and Ahlawat I P S. 2003. Response of pigeonpea (*Cajanus cajan*) + groundnut (*Arachis hypogaea*) intercropping system to planting pattern and phosphorus management. *Indian Journal of Agronomy* **48**: 156-9.

Khutate N G, S N Mendhe, K P Dongarkar, N N Gudadhe and Gavande V H. 2005. Effect of nutrient management treatments on growth and yield of soybean.*Journal of Soil and Crops* **15**: 155-9.

Kushwaha H S and Chandel A S. 1997. Effect of nitrogen on yield, yield attributes and quality of soybean (*Glycine max*) intercropped with cereals in foot-hills of Uttar Pradesh. *Indian Journal of Agronomy* **42**: 409-13.

Majumdar B., M S Venkatesh, B Lal and Kumar K. 2001. Response of soybean (*Glycine max*) to phosphorus and sulphur in acid Alfisol of Meghalaya. *Indian Journal of Agronomy* **46:** 500-5.

Menaria B L and Singh P. 2004. Effect of chemical and bio fertilizers on yield attributing characters and yield of soybean (*Glycine max* (L.) Merrill). *Legume Research* **27**: 231-2.

Padmavathi P, S P Wani and Virmani S M. 2003. Grain yield of soybean and pigeonpea based intercropping systems in vertisols with integrated nutrient management options. *Journal of Oilseeds Research* **20**: 239-43.

Reddy A A and Reddy G P. 2010. Supply side constrains in production of pulses in India: A case study of lentil. *Agricultural Economics Research Review* **23**: 129-36.

Reddy A A. 2013. Strategies for reducing mismatch between demand and supply of grain legumes. *Indian Journal of Agricultural Sciences* **83**: 243-59.

Sadasivam, S and Manickam A. 1996. Biochemical methods. II Edition. New Age International Publishers and TNAU

Sarawgi S K, S Chitale, A Tiwari and Bhoi S. 2012. Effect of phosphorus application along with PSB, Rhizobium and VAM on P fractionation and productivity of soybean (*Glycine max*). *Indian Journal of Agronomy* **51**: 55-60.

Singh A B, P K Ghosh and Ajay. 2003. Effect of integrated nutrient management practices on improvement in grain quality of soybean, sorghum and wheat in multiple cropping systems in vertisol. *Indian Journal of Agricultural Science* **73**: 65-8.

Thakur R, S D Sawarkar, U K Vaishya and Singh M. 2011. Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a vertisol. *Journal of Indian Society of Soil Science* **52**: 74-81.

Wandile R M, M M Raut, S V Washimkar and Bhaisare B S. 2005. Residual effect of long term application of N, P, Zn and FYM on soil properties of vertisols, yield, protein and oil content of soybean (*Glycine max* (L.) Merrill). *Journal of Soil and Crops* **15**: 155-9.

Wanjari S S, J P Deshmukh and Dandge M S. 2005. Intercropping of soybean with sorghum. *Agricultural Science Digest* **25**: 269-70.

Soybean Research (Special Issue Number 2): 136-141: 2014

Performance of Soybean-Sunflower Cropping System under Varied Nutrient Management Practices in Vertisols

G SURESH[1], S N SUDHAKARA BABU[2] and A AZIZ QURESHI[3],
Directorate of Oilseeds Research, Indian Council of Agricultural Research, Rajendranagar, Hyderabad 500 030, Telangana, India
E mail: sureshdor@gmail.com

ABSTRACT

A field experiment was conducted for consecutive three years (2009-10 to 2011-12) with soybean (JS 335) during kharif *and sunflower (KBSH 1 hybrid) during* rabi *on fixed plots in Vertisols under semi-arid conditions at Hyderabad. The pooled analysis of results indicated that fertilization with recommended dose (20:80:20 kg :: N:P_2O_5:K_2O/ha) to rainy season soybean and balanced fertilization of recommended NPK + 20 kg sulphur to succeeding winter sunflower recorded highest soybean seed yield (2,260 kg/ha). Seed index and oil concentration of soybean did not differ significantly. Performance and seed yield of winter sunflower varied significantly due to different nutrient management practices. Application of recommended dose of fertilizers to soybean (20:80:20::N:P_2O_5:K_2O) and sunflower (60:60:30:: N:P_2O_5:K_2O) involving single super phosphate as source of P resulted in the highest seed yield (1,763 kg/ha) of sunflower. This was followed by and at par with application of recommended dose to soybean and balanced fertilization of NPK + 20 kg sulphur to succeeding sunflower (1,761 kg/ha). Similar trend was noticed in soybean equivalent seed yield. No fertilization to either crops or imbalanced fertilization with only N or reduced fertilization by 50 per cent resulted in significantly lower yield. Similar trend was followed in stalk yield and seed index of sunflower. The oil concentration did not vary significantly due to different nutrient management practices for both the crops.*

Key words: Cropping sequence, nutrient management, oil concentration, soybean, sunflower

India holds premier position in the world in terms of rich diversity of oilseed crops and also in area under oilseed crops. Oilseed crops offer great potential for increasing cropping intensity and profitability in wide ranging cropping systems. Oilseed based crop sequences help in better utilizing the residual fertility and provide safe crop rotations. Together, the system productivity and profitability can be increased under variable fertilizer management (Reddy and Sudhakara Babu, 1996). Dynamic cropping systems take advantage of crop sequencing and synergism (Tanaka *et al.,* 2005). To optimize the benefits of cropping systems on crop parameters, it is important to understand the effects of previous crops on current crop production. Soybean is predominantly grown as a rainfed crop in Vertisols with an average crop season rainfall of 600 to 1000 mm. Introduction of soybean in these areas has led to a shift in cropping system and has enhanced the cropping intensity leading to higher cropping system efficiency and profitability. Under semi-arid agro-ecosystem, a large number of systems were found promising (Hedge, 2007), among which soybean-sunflower is one of the

[1and2]*Principal Scientist;* [3]*Senior Scientist*

important oilseed based cropping sequences in Vertisols of Maharashtra and Andhra Pradesh. Declining soil fertility, inadequate and imbalanced nutrition are the key reasons for low productivity and low yield of oilseed crops and cropping systems. The experiment was conducted to assess the requirement of major, secondary, micronutrients and organic source of nutrients in different combinations on to achieve sustainable productivity in soybean (*kharif*) sunflower (*rabi*) sequence in Vertisols on system basis.

MATERIAL AND METHODS

The trial was conducted during 2009-12 with soybean (JS 335) during *kharif* and sunflower (DRSH 1) during *rabi* under fixed plots of nutrient management. Soybean crop was raised on broad bed and furrows. Twelve treatment combinations on cropping systems basis (Table 1 and 2) consisted of application of 100 per cent recommended dose of fertilizers with two sources of P supply, *i.e.* through di-ammonium phosphate (NP) and single super phosphate (PS), inorganic fertilizers substituted with 5 t FYM per ha and sunflower crop residue incorporation to soybean. Similarly, for sunflower during *rabi*, in addition to the above treatments application of N only, NP only, application of sulphur (S) and zinc @ 5 kg per ha, 50 per cent of the recommended inorganic fertilizer substituted with 5 t FYM per ha or seed treatment with *Azospirillum* and soybean crop residue incorporation were imposed. The recommended dose of fertilization was @ 20:80:20 and 60:60:30 kg :: $N:P_2O_5:K_2O$ per ha to soybean and sunflower crops, respectively. The soil of experimental site was clay with a soil pH, organic carbon, available nitrogen, available phosphorus and potassium of 8.1, 0.44 per cent, 215 kg per ha, 9.9 kg per ha and 739 kg per ha, respectively. Nutrient management practices were evaluated on cropping system basis in a randomized block design with three replications in Vertisols. Soybean crop was raised as rainfed whereas sunflower crop was irrigated once immediately after sowing. The morphological characters of both the crops, seed yield, stalk yield and oil concentration (%) was recorded by using standard procedures. The soybean seed equivalent yield and system economic returns were derived.

RESULTS AND DISCUSSION

Performance of soybean

Pooled mean of soybean in soybean-sunflower cropping system (2010-12) in Vertisols recorded significantly higher seed yield (2,260 kg/ha) with recommended dose of fertilizer and succeeding winter sunflower fertilized with recommended dose of fertilizer + S @ 20 kg per ha and was on par with recommended NPK to both the crops with application of SSP as source of P (Table 1). Significantly lowest soybean seed yield (1,752 kg/ha) was recorded in no manure/fertilizer treatment. Application of sunflower crop residues did not show any adverse effect on soybean crop and recorded yield level of 2,171 kg per ha. Plant height differed significantly due to different nutrient management practices. Seed index (g/100 seeds) and oil concentration did not differ significantly due to nutrient management practices. Numerically the highest oil concentration (23 %) and oil yield (520 kg/ha) of soybean was recorded with recommended dose of fertilizer and succeeding *rabi* sunflower fertilized with RDF + S @ 20 kg per ha.

Table 1. Performance of soybean as influenced by different nutrient management practices in soybean - sunflower cropping system (Pooled mean over 2010 and 2011)

Treatment		Plant height (cm)	Pods (No/ plant)	Seed yield (kg/ha)	Seed index (g/100 seeds)	Oil content (%)	Oil yield (kg/ha)
Soybean (k*harif*)	**Sunflower (*Rabi*)**						
Control	Control	27.7	40.9	1752	11.8	20.9	366
Control	NPK	27.1	42.1	1768	11.3	21.7	384
FYM @ 5 t/ha	NPK	35.8	46.9	1902	12.7	21.5	409
NPK	N	34.5	44.3	1928	12.4	21.9	422
NPK	NP	35.0	53.9	2092	12.7	22.0	460
NPK	NPK	33.8	48.3	2235	12.8	22.9	512
NPK (P through SSP)	NPK (P through SSP)	38.1	53.8	2206	12.7	21.6	476
NPK	NPK + S @ 20 kg/ha	39.2	56.8	2260	12.9	23.0	520
NPK	NPK + Zn @ 5 kg/ha	37.1	53.6	2192	13.1	21.9	480
NPK	50 % NPK + 5 t FYM/ha	38.3	52.3	2129	12.9	21.8	464
NPK + Sunflower crop residue	NPK + Soybean crop residue	36.8	51.9	2171	12.7	21.7	471
NPK	50 % NPK + *Azospirillum* seed treatment +PSB	37.6	50.9	2107	12.2	22.1	466
SEm (±)		2.9	4.2	108	0.465	0.423	-
CD (P=0.05)		**8.7**	**NS**	**321**	**NS**	**NS**	**-**

Table 2. Performance of sunflower as influenced by different nutrient management practices in soybean - sunflower cropping system (Pooled mean over 2009-10; 2010-11 and 2011-12)

Treatment		Plant height (cm)	Head diameter (cm)	Girth (cm)	Seed yield (kg/ha)	Stalk yield (kg/ha)	1000 seed weight	Oil content (%)	Oil yield (kg/ha)
Soybean (*Kharif*)	Sunflower (*Rabi*)								
Control	Control	142	10.4	5.4	647	1218	40.3	40.0	259
Control	NPK	170	13.0	6.6	1295	1744	47.7	40.6	526
FYM @ 5 t/ha	NPK	179	13.4	6.7	1459	1762	52.4	40.5	591
NPK	N	170	12.1	6.2	1256	1450	44.8	40.3	506
NPK	NP	180	13.0	6.6	1506	1706	51.4	40.3	607
NPK	NPK	185	13.6	7.1	1560	2068	52.4	40.5	631
NPK (P through SSP)	NPK (P through SSP)	192	14.3	7.1	1763	1940	54.3	40.4	711
NPK	NPK + S @ 20 kg/ha	191	14.5	7.0	1761	2047	53.1	40.6	715
NPK	NPK + Zn @ 5 kg/ha	184	14.2	7.0	1663	1961	53.1	40.7	677
NPK	50 % NPK + 5 t @ FYM/ha	179	13.4	6.9	1524	1744	49.1	40.7	620
NPK + Sunflower crop residue	NPK + Soybean crop residue	185	13.4	6.9	1541	2104	50.2	40.8	629
NPK	50 % NPK + *Azospirillum* seed treatment +PSB	179	14.0	6.6	1488	1742	48.0	40.7	606
SEm (±)		4.4	0.6	0.4	86	124	2.4	0.294	-
CD (P=0.05)		**12.9**	**1.5**	**NS**	**249**	**349**	**5.0**	**NS**	**-**

Table 3. Performance of component crops and economic returns of nutrient management in soybean- sunflower cropping sequence

Treatment		Seed yield (kg/ha)				Returns (Rs/ha)		B:C ratio
Soybean (*kharif*)	Sunflower (*rabi*)	Soybean	Sun-flower	SEY	System economic yield	Gross	Net	
Control	Control	1752	647	935	2687	60458	38808	2.79
Control	NPK	1768	1295	1871	3639	81878	56006	3.16
FYM @ 5 t/ha	NPK	1902	1459	2107	4009	90203	61881	3.18
NPK	N	1928	1256	1814	3742	84195	57573	3.16
NPK	NP	2092	1506	2175	4267	96008	67258	3.34
NPK	NPK	2235	1560	2253	4488	100980	71630	3.44
NPK (P through SSP)	NPK (P through SSP)	2206	1763	2547	4753	106943	76161	3.47
NPK	NPK + S @ 20 kg/ha	2260	1761	2544	4804	108090	78240	3.62
NPK	NPK + Zn @ 5 kg/ha	2192	1663	2402	4594	103365	73815	3.50
NPK	50 % NPK + 5 t FYM/ha	2129	1524	2201	4330	97425	68509	3.37
NPK + Sunflower crop residue	NPK + Soybean crop residue	2171	1541	2226	4397	98933	69583	3.37
NPK	50 % NPK + *Azospirillum* seed treatment +PSB	2107	1488	2149	4256	95760	68102	3.46

Average price of soybean Rs 22.50/kg; Sunflower Rs 32.50/kg; SEY – Soybean equivalent yield

Similarly a multi-location trial conducted on diverse agro-climatic zones of the country indicated highest soybean yield recorded with 20 kg S per ha in north plain; 35 kg S per ha in north eastern and 30 kg S per ha in southern zone (Billore and Vyas, 2007).

Performance of sunflower

The pooled analysis of morphological characters *viz*., plant height, head diameter, stem girth, seed yield, stalk yield and seed index (g/1000 seeds) of *rabi* sunflower differed significantly due to nutrient management practices in soybean-sunflower cropping system (Table 2). The pooled seed yield of sunflower was significantly higher (1,763 kg/ha) with recommended NPK to both the crops with single super phosphate as source of P application. This was at par with recommended dose of fertilizers to soybean and sunflower fertilized with recommended dose of fertilizers + S @ 20 kg per ha (1,761 kg/ha) and RDF to soybean during rainy season followed by recommended dose of fertilizers + Zn to sunflower (1,663 kg/ha). Significantly lowest seed yield (647 kg/ha) was recorded in no manure/fertilizer treatment. No fertilization or application of only N to soybean with recommended dose of fertilizers to sunflower were similar and recorded lower seed yield in the range of 1,256-1,295 kg per ha. The stalk yield also followed a similar trend. The oil concentration of sunflower was not significantly influenced due to different nutrient management practices. The highest oil yield was noticed with the treatments involving recommended dose of fertilizers to both the crops + 20 kg S per ha to sunflower (715 kg/ha); with SSP as source of P to both the crops (711 kg/ha). Best Management practices involving appropriate fertilizer management in oilseed based cropping systems was discussed in detail by Sudhakar Babu and Hegde (2011) where in it is reported that application of sulphur @ 20-30 kg per ha positively influenced sunflower seed yield, oil yield and resulted in enhanced fertilizer use efficiency.

Application of recommended NPK to preceding crop of soybean followed by NPK to succeeding sunflower recorded significantly higher soybean equivalent seed yield (4,804 kg/ha) and highest system gross returns (Rs 1,08,090/ha), net returns (Rs 78,240) and BC ratio (3.62). No manuring or nutrient reduction or imbalance resulted in significantly lowest sunflower equivalent seed yields and economic returns (Table 3).

Based on results of study, it may be concluded that in soybean-sunflower cropping system fertilization with recommended dose (20:80:20 kg:: $N:P_2O_5:K_2O$/ha) to rainy season soybean and balanced fertilization of recommended NPK (60:60:30) + 20 kg S to succeeding winter sunflower recorded highest soybean seed yield (2,260 kg/ha), soybean equivalent seed yield, higher economic returns in Vertisols in semi-arid conditions.

REFERENCES

Billore S D and Vyas A K. 2012. Optimization of sulphur levels for soybean production under different agro-climatic regions of India. *Soybean Research* **10**: 67-74.

Hegde D M. 2007. *Agro-eco Region –Specific Cropping Systems for Sustainable Oilseed Production*, Directorate of Oilseeds Research, Hyderabad.

Reddy B N and Sudhakara Babau S N. 1996. Production potential, land utilization and economics of fertilizer management in summer sunflower based crop sequences. *Indian Journal of Agricultural Sciences* **66**(1): 16-9.

Sudhakara Babu and Hegde D M. 2011. Best management practices for increasing productivity and resource use efficiency in oilseeds. *Journal of Oilseeds Research* **28**: 1-23.

Tanaka D L, JM Krupinsky, S D Merrill, M A Liebig and Hanson J D. 2007. Dynamic cropping systems for sustainable crop production in the northern great plains. *Agronomy Journal* **99**: 904–11.

Soybean Research (Special Issue Number 2): 142-148: 2014

Effect of IPNS on Soil Fertility, Nutrient Balance and Productivity of Soybean in Vertisols of Semi-Arid Agro-ecosystem in Maharashtra

V V GABHANE[1], M M GANVIR[2] and M B NAGDEVE[3], AICRP for Dryland Agriculture, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444 104, Maharashtra, India
E mail: vvgabhane@gmail.com

ABSTRACT

A field experiment was conducted during 2009 – 2012 at Research farm, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola, to study the effect of integrated plant nutrient supply system on soil fertility, nutrient balance and productivity of soybean grown in Vertisols under rainfed conditions. The soil of the experimental site was moderately alkaline in reaction, low in available nitrogen, medium in available phosphorus and high in available potassium. Nine treatments with three replications were tried in a randomized block design consisting of control, 100 per cent recommended dose of fertilizers (RDF) (30:75:00 kg/ha), 100 per cent RDF along with biofertilizers, 100 per cent N through FYM along with biofertilizers, 100 per cent RDF along with 25 kg K_2O per ha, 100 per cent RDF along with 25kg K_2O per ha and biofertilizers, 50 per cent N through glyricidia along with 50 per cent N through inorganics, 50 per cent N through glyricidia along with 50 per cent N through inorganics and biofertilizers, 50 per cent N through glyricidia along with 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha. The pooled results indicated that the application of 100 per cent RDF along with 25 kg K_2O per ha and biofertilizers resulted in higher yield of soybean and did not significantly vary with the application of 50 per cent N through glyricidia along with 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha. However, significant improvement in soil fertility and nutrient balance was observed with the application of 50 per cent N through glyricidia + 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha. Hence, it is concluded that the conjunctive application of 50 per cent N through glyricidia along with 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha resulted in sustaining the yield of soybean with improvement in soil fertility and nutrient balance under soybean grown in Vertisols under rainfed conditions.

Key words: IPNS, nutrient balance, soil fertility and Vertisols

Soybean is an important oilseed as well as pulse crop grown in various countries. It has been recognized today, as one of the best agricultural crop for various reasons. It contains 20 per cent oil, 40-48 per cent protein, 20 to 30 per cent carbohydrates and 5.5 per cent minerals (Chauhan *et al.,* 1988). Among the oilseeds, it has highest content of lysine, which is limiting factor in cereals. It is considered as highly proteinious and nutritious food. The crop has been therefore, popularized among the farmers with higher demand.

In Maharashtra, during *kharif* 2012 the area under soybean was 3.21 million ha, with production of 3.99 million tonnes and an

[1]Associate Professor; [2]Assistant Professor; [3]Chief Scientist

average productivity of 1,243 kg per ha, while in Vidarbha, the area under soybean cultivation was 1.78 million ha with a production of 2.62 million tonnes and an average productivity of 1,328 kg per ha (Anonymous, 2013).

Integrated nutrient manage -ment is the maintenance of soil fertility and plant nutrient supply to an optimum level for sustaining desired crop productivity through optimization of benefits from all possible sources of plant nutrients in an integrated manner. Integrated nutrient management envisages the use of chemical fertilizers in conjunction with organic manures, legumes in cropping system, biofertilizer and other locally available nutrient sources for sustaining soil health and crop productivity.

Among the nutrient elements, potassium plays a significant role in increasing the crop yield and also exerts a balancing effect on both nitrogen and phosphorus. Potassium fertilization leads to numerous positive effect on the many plant function for which it is indispensable (Tiwari, 2000).

MATERIAL AND METHODS

The present field experiment was conducted during *kharif* 2009 to 2012 at Research Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The soil of the experiment site was Vertisols, which was moderately alkaline in reaction (pH 8.1), low in available nitrogen (195 kg N/ha), medium in available phosphorus (18.5 kg P_2O_5/ha) and very high in available potassium (319 kg K_2O/ha). Nine treatments with three replications were tried in randomized block design comprising of control, 100 per cent recommended dose of fertilizers (RDF) (30:75:00 kg :: N:P_2O_5: K_2O/ha), 100 per cent RDF along with biofertilizers, 100 per cent N through FYM along with biofertilizers, 100 per cent RDF along with 25 kg K_2O per ha, 100 per cent RDF along with 25 kg K_2O per ha and biofertilizers, 50 per cent N through glyricidia along with 50 per cent N through inorganics, 50 per cent N through glyricidia along with 50 per cent N through inorganics and biofertilizers, 50 per cent N through glyricidia along with 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha. Rhizobium and PSB were used as seed treatment (25 g/kg seed) and recommended P was applied to all treatments except in control and 100 per cent RDF along with biofertilizers.

The surface (0-20 cm) soil samples were taken from each experimental plot after harvest of crop and were subsequently analysed for pertinent chemical properties as per standard procedures. Walkley and Black method as described by Nelson and Sommers (1982) was used to determine soil organic carbon content, available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus was determined by Olsen's method (Watanabe and Olsen,1956), available potassium was determined by flame photometer using neutral N ammonium acetate (pH 7.0) as an extractant as described by Hanway and Heidel (1952). The data on different parameters was tabulated and analysed statistically (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

Yield of soybean

The pooled data (2009 to 2012) on seed yield of soybean as influenced by integrated nutrient management (Table 1) revealed that seed yield (1,967 kg/ha) was significantly higher in treatment comprising of 100 per cent RDF + 25 kg K_2O per ha + biofertilizers and did not significantly vary with the application of 100 per cent RDF along with 25 kg K_2O per ha and 50 per cent N through glyricidia along with 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha treatments. The lowest seed yield (1,521 kg/ha) was recorded in control treatment. Similarly, the straw yield (2,897 kg/ha) was also significantly higher in the treatment consisting of 100 per cent RDF + 25 kg 25 kg K_2O per ha + biofertilizers and was not significantly different with the application of 100 per cent RDF

Table 1. Effect of IPNS on pooled yield of soybean

Treatment	Soybean yield (kg/ ha)	
	Seed	**Straw**
Control	1521	2460
100 % RDF (30:75:00 kg $N:P_2O_5:K_2O$ /ha)	1757	2661
100 % RDF + biofertilizer	1809	2698
100 % N through FYM + biofertilizers	1661	2602
100 % RDF + 25 kg K_2O /ha	1867	2768
100 % RDF + 25 kg K_2O /ha + biofertilizer	1967	2897
50 % N through glyricidia + 50 % N through inorganics	1787	2701
50 % N through glyricidia + 50 % N through inorganics + biofertilizers	1803	2631
50 % N through glyricidia + 50 % N through inorganics + biofertilizers + 25 kg K_2O/ha	1886	2758
SE(m) ±	61	48
C D (P = 0.05)	182	144

along with 25 kg K_2O per ha, 50 per cent N through glyricidia along with 50 per cent N through inorganics and 50 per cent N through glyricidia along with 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha treatments. The straw yield (2,460 kg/ha) was found to be lowest in control treatment.

This may be due to beneficial role of potassium which might have increased nodulation of legumes (Tiwari, 2000) and biofertilizers also perform better when soil is well supplied with nutrients particularly nitrogen and phosphorus by fixing atmospheric nitrogen.

The study of Govindan and Thirumurugan (2003) indicated a positive effect of Rhizobium and phosphate solublizing micro-organism in increasing the growth and yield of soybean, while Manral and Saxena (2010) reported higher productivity of soybean with combined use of inorganic and organic sources of nutrients than applied alone.

Effect of various treatments on soil fertility

Organic carbon

The organic carbon content of soil as influenced by various treatments was statistically significant and it ranged from 5.03 to 6.13 g per kg. The highest organic carbon was recorded in treatment comprising of 50 per cent N through green leaf manure + 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha treatment and did not vary significantly with the treatments 100 per RDF + 25 kg K_2O per ha + biofertilizers and 50 per cent N through glyricidia + 50 per cent N through inorganics + biofertilizers.. The lowest value of organic carbon (5.03 g/kg) was observed in control (Table 2). The higher values of organic carbon content in above said treatments may be due to higher addition of biomass into the soil as evidenced from the higher yields obtained in these treatments. Gholve *et al.* (2005) observed that the application of 50 per cent RDF + vermicompost @ 3t + biofertilizers followed by 50 per cent RDF + FYM @ 5 t per ha + biofertilizers had significant effect for organic carbon.

Available N status

The available N in soil varied from 192.49 to 209.42 kg per ha indicating that the soil was low in available N content. The maximum N was observed in treatment 50 per cent N through glyricidia +50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha and it was found to be at par with treatment 50 per cent N through glyricidia + 50 per cent N through inorganics + biofertilizers. The lower value of N was found in control treatment (Table 2).

The higher value of available N over the initial value might be due to nitrogen fixation by soybean crop. Raut and Ghonshikar (1971) observed increase in nodulation and N content in soil due to Rhizobium inoculation.

Available P status

Available P content of soil varied significantly and it ranged from 16.57 to 20.59 kg P_2O_5 per ha indicating that the soil was low to medium in available phosphorus content. The highest available P was found in treatment 50 per cent N through glyricidia + 50 per cent N through inorganics + bio-fertilizers + 25 kg K_2O per ha and did not vary significantly with the treatments 100 per cent RDF + 25 kg K_2O per ha and 100 per cent RDF + 25 kg K_2O per ha + biofertilizers (Table 2).

The higher values of available phosphorus in treatment 50 per cent N through glyricidia along with 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha and 100 per cent RDF along with 25 kg K_2O per ha and biofertilizers may be due to the phosphate solubilizing bacteria (PSB) which increases the availability of P in the soil. Similar results were recorded by Varalaxmi *et al.* (2005) and Singh *et al.* (2007).

Available K status

The available K content of soil varied significantly from 317.97 to 368.53 kg K_2O per ha indicating that the soil was high to very high in available K content. Highest available K content was observed in treatment 100 per cent RDF + 25 K_2O per ha + biofertilizers and was significantly similar to treatments 100 per cent RDF + 25 kg K_2O per ha and 50 per cent N through glyricidia + 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha. The higher values of available potassium in above three treatments may be due to incorporation of potassium, which might have increased the K content in soil (Table 2).

Kundu *et al.* (1990) studied the response of soybean and wheat to applied K and build up and depletion of available and non-exchangeable K in soil profile on a sandy loam soil continuously cropped for 14 years and observed the build up of potassium and yield response of soybean to applied K over the years, while Surekha and Rao (2009) reported that organic sources improved the soil fertility, soil organic carbon, available N and K over inorganic fertilizer alone.

Nutrient balance after harvest of soybean

Organic carbon balance

The highest gain in soil organic carbon to an extent of 0.93 g per kg was observed with

Table 2. Effect of IPNS on soil organic carbon, available nitrogen, phosphorus and potassium

Treatments	Organic carbon (g/kg)	Available nutrients (kg/ha)		
		N	P_2O_5	K_2O
Control	5.03	192.49	16.57	317.97
100 % RDF (30:75:00 kg N:P_2O_5:K_2O /ha)	5.27	197.37	18.56	329.81
100 % RDF + biofertilizer	5.50	198.07	19.05	342.48
100 % N through FYM + biofertilizers	5.57	197.64	18.39	341.70
100 % RDF + 25 kg K_2O /ha	5.80	200.01	19.38	358.67
100 % RDF + 25 kg K_2O /ha + biofertilizer	6.03	202.58	20.26	368.53
50 % N through glyricidia + 50 % N through inorganics	5.83	200.19	18.39	339.17
50 % N through glyricidia + 50 % N through inorganics + biofertilizers	5.87	204.48	19.16	348.67
50 % N through glyricidia + 25 kg K_2O/ha	6.13	209.42	20.59	365.33
SE(m) ±	0.09	1.89	0.43	5.77
C D (P = 0.05)	**0.27**	**5.67**	**1.30**	**17.30**
Initial	5.2	195	18.5	319

application of 50 per cent N through glyricidia + 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha followed by treatment 100 per cent RDF + 25 kg K_2O per ha + biofertilizers (0.83g/kg) while loss in soil organic carbon (-0.17 g/kg) was observed in control treatment (Table 3).

Nitrogen balance

The highest gain in the available nitrogen to an extent of 14.42 kg per ha was observed in treatment 50 per cent N through glyricidia + 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha followed by treatment 50 per cent N through glyricidia +50 per cent N through inorganics + biofertilizers (9.48 kg N/ha) and 100 per cent RDF + 25 kg K_2O per ha + biofertilizers (7.58 kg N/ha), while loss in available nitrogen (-2.51 kg N/ha) was observed in control treatment (Table 3).

The final status of available N in soil after harvest of soybean (actual fertility status) was increased (195 to 209.42 kg/ha) in all the treatments over initial fertility status of soil with an exception of control treatment, which indicated the beneficial effect of the conjunctive use of organics and biofertilizers with chemical fertilizers in legume cropping which helped in increasing the available N in soil. These results are in conformity with the finding of Ravankar *et al.* (1998) wherein they observed that the combined use of organics with inorganics to legumes improved the fertility status of soil.

Phosphorus balance

The higher gain in phosphorus (1.76 kg P_2O_5/ha) was observed with application of 100 per cent RDF + 25 kg K_2O per ha + biofertilizers followed by treatment 100 per cent RDF + 25 kg K_2O per ha (0.88 kg P_2O_5/ha). The data with respect of gain or loss of phosphorus revealed that there was gain of phosphorus in most of the treatments, while loss of phosphorus was highest (-1.93 kg P_2O_5/ha) in control treatment followed by (-0.11 kg P_2O_5/ha) in treatments consisting of 100 per cent N through FYM along with biofertilizers (-0.11 kg P_2O_5/ha) and 50 per cent N through glyricidia along with 50 per cent N through inorganics (-0.11 kg P_2O_5/ha) (Table 3). Thus, the data indicated that increase in rate of phosphorus application also increased actual gain in P content of soil after harvest of crop. Malewar *et al.* (1999) noticed that oil seed crops showed differential effect on the availability of N, P and K in soil at various levels of fertilizer application.

The final status of available phosphorus in soil was considerably increased in all treatments over control, clearly indicating the beneficial effect due to the legume which absorb more soil P from sub-surface and a part of which left in the surface layer and sub- surface soil with roots.

Potassium balance

There was a highest gain (49.53 kg/ha) in treatment 100 per cent RDF+ 25 kg K_2O per ha + biofertilizers whereas the loss of potassium (-1.03 kg K_2O/ha) was observed in control treatment (Table 3).

Table 3. Effect of IPNS on nutrient balance

Treatments	**Organic carbon gain/loss (g/kg)**	**Nutrient gain/loss (kg/ha)**		
		N	**P**	**K**
Control	-0.17	-2.51	-1.93	-1.03
100 % RDF (30:75:00 kg N:P_2O_5:K_2O/ ha)	0.07	2.37	0.06	10.81
100 % RDF + biofertilizer	0.30	3.07	0.55	23.48
100 % N through FYM + biofertilizers	0.37	2.64	-0.11	22.70
100 % RDF + 25 kg K_2O /ha	0.60	5.01	0.88	39.67
100 % RDF + 25 kg K_2O /ha + biofertilizer	0.83	7.58	1.76	49.53
50 % N through glyricidia + 50 % N through inorganics	0.63	5.19	-0.11	20.17
50 % N through glyricidia + 50 % N through inorganics + biofertilizers	0.67	9.48	0.66	29.67
50 % N through glyricidia + 50 % N through inorganics + biofertilizers + 25 kg K_2O/ha	0.93	14.42	2.09	46.33
Initial	5.2	195	18.5	319

The final status of available potassium of soil considerably increased in all the treatments. The higher actual gain of potassium in treatment 100 per cent RDF + 25 kg K_2O per ha + biofertilizers, may be due to addition of potassic fertilizer to soil.

In view of the above, it can be concluded that the conjunctive application of 50 per cent N through glyricidia + 50 per cent N through inorganics + biofertilizers + 25 kg K_2O per ha resulted in sustaining the yield of soybean with improvement in soil fertility and nutrient balance under soybean grown in Vertisols of semi-arid region of Maharashtra.

REFERENCES

Anonymous, 2013. Agriculture Research Website, www.sopa.org.

Chauhan G S, Verrna N S and Bains G S. 1988. Effect of extrusion processing on the nutritional quality of protein in rice-legume blends. *Nahrung* **32**(1): 43.

Gholve S G, Shinde S H and Gaikwad C B. 2005. Efficacy of integrated nutrient management for pigenpea-pearlmillet intercropping system under dryland conditions. *Journal of Maharashtra Agricultural Universities* **30**(1): 41-3.

Govindan K and Thirumurugam K. 2003. Effect of Rhizobium and PSMS in soybean. *Journal of Maharashtra Agricultural Universities* **28**(1): 54-60.

Hanway J J and Heidel H. 1952. Soil analysis methods as used in IOWA state College Soil Testing Laboratory. *IOWA State College of Agriculture Bulletin* **57**: 1-13.

Kundu S, Bhatnagar V K, Prakash Ved, Joshi H C and Khorane K D. 1990. Yield response of soybean – wheat rotation to K application in a long term field application. *Journal of Potassium Research* **6**(2): 70-8.

Malewar G U, Ganure C K, Rudraksha G B and Ismail S. 1999. Impact of oilseed-based cropping systems on physico-chemical properties, soil nutrient dynamics and nutrient balance. *Journal of Maharashtra Agricultural Universities* **24**(2): 125-7.

Manral H S and Saxena S C. 2010. Plant growth, yield attributes and grain yield of soybean as affected by the application of inorganic and organic sources of nutrients. *Indian Journal of Agronomy* **58**(3): 147-50.

Nelson D W and Sommers L E. 1982. Total carbon, organic carbon and organic matter. *In*: *Methods of Soil Analysis Part-II*, Page A L (Ed.), Soil Science Society of America Madison, Wisconsin, USA, 539-77.

Panse V G and Sukhatme P V. 1985. *Statistical Methods for Agricultural Workers*, ICAR, New Delhi.

Raut S P and Ghonshikar C P. 1971. Effect of seed inoculation with *Rhizobium japonicum* on nodulation and grain yield of soybean. *Soybean Abstract* **64**(2): 834-5.

Ravankar H N, Puranik R B and Deshmukh P W. 1998. Soil fertility management with legume-wheat sequence. *PKV Research Journal* **22**(1): 15-8.

Singh S R, Nasar G R and Singh U. 2007. Productivity and nutrient uptake of soybean (*Glycine max*) as influenced by bio-inoculants and farm yard manure under rainfed condition. *Indian Journal of Agronomy* **52**(4): 325-9.

Subbiah B V and Asija G L 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25**: 259-60.

Surekha K and Rao K V. 2009. Direct and residual effect of organic sources on rice productivity. *Journal of the Indian Society of Soil Science* 57(1): 53-7.

Tiwari K N 2000. *Potash in Indian Farming*, Potash and Phosphate Institute of Canada- India Programme, Gurgaon.

Varalakshmi L R, Srinivasamurthy C A and Bhaskar S. 2005. Effect of integrated use of organic manures and inorganic fertilizers on organic carbon, available N, P and K in sustaining productivity of groundnut - fingermillet cropping system. *Journal of Indian Society of Soil Science* **53**(3): 315-8.

Watanabe F S and Olsen S R. 1965. Test of ascorbic acid method for determining phosphorus in water and sodium bicarbonate extracts of soils. *Proceedings Soil Science Society of America* **29**: 677-8.

Soybean Research (Special Issue Number 2): 149-153: 2014

Effect of Phosphogypsum (PG) Applications on Yield of Soybean (*Glycine max*) in Soybean-Wheat Cropping System

MADHVI TIWARI[1], DEEPIKA RAJAK[2], A K SHARMA[3] and RAJENDRA HAMAD[4],
Central Institute of Agriculture Engineering,
Bhopal 462038, Madhya Pradesh, India
E mail: tiwarimadhvi7@gmail.com

ABSTRACT

Field experiments under randomized block design with four replications were carried out during kharif *and* rabi *seasons of 2009-2010 to evaluate nutrient management and its response in soybean-wheat cropping system under Indore region of Madhya Pradesh. The treatments were comprised of phosphogypsum (0, 50,100,150,200 and 250 kg/ha) along with recommended dose of nutrients (30:60:40 and 120:60:40 kg N:P_2O_5:K_2O/ha) for soybean and wheat, respectively). Levels of phosphogypsum had significant effect on yield attributing characters of soybean and wheat. Soybean recorded significantly highest seed yield (2,162 kg/ha) with 150 kg phosphogypsum per ha which was 19.91 and 18.21 per cent higher than that recorded over control and phosphogypsum @ 50 kg per ha, respectively. Following wheat as well yielded higher under this treatment. Highest sulphur use efficiency of 14.96 per cent for soybean was recorded with 150 kg phosphogypsum per ha followed by 100 kg phosphogypsum per ha (14.63%), while it was lowest with 200 kg phosphogypsum per ha (1.31%). In case of wheat it was found to be 50.96 per cent, 49.71 per cent and 48.07 per cent by application of phasphogypsum @ 50, 100, 150 kg per ha.*

Keywords: Phosphogypsum, seed yield, soybean- wheat cropping system, yield attributing characters

Soybean is a major oil seed crop recognized as the efficient producer protein (40-42 %) and oil (20-22 %) (Baric and Chandel, 2001). In India, the total area under soybean cultivation is 10.8 million ha producing 11.50 million tones with productivity of 1,065kg per ha productivity. Madhya Pradesh contributed 55 per cent to total soybean production of India. Wheat is the world's most widely cultivated food crop. In India, it is second most important staple food crop. It is cultivated over an area of about 29.90 million ha with a production and productivity of 94.88 million tones and 3,173 kg per ha, respectively (FAOSTAT, 2012). Sulphur is now recognized as fourth major plant nutrient after N, P and K. It plays certain specific roles (part of every living cell, necessary for chlorophyll formation, component of essential amino acids, helps in formation of enzymes and vitamins, *etc*.) that cannot be corrected by any other nutrient. Sulphur is relatively immobile within the plant. Sulphur can improve yield and quality

[1]*Senior Research Fellow (CIAE, Bhopal);* [2]*Seed Analyst (Seed Testing Laboratory);* [3]*Associate Professor (College of Agriculture, Indore);* [4]*Senior Research Fellow (CIAE, Bhopal)*

of crops as it makes direct impacts on the various biochemical reactions in the plant and takes part in the chlorophyll formation. Now-a-days agriculture is moving towards low cost input technologies, which needs low cost of fertilizers recommendation to achieve the good sustainability and productivity. Phosphogypsum is the byproduct of gypsum and can thus serve as a source of S and Ca for plant growth like mineral gypsum. Phosphogypsum contained about 15 per cent S, 21 per cent Ca and 0.2-1.2 per cent P_2O_5. Phosphogypsum improves soil bulk density, total porosity and number of pores >30 μm in diameter to a depth of 30 cm. Since India is the net importer of S containing materials/fertilizers, it is thus very important to use this material for improving the productivity of the land resources where it could combat possible pollution hazard. Phosphogypsum has higher sulphur use efficiency as compared to other sources of sulphur (Sakal *et al.*, 2000).

MATERIAL AND METHODS

The present experiments were laid out under the Research Farm of College of Agriculture, Indore during *kharif* and *rabi* (2009-10). The topography of the field was uniform with an adequate drainage. Indore is situated at 22°43′ North latitude and 75°66′ East longitude with an altitude of 555.7 meter above the mean sea level in *Malwa* plateau of western Madhya Pradesh. This region belongs to sub-tropical semi-arid region having range of maximum temperature between 23° to 43° C and 6°-25° C as minimum temperature. Most of the rains received through South -West Monsoon between mid-June and third week of September. The experimental soil analysed low in organic carbon (0.46%) and available nitrogen (212.85 kg N/ha), phosphorus (7.72 kg P_2O_5/ha), potash (219.95 kg K_2O/ha). The soil was slightly saline in nature (pH 7.8 and EC 0.29dS/m) with sulphur in the low range (8.62 ppm). The experiment consisted of 6 treatment combinations of phosphogypsum (0, 50, 100, 150, 200 and 250 kg/ha) with recommended dose of nutrients replicated four times. The recommended dose of nutrients (30:60:40:: N:P_2O_5:K_2O/ha) to soybean and wheat (120:60:40:: N:P_2O_5:K_2O/ha) was applied through chemical fertilizers. Soybean (variety JS 93-05) and wheat (variety HI14-18) crops were sown 28thJune and 28thNovember in 2009 with seed rate 80 and 120 kg per ha at row spacing 30 cm and 22.5 cm, respectively. Seeds of soybean inoculated with *Rhizobium japonicum* prior to sowing. The data of yield and yield attributing characters were recorded for both crops. Number of pods per plant of soybean was recorded at 60 and 75 days after sowing (DAS) and at harvest. The data recorded were analysed statistically by using the analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984).

RESULT AND DISCUSSION

Effect of phosphogypsum on yield attributes

The number of pods of soybean enhanced considerably with the increment in the growth and development of plant up to the harvest stage. The number pods per plant increased from 13.48 at 60 days after sowing to 23.15 per plant at harvest in the control. Addition of increasing dose of phosphogypsum increased the number of pods per plant significantly only up to 150 kg per ha at every stage of the crop growth (Table 1). Further increase in phosphogypsum dose to 250 kg per ha exerted a detrimental effect on this parameter. The finding gets support form results reported by Verma *et al*. (2013), who reported significant increase in number of pods per plant and number of seeds per pod of soybean increased with the increase in phosphogypsum application up to 200 kg per ha over control. Similarly, Mandal and Sikdar (1999) observed an increase in the pod dry matter and number of pods per plant with increasing S rate.

Table 1. Effect of various levels of S application as phosphogypsum on yield attributes, yield and sulphur use efficiency of soybean

Phosphogypsum levels (kg/ha)*	Pods(No/plant)			Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Sulphur use efficiency (%)
	60 DAS	75 DAS	Harvest				
00	13.48	23.30	23.15	1803	1785	50.58	0.00
50	14.90	24.28	26.45	1829	1875	49.44	3.21
100	15.73	26.85	27.13	2037	1736	53.97	14.63
150	22.05	31.78	32.20	2162	1889	53.90	14.96
200	18.40	31.20	31.95	1845	2044	47.88	1.31
250	18.05	28.05	27.80	1907	1819	51.11	2.61
S.E. (±)	1.28	1.43	1.43	66	79	3.02	
CD(P = 0.05)	**3.86**	**4.30**	**4.32**	**199**	**NS**	**NS**	

**Recommended dose of nutrients (30:60:40:: N:P_2O_5:K_2O/ha) was common to all treatments*

Application of sulphur through phosphogypsum along with recommended dose of NPK proved significantly increased the number of seeds per spike of wheat at all doses of phosphogypsum over control (Table 2). Application of 150 kg phosphogypsum per ha resulted in significantly highest seeds per spike over lower as well as higher doses of phosphogypsum. Mishra *et al*. (2001) also reported that increasing levels S significantly increased the yield attributes (earhead/plant, spikelets/earhead and seeds /ear) and seed yield of wheat up to 40 kg S per ha.

Effect of phosphogypsum application on yield

Application of different doses of phosphogypsum linearly increased the seed yield of soybean up to 150 kg per ha. This increase was significantly higher by application of 100 (2037 kg/ha) and 150 kg (2,162 kg/ha) phosphogypsum over 50 kg phosphogypsum (1,829 kg/ha) and control (1,803 kg/ha) (Table 1). However, the seed yield @ 150 kg per ha was found at par with 100 kg phosphogypsum per ha. Further increase in dose of phosphogypsum (200 and 250 kg /ha) reduced the seed yield and were at par with control treatment. Raghuwanshi *et al.* (2013) revealed that the increasing levels of sulphur up to 50 kg S per ha significantly and progressively enhanced seed and straw yield of soybean. The highest seed (2,591 kg/ha) and stover (2,784 kg/ha) yield were recorded by Verma *et al*. (2013) on application of gypsum @ 0.3 t per ha, which was statistically at per with @ 2.2 t per ha. Application of phosphogypsum at any of the level did not influence the straw yield significantly (Table 1).

In wheat, application of phosphogypsum at all the levels enhanced the seed yield significantly over control. Application of phosphogypsum @ 150 kg per ha resulted in highest seed yield (5,692 kg /ha), which was at par with 100 and 200 kg per ha and control. Significant seed yield reduction was noticed on application of phosphogypsum at 250 kg per ha over 100, 150 and 200 kg per ha (Table 2). In case of straw yield, application of 100 kg phosphogypsum per ha was at par with 150, 200 and 250 kg phosphogypsum per ha, which significantly over 50 kg

Table 2. Effect of various levels of S application as phosphogypsum on yield attributes, yield and sulphur use efficiency of wheat

Phosphogypsum levels (kg/ha)*	Seed (No/ spike)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Sulphur use efficiency (%)
00	33.16	4538	6399	41.49	0.00
50	34.30	4946	6677	42.55	50.96
100	35.49	5333	7083	42.96	49.71
150	42.40	5692	7001	44.84	48.07
200	37.71	5388	6950	43.67	26.56
250	36.60	4936	6905	41.68	9.95
S.E. (±)	0.69	119	125	1.14	
C D (p = 0.05)	2.08	358	377	NS	

**Recommended doses of nutrients (120:60:40:: N:P_2O_5:K_2O/ha) was common to all treatments* differed

phosphogypsum per ha and control. Gupta *et al.* (2004) reported that seed and straw yields were significantly higher with 30 kg S per ha compared to its lower level, but was found at par with 45 kg S per ha.

Effect of phosphogypsum application on harvest index and sulphur use efficiency

Harvest index was not altered significantly due to different phosphogypsum treatments in soybean and wheat (Table 1 and 2). The highest sulphur use efficiency (14.96 %) in soybean was recorded on application of phosphogypsum @ 150 kg per ha followed by the application of 100 kg phosphogypsum per ha (14.63%). The highest sulphur use efficiency (50.96 %) in wheat was found with application of phosphogypsum @ 50 kg per ha followed 100 kg per ha (49.71%) and 150 kg per ha (48.07 %).

Thus, the present investigation indicated that the crop of soybean and wheat fertilized with 150 phosphogypsum per ha along with recommended doses of nutrients leads to enhancement of yield in Malwa region.

REFERENCES

Baric K C and Chandel A S. 2001. Effect of P application on growth, yield and phosphorus uptake in soybean and their residual availability in Mollisol. *Indian Journal of Agronomy* **46**(1): 7-13.

FAOSTAT. 2012. *A Publication of Statistics Division of Food and Agriculture Organization,* United Nations.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research,* John Willey and Sons, New York.

Gupta V K, S Kumar and Singh A K. 2004. Yield and quality of wheat (*Triticum aestivum*) as influenced by sulphur nutrition and weed management. *Indian Journal of Agricultural Sciences* **74**(5): 254-6.

Mandal R and Sikdar B C. 1999. Response of soybean to N and S fertilization in saline soil. *Journal of Phytological Research* **12**(1-2): 31-4.

Mishra J, P H Mishra and Pandey J P. 2001. Nitrogen and sulphur nutrient of wheat crop I. Growth and yield. *Annual Plant Soil Research* **3**(1): 84-8.

Raghuwanshi S R S, O P S Raghuwanshi, R Umat, G R Ambawatia and Bhargav K S. 2013. Effect of sulphur on seed yield, nutrient content and uptake by soybean [*Glycine max* (L.) Merill]. *Soybean Research* **11**(1): 80-3.

Sakal R, A P Singh, R B Sinha and Ismail M. 2000. Relative performance of some sulphur sources on sulphur nutrition of crops in calcareous soil. *Annals Agricultural Research* **21**(2): 206-11.

Verma S K, S R S Raghuwanshi, S C Tiwari and Jain R. 2013. Effect of gypsum as a source of sulphur on soybean [*Glycine max* (L.) Merill] at farmer's field on Malwa region of Madhya Pradesh. *Soybean Research* **11**(1): 29-35.

Soybean Research (Special Issue Number 2): 154-159: 2014

Response of Sulphur Levels and Application Frequency on Soybean – Chickpea Cropping System

O P GIROTHIA[1], S D BILLORE[2] and H S KUSHWAHA[3],
Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya,
Chitrakoot, Satna 485 331, Madhya Pradesh, India
E mail: omgirothia@ymail.com

ABSTRACT

A field experiment was conducted during kharif *and* rabi *seasons of 2008-10 to study the response of sulphur levels and application frequency on soybean-chickpea cropping system. The results revealed that the yield of soybean and chickpea as well as system productivity increased linearly with the increase in the levels of sulphur application up to 60 kg S per ha. Further increase in sulphur levels decreased the yield. The magnitude of yield enhancement was to the tune of 8.96 to 38.52 per cent in soybean, 11.07 to 28.91 per cent in chickpea and 10.50 to 25.20 per cent in system productivity. The mean residual response of rabi and kharif applied sulphur on soybean and chickpea was 11.81 and 13.21 per cent, respectively. The application of sulphur to both the crops was found to be the most productive and remunerative than individual season application.*

Key words: Application frequency, sulphur, system efficiency

Sulphur is one of the essential nutrients for plant growth with crop requirement similar to phosphorus. This element received little attention for many years, because fertilizers and atmospheric inputs supplied the soils with adequate amounts. With subsequent change in type of fertilizer usage, this element has become one of the limiting plant nutrients threatening the sustainability of crop production in semi-arid tropical regions of India, which cover 73 million ha of Vertisols and associated soils (Subbarao and Ganeshamurthy, 1994). Sulphur as a fertilizer or as a constituent of other fertilizers is generally not applied by farmers. As a result, large areas of sulphur deficiency are reported from this agro-ecological region (Ganeshmurthy and Saha, 1999).

Introduction of soybean [*Glycine max* (L) Merrill] in central India has led to a shift in cropping system from rainy season fallow-wheat or chickpea system to soybean–wheat (irrigated) or chickpea (rainfed) system, which presently constitutes the most predominant cropping systems in the region. However, the productivity of soybean-chickpea cropping system is very low as compared to other soybean based cropping systems. Chickpea (*Cicer arietinum* L.) is the most important pulse crop of *rabi* season cultivated mainly under rainfed condition. To improve the crop productivity through the adoption of high-yielding varieties and multiple cropping systems, fertilizer use has become more and more important. For oilseeds producers, sulphur fertilizer is especially important as the requirement of these crops for this element is higher than cereals. The importance of sulphur in agriculture is being increasingly emphasized

Scientist; [2]Principal Scientist, DSR, Indore; [3]Professor and its role in crop production is well recognized (Jamal *et al.,* 2005, Scherer, 2009). Since the farmers of this region are largely cash–limited, which restricts their capacity to buy fertilizers, it is important to develop production systems that are more nutrient-use efficient. Synchrony of nutrient supply with crop requirement and optimal utilization of residual fertilizer and soil sulphur by succeeding crops grown in rotation are among the practical ways to achieve such an objective. The main objective of the study was to assess strategies for sulphur management in a soybean-chickpea.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* and *rabi* season of 2008-09 and 2009-2010 at College of Agriculture, Indore (Madhya Pradesh). The experimental soil belonged to Sarol series (fine, isohypothermic, montmorollitic, Typic Haplausters) and analysed: pH - 7.76, EC -0.18 dS per m, organic carbon 4.2 g per kg and available S - 10.12 mg per kg. Thirteen treatment combinations encompassing of four levels of sulphur (20, 40 60 and 80 kg S/ha) and three application frequencies (applied to soybean only, applied to chickpea only and applied to both the crops and one control were laid out in randomized block design in factorial arrangement with four replications. Soybean (*var*. JS 95-60) and chickpea (*var*. JG 218) were raised following the recommended package of practices. A uniform basal dose of fertilizer (20 N: 60 P_2O_5:20 K_2O kg/ha) was supplied through di-ammonium phosphate (18 % N and 46 % P_2O_5) and muriate of potash (60 % K_2O) to both the crops. The appropriate quantity of sulphur as per the treatments was supplied through gypsum (14 % S). The rainfall during 2008-09 and 2009-10 was 622.8 and 1074.1 mm, respectively.

Yield of both the crops were recorded after the harvesting of crops. System efficiency in terms of soybean equivalent yield was computed by using the standard formula. The economical parameters were determined by considering the prevailing market price of inputs and outputs.

RESULT AND DISCUSSION

Effect of sulphur levels on seed and strover yield

Soybean and chickpea seed as well as stover yield, significantly increased as the levels of sulphur increases up to 60 kg S per ha and further increase level decreased the yield significantly during both the years of study and also in the pooled data (Table 1). The increase in soybean yield was to the tune of 8.96, 22.11, 38.52 and 25.53 per cent by the application of 20, 40, 60 and 80 kg S per ha, respectively as compared to control. On comparing higher levels with the recommended level of sulphur, yield increase was to the extent of 12.06, 27.12 and 17.95 per cent due to 40, 60 and 80 kg S per ha, respectively. The enhancement of chickpea yield was 11.07, 19.53, 28.91 and 24.62 per cent by the applied sulphur @ 20, 40, 60 and 80 kg S per ha over control and 7.62, 16.07 and 12.20 % due to 40, 60 and 80 kg S per ha over recommended level, respectively. The increase in yield owing to sulphur addition could be attributed to the increased yield attributes like dry matter accumulation, which ultimately translocated to sink, activities of roots and nodules in nutrient extraction from large soil volume and greater biological nitrogen fixation, growth efficiency (CGR, RGR) and net assimilation rate of crops, pods per plant, seed yield per plant, seed index and increased uptake of nutrients *viz*., N, P, K and S, thus resulting in higher yield. These results are in agreement with the findings of Vyas, *et al* (2006), Sarangthem e*t al*

Table 1. Effect of sulphur levels and application frequency on dry matter, soybean equivalent yield, net returns and B: C ratio

Treatment	Dry matter per plant at 60 DAS (g)						Seed yield (kg/ha)						Stover yield (kg/ha)		Soybean Equiva-lent yield (kg/ha)	Net returns (Rs/ha)	B: C ratio
	Soybean			Chickpea			Soybean			Chickpea			Soy-bean	Chick-pea			
	2008	2009	Pooled	2008 - 09	2009 - 10	Pooled	2008	2009	Pooled	2008 - 09	2009 - 10	Pooled					
Sulphur levels (kg/ha)																	
20	20.4	20.9	20.6	8.32	10.01	9.17	1737	1860	1799	1797	2137	1967	2814	3046	4949	62657	2.72
40	21.8	22.7	22.3	9.06	10.57	9.81	1944	2087	2016	1930	2303	2117	2888	3261	5381	70286	2.88
60	22.5	22.9	22.7	9.47	11.20	10.33	2188	2391	2289	2124	2443	2283	3117	3534	5924	80145	3.09
80	22.2	23.2	22.7	9.34	10.63	9.98	2014	2229	2122	2111	2303	2207	3009	3429	5638	73421	2.87
SEm (±)	0.14	0.12	0.09	0.11	0.15	0.09	49	62	39	31	31	22	37	26	45	909	0.02
CD (P = 0.05)	**0.41**	**0.35**	**0.27**	**0.32**	**0.42**	**0.26**	**142**	**177**	**111**	**88**	**89**	**62**	**105**	**73**	**128**	**2561**	**0.07**
Sulphur application frequency																	
Kharif only	22.1	22.6	22.4	9.04	9.99	22.1	2038	2120	2079	1884	2127	2005	2803	3154	5295	69324	2.89
Rabi only	21.5	22.5	22.0	8.92	11.01	21.5	1709	1983	1846	1905	2344	2124	2919	3285	5229	66756	2.76
Kharif + *Rabi*	21.6	22.2	21.9	9.17	10.81	21.6	2162	2323	2242	2182	2419	2301	3150	3514	5894	78802	3.02
SEm (±)	0.13	0.10	0.08	0.10	0.13	0.13	43	53	34	27	27	19	32	23	39	787	0.02
CD (P = 0.05)	**0.36**	**0.30**	**0.23**	**NS**	**0.36**	**0.36**	**123**	**153**	**96**	**76**	**77**	**53**	**91**	**64**	**111**	**2218**	**0.06**
Control	18.9	19.5	19.2	6.49	7.50	18.9	1575	1727	1651	1717	1826	1771	2422	2583	4431	53298	2.51
SEm(±)	0.26	0.22	0.17	0.20	0.26	0.26	89	111	71	55	56	39	67	47	82	1638	**0.04**
CD (P = 0.05)- T *vs* Control	**0.75**	**0.63**	**0.48**	**0.58**	**0.76**	**0.75**	**255**	**319**	**201**	**159**	**161**	**111**	**189**	**132**	**231**	**4617**	**0.12**

(2008), Shekhawat and Shivay (2008) and Farhad, *et al*. (2010). The stover yield of both the crops also followed a trend similar to seed yield. The variation in stover yield under different treatments may be due to the differences in accumulation of photosynthates and their translocation to the sink. These results are in line with the findings of Deo and Khaldelwal (2009), Srinivasarao *et al.* (2010), Farhad, *et al*. (2010) and Najar *et al.* (2011).

Significantly highest soybean equivalent yield was recorded with the application of 60 kg S per ha during both the years, which was 10.5, 17.6, 25.2 and 21.4 per cent higher over control, respectively and 8.0, 16.4 and 12.2 per cent over 20 kg S per ha, respectively on the pooled basis. Significantly maximum and minimum net returns per ha were noted in at sulphur level @ 60 kg per ha and in control, respectively.

Effect of S levels on application frequency

Significantly maximum soybean yield was recorded when sulphur applied to both the seasons (*kharif* and *rabi)* during both the years as well as reflected in the pooled data. The soybean yield hike was found to be 21.45 and, 12.62 per cent when sulphur applied to both the seasons and *kharif* only, respectively over sulphur applied to only *rabi* season. Application of sulphur to both the season produced 7.84 per cent more yield as compared to sulphur applied to *kharif* crop only. The yield difference between control and sulphur applied to *rabi* season only was found to be non-significant. The maximum chickpea yield was also recorded when sulphur was applied to both the crops during both the years of study and pooled data. The yield difference between sulphur applied to *kharif* only, *rabi* only and control was found to be non-significant. The chickpea yield increased to the extent of 13.21, 19.93 and 29.92 per cent due to sulphur applied to *kharif*, *rabi* and both the crops over control and 5.93 and 14.76 per cent as compared to sulphur applied to *kharif* only, respectively. The sulphur application in both the seasons produced 8.83 per cent higher yield as compared to sulphur applied to only *rabi* season.

Application of sulphur in both the seasons (*kharif* + *rabi*) produced significantly maximum soybean equivalent yield as compared to applied to individual season. Though the difference between sulphur applied in individual seasons was non-significant. Significantly highest and lowest soybean equivalent yield was recorded when 60 kg S per ha applied in both the seasons and 20 kg S per ha applied in *kharif* only, respectively. The increased yield levels of individual crops and total system productivity in application of sulphur in current season as well as in both the seasons might be due to the maintained the sulphur availability in soil matching to the crop requirement. This has resulted in higher growth and yield attributes of soybean and chickpea, ultimately resulting in higher yield of both the crops. These results are in agreement with the findings of Vyas *et al.* (2006) and Sarangthem *et al*. (2008).

The net returns and B: C ratio linearly increased as the levels of sulphur increases up to 60 kg per ha when applied to both the crops. Evidently the variations in all the economical parameters due to sulphur levels and their application frequencies can be explained on the basis of variations in seed and straw yields, because they usually follow the almost identical trends. The existing variation might be due to variations occurred in yield levels and their respective cost of cultivation. Similar were the findings of Srinivasarao *et al.* (2010) and Kumar *et al*. (2011).

Residual response of sulphur

The average residual response of *rabi* and *kharif* applied sulphur on soybean and chickpea was 11.81 per cent (8.50 to 14.82 %) and 13.21 per cent (9.72 to 16.48 %), respectively. This might be due to the fact that the entire quantity of applied nutrient was not utilized by the crop during the life cycle and moreover, the nutrient experiences immobilization and mobilization phase under the soil environment. These results are well in agreement with the findings previously reported by Srinivasarao *et al.* (2010) in chickpea, Rana *et al*. (2007) in urdbean, Bhatathi and Poongothai (2008) in moong, Sreemannarayana and Sreenivasa Raju (1993) in sunflower based cropping system, Aulakh *et al*. (2002) in soybean-wheat and Islam *et al.* (1997) in rice - mustard .

On the basis of two years results, it could be concluded that the application of sulphur @ 60 kg per ha to each crop is essential to enhance the system productivity and profitability of soybean-chickpea cropping system.

REFERANCES

Aulakh Milkha S, Ramesh C Jaggi and Sharma R. 2002. Mineralization, immobilization of soil organic S and oxidation of elemental S in subtropical soils under flooded and non-flooded conditions. *Biology and Fertility of Soils* **35:** 197-203.

Bharathi C and Poongothai S. 2008. Direct and residual effect of sulphur on growth, nutrient uptake, yield and its use efficiency in maize and subsequent greengram. *Agriculture and Biological Sciences* **4**(5): 368-72.

Deo Chandra and Khaldelwal R B. 2009. Effect of P and S nutrition on yield and quality of chickpea (*Cicer arietinum* L.) *Journal of the Indian Society of Soil Science* **57**(3): 352-6

Farhad I S M, Islam M N, Hoque S and Bhuiyan M S I. 2010.Role of potassium and sulphur on the growth, yield and oil content of soybean (*Glycine max* L.). *Academic Journal of Plant Sciences* **3**(2): 99-103.

Ganeshamurthy A N and Saha J K. 1999. Status in the soils of agroecological regions of India. *Fertilizer News* **44**: 57-66.

Islam M R, Riasat T M and Lahiruddin M. 1997. Direct and residual effects of S, Zn and B on yield and nutrient uptake in a rice-mustard cropping system. *Journal of the Indian Society of Soil Science* **45**(1): 126-9.

Jamal A, Fazli I S, Ahmad S, Abdin M Z and Yun S J. 2005. Effect of sulphur and nitrogen application on growth characteristics, seed and oil yield of soybean cultivars. *Korean Journal of Crop Science* **50**(5): 340-5.

Kumar S, Verma S K, Singh T K and Singh S. 2011. Effect of nitrogen and sulphur on growth, yield and nutrient uptake by Indian mustard (*Brassica juncea*) under rainfed condition. *Indian Journal of Agricultural Sciences* **79**(8): 648-50.

Najar G R, Singh S R, Akhtar F, Hakeem S A. 2011. Influence of sulphur level on yield, uptake and quality of soybean (*Glycine max*) under temperate conditions of Kashmir valley. *The Indian Journal of Agricultural Sciences* **81**(4): 340-3.

Rana D S, Giri G and Pachauri D K. 2007. Direct and cumulative residual effect of phosphorus and sulphur on yield trend, system productivity, economics and balance sheet of Indian mustard (*Brassica juncea*)-sunflower (*Helianthus annuus*)-urdbean (*Vigna mungo*) cropping system. *Indian Journal of Agriculture Sciences* **77**(7): 408-14.

Sarangthem I, Singh L S, Singh N G and Sarkar A K. 2008. Response of rapeseed to nitrogen and sulphur. *Journal of the Indian Society of Soil Science* **56**(2): 222-4.

Scherer H W. 2009, Sulfur in soils. *Journal of Plant Nutrition and Soil Science* **172**: 326-35.

Shekhawat K. and Shivay Y S. 2008, Effect of nitrogen sources, Sulphur and boron levels on productivity, nutrient uptake and quality of sunflower (*Helianthus annuus*). *Indian Journal of Agronomy*, **53**(2): 129-134.

Sreemannarayana B and Sreenivasa Raju A. 1993, Direct and residual effect of applied sulphur in sunflower based cropping systems. *Fertilizer News* **38**(9): 39-42.

Srinivasrao C H, Ali Masood, Venkateswarlu, S., Rupa T R, Singh K K, Kundu Smanta, Prasad J V N S. 2010. Direct and residual effects of integrated sulphur fertilization in maize (*Zea mays*)- chickpea (*Cicer arietinum*) cropping system on Typic Ustochrept. *Indian Journal of Agronomy* **55**(4): 259-63.

SubbaRao A and Ganeshamurthy A N. 1994. Soybean responses to applied phosphorus and sulfur on VerticUstochrepts in relation to available phosphorus and sulfur. *Journal of Indian Society of Soil Science* **42**: 606-10.

Vyas A K, Billore S D, Joshi O P and Pachlania N. 2006. Productivity of soybean (*Glycine max*) genotypes as influenced by nitrogen and sulphur nutrition, *Indian Journal of Agricultural Sciences* **76**(4): 272-3.

Soybean Research (Special Issue Number 2): 160-172: 2014

Evaluation of Soybean (*Glycine max* (L.) + Pigeonpea (*Cajanus cajan* (L.) Intercropping System Productivity and Efficiency under Integrated Nutrient Management Practices

M SENTHIVELU[1], P SUBBIAN[2] and A C SURYA PRABHA[3],
Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam 641 301 and FLUCC Division, Institute of Forest Genetics and Tree Breeding, Coimbatore 641 002, Tamil Nadu, India
E mail: senthivelu.m@gmail.com,m.senthivelu.yahoo.com

ABSTRACT

Field experiments under irrigated condition were conducted at Department of Pulses, Tamil Nadu Agricultural University, Coimbatore during kharif 2006 and f2007 to study the productivity and efficiency of soybean + pigeonpea intercropping system at 2:1 row ratio as replacement series under integrated nutrient management practices. The experiments were laid out in factorial randomized block design and replicated thrice. Recommended dose of fertilizer (RDF) at three levels viz., 50, 75 and 100 per cent to the base crop were assigned as factor I and two levels and combinations of organic manure (farmyard manure - FYM @ 0 and 5t/ha) and micronutrient (zinc - Zn @ 0 and 5 kg/ha) were assigned as factor II, and a total of twelve treatments were implemented in soybean + pigeonpea intercropping system. In addition, sole crop of both soybean and pigeonpea with recommended dose of fertilizers (RDF) were raised as control. Sole soybean with 100 per cent RDF (20:80:40 kg::N:P_2O_5:K_2O/ha) and sole pigeonpea with 100 per cent RDF (25:50:00 kg::N:P_2O_5:K_2O/ha) recorded the highest grain yield (1,582 and 1,565 kg/ha) and (1,325 and 1,289 kg/ha) than intercropping system during 2006 and 2007, respectively. In intercropping system, application of 100 per cent RDFproduced the higher soybean seed yield (1,298 and 1,284 kg/ha) and pigeonpea yield (1,084 and 991 kg/ha) than 75per cent and 50 per centRDF during 2006 and 2007. Combined application of FYM @ 5 t per ha+ Zn @5 kg per ha to intercropping system alsoproduced the higher seed yield of soybean (1,240 and 1,229 kg/ha) and pigeonpea (1,043 and 954 kg/ha). Application of higher level of fertilizer, organic manure and micronutrient also significantly enhanced the biological yield advantage of the intercropping system as well as productivity and land use efficiency of the cropping system. Application of 100 per cent RDF recorded the highest land equivalent ratio (1.65 and 1.60), land equivalent coefficient (0.69 and 0.65), soybean seed equivalent yield (3,466 and 3,266 kg/ha), area-time equivalency ratio (1.38 and 1.34) and crop performance ratio (1.23 and 1.19) during 2006 and 2007, respectively. Similarly integrated application of FYM @ 5 t per ha+ Zn @ 5 kg per ha registered the higher values of land equivalent ratio (1.58 and 1.54), land equivalent coefficient (0.63 and 0.61), soybean seedequivalent yield (3,326 and 3,137 kg/ha), area-time equivalency ratio (1.32 and 1.29) and crop performance ratio (1.18 and 1.15) during 2006 and 2007, respectively. Intercropping efficiency in terms of aggressivity indices/competitive complementarity also improved by 100 per cent RDF application and combined application of organic manure and zinc nutrient.

Key words: Area-time equivalency ratio, crop performance ratio, INM practices, land equivalent ratio, soybean seed equivalent yield, yield, yield advantage indices

[1]Assistant Professor; [2]Ex-Professor (Agronomy); 3Scientist C

Indian agriculture had witnessed a gradual trans-formation from subsistence farming of early fifties to the present intensive agriculture especially in better-endowed region. India although balanced with abundant natural resources and low cost labour has never been in the forefront of agricultural production. With the exception of wheat and rice, there has not been much increase in the production of other crops like pulses, oilseeds and minor cereals, because these are the crops grown by resource poor farmers in marginal lands (Kumar and Rana, 2007). Degradation of cultivable land, natural resources and competition for land from modern urbanization and industrialization limit the horizontal expansion of cultivable land (Kumar *et al.,* 2012). Hence, the only way to increase the food production is through vertical expansion by intensive agriculture such as intercropping, sequential cropping *etc*., on time and space dimension. Such intensification needs a new outlook in crop, fertilizer and natural resource management.

Pulse crops are considered as second major agricultural crops in Indian agrarian economy. Normally pulse crops are raised under marginal land condition with low input and poor management practices leading to lower production and productivity level. Soybean and pigeonpea are the most important pulse crops cultivated in India covering 14.22 million hectares with the combined total production of 14.93 million tonnes (Anonymous, 2012). Soybean, being short duration crop having high protein content, is spreading fast and also fits suitably in different cropping systems. Initial slow growth of soybean coupled with little lateral spread increases opportunity for accommodating another slow growing crop (Sarawgi *et al.*, 2012). Intercropping of pigeonpea with short duration grain legumes like greengram, blackgram, cowpea and groundnut proved successful without any loss in yield (Kumar and Rana, 2007; Kumar *et al.*, 2012). In the initial stage, vegetative growth of pigeonpea is slow, whereas that in soybean is fast; therefore soybean can complete its life cycle faster than pigeonpea. Hence, pigeonpea as an intercrop in soybean seems to be a highly efficient system.

Intercropping system is one such method which offers great scope for pulse crops sustainability in the overall productivity and profitability. Intercropping in general assumes great importance with regard to better stability, productivity and profitability. It is largely a system useful for small and marginal farmers (Lal *et al*., 2013). In view of its various benefits like better utilization of solar radiation, soil moisture, inherent and applied nutrients the intercropping not only helps to solve the problem of pulse production but also helps to bring additional income to farmers and to get higher benefits with lower cost of cultivation and helps to utilize the space (land), time (duration) very efficiently, effectively and numerically the land usage can be intensified (Kantwa *et al.,* 2006; Vishwanathan *et al*., 2011). The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with each sole crop of the mixture. It also observed that land equivalent ratio, land equivalent co-efficient, area-time equivalency ratio and crop equivalent yield shows the efficiency of intercropping for using the environmental resources compared with monocropping (Mucheru-Muna *et al*., 2010).

For sustainable crop production, it is important to develop feasible and remunerative intercropping systems suitable for different agro-climatic regions and agro-ecological zones. The concept of intercropping is aimed at maximizing the crop production per unit area per unit time. Thus, although intercropping has been practiced traditionally for hundreds of years and is widespread in many parts of the world, it is still poorly understood from an agronomic perspective and research in this area is less advanced than comparable work in monocropping. This is due in part to the wide use of pure crop cultures in the developed world, in part to the relative lack of resources in the developing world, but not lack to the complexity of the problems involved. Thus, more research is needed to better understand how intercrops function and to develop intercropping systems that are compatible with current cropping systems. With this background, the present field study was conducted for assessment of yield advantages, productivity and efficiency of soybean + pigeonpea intercropping system under integrated nutrient management practices.

MATERIAL AND METHODS

Field experiments under irrigated condition were conducted to study the productivity and efficiency of soybean + pigeonpea intercropping system at 2:1 row ratio as replacement series under integrated nutrient management practices during *kharif* 2006 and 2007 at experimental farm of Department of Pulses, Tamil Nadu Agricultural University, Coimbatore situated in Southern India at 11^{o} N latitude and 77^{o} E longitude with an altitude of 426.72 m above mean sea level. The experimental farm extends over an area of 78.4 ha with Alfisol (red soil) as major soil type and the experimental area falls under Southern agro-climatic zone of India and Western agro-climatic zone of Tamil Nadu, respectively. The mean annual rainfall of TNAU, Coimbatore is 670 mm in 40 rainy days distributed at 209.4 mm (31.25 %) and 305.4 mm (45.58 %), respectively during south-west monsoon period (June-September) and north-east monsoon (October-December). The mean maximum and minimum temperature are 32.12 ^{o}C and 21.51 ^{o}C, respectively. The relative humidity ranges from 61 to 91 per cent during forenoon and 14 to 68 per cent during afternoon. Wind velocity is 5.8 km per h, the mean daily sunshine is 7.4 h per day with mean solar radiation of 400 Cal. cm^{-2} $day^{-1}$and pan evaporation of 5.4 mmper day. The soil of experimental field was sandy loam type (15.0 % coarse sand, 30.5 % fine sand, 35.8 % silt and 18.7 % clay) in texture and classified as Typic Ustivertept belonging to Periya Nayakkan Palayam (P.N. Palayam) series and had 8.2 pH (1:2 soil : water), 0.46 dS per m EC, 0.34 per cent organic carbon (chromic acid wet oxidation method), 254.0 kg per ha available nitrogen (by Alkaline permanganate method), 10.2 kg per ha available phosphorus (Olsen method) and 496.0 kg per ha of 1 N neutral ammonium-acetate-extractable potassium (by flame photometry) with bulk density of 1.48 Mg per m^3.

The experiments were laid out in factorial randomized block design with two treatment factors comprising of (i) inorganic fertilizer at three levels *viz.*, 50 per cent RDF, 75 per cent RDF and 100 per cent RDF (20:80:40 kg::N:P_2O_5:K_2O/ha) to the base crop were assigned as factor I and, (ii) two levels and combinations of organic manure (FYM @ 0 and 5 t/ha) and micronutrient (zinc @ 0 and 5 kg/ha) were assigned as factor II and a total of twelve treatments were implemented in soybean + pigeonpea intercropping (2:1 replacement series) system. In addition, sole crop of both soybean with RDF (20:80:40 kg ::N:P_2O_5:K_2O/ha) and pigeonpea with RDF (25:50:00 kg::N:P_2O_5:K_2O/ha) were raised as control and replicated thrice. In sole cropping system, chemically and biologically treated seeds of soybean and pigeonpea were sown at 30 cm x 10 cm and 60 cm x 30 cm spacing respectively, while in intercropping system, treated pigeonpea seeds were dibbled in appropriate lines (2:1 ratio of soybean and pigeonpea) adopting a row spacing of 60 cm and 30 cm between plant to plant within the lines. Soybean and pigeonpea were harvested in 95 days after sowing (DAS) and 140 DAS, respectively in both the years of field experimentation. The border rows in each plot were harvested first and then the plants in the net plots were harvested separately. Seeds were separated through manual threshing. The cleaned seeds were dried and the yield was recorded at 12 per cent moisture level. From these values, indices for assessment of competition and yield advantage, indices for assessment of land use and productivity and indices based on biological potential in intercropping system were worked out for each treatment.

Land equivalent ratio (LER)

Land equivalent ratio was calculated to evaluate the yield advantage under intercropping system. LER actually denotes the relative land area under sole crop that is required to produce the yields achieved in the intercropping system. LER sometime referred to land efficiency ratio. Land equivalent ratio values were worked out by using the formula narrated by Willey (1979).

$$LER = Y_{ij}/ Y_{ii} + Y_{ji}/ Y_{jj}$$

where, Y_{ij}-Yield of the main crop in intercropping system; Y_{ji}-Yield of the intercrop in intercropping system; Y_{ii}- Yield of the main crop in pure stand; Y_{jj}-Yield of the intercrop in pure stand

Land equivalent coefficient (LEC)

It is defined as the product of the land equivalent ratio of the intercrop components. LEC is developed to assess the interaction and productive potential of crop mixtures. To work out the land equivalent coefficient the formula suggested by Adetiloye and Ezedinma (1983) was followed.

$$LEC = Y_{ij}/ Y_{ii} * Y_{ji}/ Y_{jj}$$

where, Y_{ij}-Yield of the main crop in intercropping system; Y_{ji}-Yield of the intercrop in intercropping system; Y_{ii}- Yield of the main crop in pure stand; Y_{jj}-Yield of the intercrop in pure stand

Aggressivity (A)

Mc Gilchrist (1965) proposed the term aggressivity to denote the yield increase in one species than other. A value of zero indicates that the component species are equally competitive and higher the value, the more is the competitive ability.

$$A_{ab} = Y_{ab}/ Y_{aa} \times Z_{ab} - Y_{ba}/ Y_{bb} \times Z_{ba}$$

where, Y_{ab} - Mixed yield of species "a" (in combination with b); Y_{ba} - Mixed yield of species "b" (in combination with a); Y_{aa} - Pure stand yield of species "a"; Y_{bb} - Pure stand yield of species "b"; Z_{ab} - Sown proportion of "a" (in mixture with b); Z_{ba} - Sown proportion of "b" (in mixture with a)

Soybean seed equivalent yield (SSEY)

In order to compare the productivity in intercropping system, seed yield of soybean and the grain yield of pigeonpea were expressed as soybean seed equivalent yield. SSEY was derived by converting the seed yield of pigeonpea into the soybean seed equivalent yield on the basis of market prices (soybean - Rs 10/kg and pigeonpea – Rs 20/kg) as suggested by Halvankar *et al*. (2000).

SSEY= Soybean seed yield + {pigeonpea grain yield x sale price of pigeonpea/sale price of soybean}

Area time equivalency ratio (ATER)

The area time equivalency ratio was calculated by using the formula narrated by Heibsch and Mc Collum (1987). This takes into account the duration of the crop (from planting to harvesting). It also permits an evaluation of crops on yield per day basis.

$$ATER = \sum_{i=1}^{n} \{(t_i^M / t_i^I) \times (Y_i^I / Y_i^M)\}$$

where, t_i^M - Duration of $crop_i$ in monocropping; t_i^I - total duration of the intercropping system; Y_i^I- Yield of $crop_i$ in intercropping system; Y_i^M- Yield of $crop_i$ in sole system

Crop performance ratio (CPR)

Crop performance ratio is defined as the productivity of an intercrop per unit area of ground compared with that expected from sole crops sown in the same proportions. The CPR was calculated by the formula developed by Ali *et al.* (1990).

$$CPR = Q_i^a / P_i^a \times Q_s^a + Q_i^b / P_i^b \times Q_s^b$$

where, Q_i^a and Q_i^b - productivity per unit area in the intercrop of 'a' and 'b'; Q_s^a and Q_s^b - productivity per unit area under the sole crop of 'a' and 'b'; P_i^a and P_i^b - proportion of the intercrop sown with species a and b

The data on various characters studied in the experiment were statistically analysed using the standard anaylysis of variance suggested by Gomez and Gomez (1984). The significance of the treatment effect was determined using the *f*-test. To determine the significance of the difference between the means of two treatments, least significance difference (LSD) was computed at 5 per cent probability and values were furnished. The treatment differences that are non-significant were indicated as non-significant (NS).

RESULTS AND DISCUSSION

Grain yield

Cropping system, inorganic fertilizers, organic manure and zinc application had remarkable effect on the grain yield of soybean and pigeonpea in both the years (Table 1). Sole soybean and sole pigeonpea with 100 per cent RDF registered significantly higher soybean seed yield of 1,582 and 1,565 kg per ha and higher pigeonpea yield of 1,325 and 1,289 kg per ha than intercropping system during *kharif* 2006 and *kharif* 2007, respectively. This might be due to beneficial effects of higher availability of space, light, moisture and nutrients, besides less competitive effect within and between rows favoured the formation of root nodules, vigorous root development, better nitrogen fixation and overall plant growth and development in sole cropping system. These ultimately resulted in increased yield attributing characters and the thereby yield of soybean and pigeonpea. Similar finding were reported by Kantwa *et al.* (2005) and Kantwa *et al.* (2006).

In the intercropping system higher levels of inorganic fertilizer application (100 % RDF) to the base crop, enhanced the soybean and pigeonpea seed yield from 1,077 kg per ha to 1,298 kg per ha and from 909 kg per ha to 1,084 kg per ha, respectively in *kharif* 2006 and from 1,053 kg per ha to 1,284 kg per ha and from 826 kg per ha to 991 kg per ha, respectively in *kharif* 2007. This was followed by application of 75 per cent RDF and 50 per cent RDF. The increased economic yield is mainly attributed due to the increased number of pods per plant, seeds per pod and test weight with increased inorganic fertilizers application. Pulse crops, being a high protein crop, need large quantity of nutrients. Though, it is a leguminous crop it requires nitrogen at initial stage for better growth. Hence, higher levels ofsynthetic fertilizer application positively favoured the plant growth, physiological attribute and higher photosynthetic area and thereby yield contributing characters (Sarawgi *et al.*, 2012).

Table 1. Influence of integrated nutrient management practices on yield of soybean and pigeonpea under intercropping system

Treatments	Soybean seed yield (kg/ha)		Pigeonpea grain yield (kg/ ha)	
	Kharif 2006	*Kharif* 2007	*Kharif* 2006	*Kharif* 2007
Factor I-NPK levels of the base crop				
50% RDF (10:40:20kg::N:P_2O_5:K_2O/ha)	1077	1053	909	826
75% RDF (15:60:30kg ::N:P_2O_5:K_2O/ha)	1177	1165	998	912
100% RDF (20:80:40kg::N:P_2O_5:K_2O/ha)	1298	1284	1084	991
SEd (±)	37	42	31	33
CD (P = 0.05)	**77**	**86**	**65**	**68**
Factor II - FYM and zinc levels				
Control	1125	1105	951	865
FYM @ 5 t/ha	1238	1223	1035	946
Zinc @ 5 kg/ha	1134	1111	959	873
FYM@ 5 t/ha+ zinc@ 5 kg/ ha	1240	1229	1043	954
SEd (±)	43	48	36	38
CD (P=0.05)	**89**	**99**	**75**	**79**
Cropping systems				
Soybean + pigeonpea (2:1 ratio)	1184	1167	997	909
Soybean sole (20:80:40kg ::N:P_2O_5:K_2O/ha)	1582	1565	-	-
Pigeonpea sole (20:50:00kg ::N:P_2O_5:K_2O/ha)	-	-	1325	1289
SEd (±)	55	61	46	49
CD (P = 0.05)	**113**	**127**	**95**	**100**

Application of organic manure (FYM @ 5 t/ha) alone or in combination with micronutrients (FYM @ 5 t/ha + zinc @ 5 kg/ha) also significantly increased the grain yield of soybean and pigeonpea under intercropping system than application zinc alone and control. Combined application of FYM and zinc to the base crop registered the highest soybean yield (1,240 and 1,229 kg/ha) and pigeonpea yield (1,043 and 954 kg per ha) during *kharif* 2006 and *kharif* 2007, respectively. The improvement in structural attributes of yield with integrated applications of organic manure and micronutrient levels might be attributed to better supply of nutrients through incorporation of organic manures along with conducive physical environment leading to better root activity and higher nutrient absorption which resulted in better plant growth, improvement in various physiological processes and efficient partitioning of assimilates to the economic sink. Similar results were reported by Kantwa *et al.* (2006) and Thakur *et al*. (2011).

Yield advantage based on biological potential

Cropping systems, inorganic fertilizer, organic manure and micronutrients levels exhibited measurable improve-ments in land equivalent ratio (LER), land equivalent coefficient (LEC) and soybean seed equivalent yield (SSEY) in both the years of field experimentation (Table 2). LER is basic criteria used for assessing the biological potential yield advantage over monocropping and LER was calculated based on relating the yield of each crop in an intercrop treatment mixture to the yield of that crop grown as a sole crop. The interpretation in LER represents the land area required for sole crops to produce the yield achieved in the intercropping mixture. LEC is the product of LER of the intercrop components therefore it regarded as measure of association/interaction and concerned with the strength of relationship. Soybean seed equivalent yield (SSEY) is another form of single measurement comparison, which is exactly equivalent to the financial value index it was computed by converting the yield of pigeonpea into the yield of soybean based on ratio of existing market price of pigeonpea and soybean.

Soybean intercropped with pigeonpea registered significantly higher LER of 1.51 and 1.47, LEC of 0.58 and 0.55 and SSEY of 3178 and 2,986 kg per hathan respective sole cropping system during *kharif* 2006 and *kharif* 2007, respectively. It was due to similar yield of intercropped soybean as that of its sole stand and additional yield of pigeonpea as a bonus in intercropping system. A value of LER greater than 1, LEC greater than 0.25 and SSEY value greater than mono-cropping value indicates an overall biological advantage, complementary yield, elasticity and productive potential of intercropping system over sole crop culture due to better utilization of natural resources on time and space dimension (Bhatti *et al*., 2006; Kumar *et al*., 2012).

Inorganic fertilizer application showed remarkable improvement in yield advantage by biological means in terms of LER, LEC and SSEY. Among the levels of fertilizer, application of 100 per cent RDF (20:80:40 kg ::$N:P_2O_5:K_2O$/ha) significantly increased the LER (1.65 and 1.60), LEC (0.69 and 0.65) and SSEY (3,466 and 3,266 kg/ha) during *kharif* 2006 and *kharif* 2007, respectively followed by 75 per cent RDF (15:60:30kg:: $N:P_2O_5:K_2O$/ha) which recorded LER of 1.50 and 1.47, LEC of 0.57 and 0.55 and SSEY of 3,173 and 2,989 kg per ha in *kharif* 2006 and *kharif* 2007, respectively. Higher LER, LEC and SSEY values in intercropping system in higher level of inorganic fertilizer application mainly attributed by good realization of sink in grain legumes through adequate balance of nutrients in the soil (Kantwa *et al.*, 2005; Lal *et al.*, 2013). This can only be achieved through judicious use of fertilizer under limited resource conditions in inter-cropping system. Application of higher level of synthetic fertilizers stabilize the available nutrient content of the soil throughout the crop growth period and more specifically at critical stages, thereby enhancement in various physiological determinants of crop growth and development which lead to realization of maximum biological productivity of component crops and competitive complementarity in intercropping system.

Cropping system land productivity in terms of LER and LEC and total productivity in terms of SSEY in application of FYM @ 5t per ha alone or in combination with zinc @ 5kg per ha also showed measurable improvement. Combined application of FYM @ 55 t per haand zinc @ 5 kg per ha to the intercropping system significantly produced higher LER of 1.58 and 1.54, LEC of 0.63 and 0.61 and S SEY of 3,326 and 3,137 kg per ha during *kharif* 2006 and *kharif* 2007, respectively and this was on par with application of FYM @ 5t per ha and significantly higher than application of zinc @ 5 kg per haand control. It might be due to the fact that significant increases in grain yield of both the component crops was with organic manure and micronutrient application (Kantwa *et al.*, 2006; Kumar *et al.*, 2012). It implies that intercropping system involving soybean and pigeonpea has given higher biological efficiency than either of the component crops alone. It also might be concluded that complimentary relationship exists between the component crop therefore yield from individual crop was more than the expected. In the intercropping system, differences in growth pattern and peak development period between soybean and pigeonpea made possible for better temporal and spatial utilization of all the available resources. Similar finding was reported by Imran *et al.* (2011).

Land use efficiency and productivity

Land use efficiency and productivity in terms of area-time equivalence ratio and crop performance ratio were positive which showed a definite yield advantage with all nutrient management practices and fertilizer and manure level in intercropping system as compared to sole cropping of component crops during both the years of field study (Table 3). However, aggressivity values were negative and it indicated that there was least competitive interaction/ dominant ability between component crops in intercropping system. Area-time equivalency ratio (ATER) is only appropriate in systems with component crop of contrasting maturities such as 95 days soybean and 150 days pigeonpea. When the difference between growth duration of component crops is substantial, time becomes an important element and ATER is considered to be a more appropriate index of efficiency of the intercropping system. Crop performance ratio (CPR) is the productivity of an intercrop per unit area of ground compared with that expected from the sole crops sown in the same proportion. If a value CPR greater than unity implies an intercrop advantage and a value less than unity an intercrop disadvantage. The concept of CPR can also be extended to analyze the use of a resource by an intercrop compared with its constituent species.

Area-time equivalency ratio (ATER), crop performance ratio (CPR) values were positive which represented a definite quantity of yield advantage in intercropping system with all nutrient management practice and fertility level as compared to sole cropping of each crops. Scrutiny of the productivity and efficiency indices data in Table 3 clearly indicated that the imposed treatments in intercropping system produced marked variation in ATER, CPR and A values in both field trials. Soybean + pigeonpea inter-cropping system recorded significantly higher ATER of 1.26 and 1.23 and CPR of 1.13 and 1.11 in *kharif* 2006 and *kharif* 2007, respectively as compared to sole cropping. ATER and CPR provided more realistic comparison of the yield advantages of intercropping system over sole cropping in terms of variation in time taken by the component crops and productivity of component crops in soybean+pigeonpea intercropping system under different fertilizer management and organic manure and micronutrient management practice. It might bedue to the higher grain yield of both soybean and pigeonpea in intercropping as compared to sole cropping (Ghosh *et al*., 2006; Lal *et al*., 2013). More than unity values of ATER and CPR indicated advantage of intercropping system.

Application of inorganic fertilizer at various levels significantly recorded more than unity value of ATER and CPR by means of yield advantage and better productivity of component crops in intercropping systems. In the field experiments, 100 per cent RDF significantly enhanced the ATER value (1.38 and 1.34) and CPR value (1.23 and 1.21) in *kharif* 2006 and *kharif* 2007 respectively followed by 75 per cent RDF which was due to similar yield of soybean to that of its sole stand and additional yield of pigeonpea as a bonus in intercropping system. Similar finding was also reported by Padhi *et al.* (2010) and Lal *et al*. (2013). Integrated application of FYM @ 5 t per ha + zinc @ 5 kg per ha or application of FYM @ 5 t per ha alone in intercropping system also significantly registered higher ATER value of 1.32 and 1.29 and CPR value of 1.18 and 1.17in *kharif* 2006 and *kharif* 2007, respectively.

Combined application of organic manure and micronutrient markedly improved nutrient availability on temporal and spatial distribution and enhanced the utilization of available nutrients. This might be attributed to increase in economic yield of component crops with integrated nutrient management practices. The contributing effect of various yield attributes and yield fetched maximum ATER and CPR values with increasing fertility levels. These findings are also in line with those of Kantwa *et al.* (2006) and Kumar *et al*. (2012).

Aggressivity (A) indices give a simple measure of the relative competitiveness/domi-nance of the component crops in intercropping system and it also helps to calculate quantity of relative yield increase in species 'a' greater than that of species 'b'. An aggressivity value zero indicates that the component species are equally competitive. The basic process in the aggressivity indices is the calculation of two equivalent factors, one for each component species. It is the product of two equivalence factors. The equivalence factor is the number of plants of component crop 'a' which equally competitive to one plant of component crop 'b'. If a component crop 'a' has an equivalence factor of less than one, it means crop has more competitive ability and there has been an advantage of mixing. In this study, there were significant differences among the nutrient management treatments. In all treatments, value of aggressivity was lesser than unity in soybean + pigeonpea intercropping systems. This indicates that in order to improve the efficiency of the intercropping systems, efforts should be accelerated towards improving the productivity of dominated components as sole cropping.

Table 2. Land equivalent ratio, land equivalent coefficient and soybean seed equivalent yield of intercropping system as influenced by integrated nutrient management practices

Treatments	Land equivalent ratio (LER)				Land equivalent coefficient (LEC)				Soybean seed equivalent yield (SSEY) (kg/ha)			
	Kharif 2006		*Kharif* 2007		*Kharif* 2006		*Kharif* 2007		*Kharif* 2006		*Kharif* 2007	
Factor I - NPK levels to the intercrop (F)												
50% RDF (10:40:20 kg :: $N:P_2O_5:K_2O$/ha)	1.37		1.32		0.48		0.45		2895		2705	
75% RDF (15:60:30 kg :: $N:P_2O_5:K_2O$/ha)	1.50		1.47		0.57		0.55		3173		2989	
100% RDF (20:80:40 kg :: $N:P_2O_5:K_2O$/ha)	1.65		1.60		0.69		0.65		3466		3266	
Factor II - FYM and zinc levels to the intercrop (M)												
Control	1.43		1.39		0.52		0.49		3027		2835	
FYM @ 5 t/ha	1.57		1.53		0.63		0.60		3308		3115	
Zinc @ 5 kg/ha	1.45		1.39		0.53		0.49		3052		2857	
FYM@ 5 t/ha+ zinc @ 5 kg/ ha	1.58		1.54		0.63		0.61		3326		3137	
Cropping system												
Soybean + pigeonpea intercropping	1.51		1.47		0.58		0.55		3178		2986	
Soybean sole	1.00		1.00		0.25		0.25		1582		1565	
Pigeonpea sole	1.00		1.00		0.25		0.25		2650		2578	
Factor	SEd (±)	**CD (P=0.05)**	SEd (±)	**CD (P=0.05)**	SEd (±)	**CD (P=0.05)**	SEd (±)	**CD (P=0.05)**	SEd (±)	**CD (P=0.05)**	SEd (±)	**CD (P=0.05)**
F	0.05	**0.10**	0.05	**0.11**	0.04	**0.08**	0.04	**0.08**	104	**213**	96	**197**
M	0.05	**0.11**	0.06	**0.13**	0.04	**0.09**	0.05	**0.10**	120	**246**	111	**228**
F x M	0.09	**NS**	0.11	**NS**	0.08	**NS**	0.08	**NS**	207	**NS**	192	**NS**
Intercropping *vs* soybean sole	0.07	**0.14**	0.08	**0.16**	0.06	**0.11**	0.06	**0.12**	152	**312**	141	**290**
Intercropping *vs* pigeonpea sole	0.07	**0.14**	0.08	**0.16**	0.06	**0.11**	0.06	**0.12**	152	**313**	141	**290**

Table 3. Productivity and efficiency indices of soybean+pigeonpea intercropping system as influenced by organic manure and fertility levels

Treatments	Area-time equivalency ratio (ATER)				Crop performance ratio (CPR)				Aggressivity (A)			
	Kharif 2006		*Kharif* 2007		*Kharif* 2006		*Kharif* 2007		*Kharif* 2006		*Kharif* 2007	
Factor I - NPK levels to the intercrop (F)												
50% RDF (10:40:20 kg ::N:P_2O_5:K_2O/ha)	1.15		1.11		1.03		1.00		-0.35		-0.31	
75% RDF (15:60:30 kg ::N:P_2O_5:K_2O/ha)	1.26		1.23		1.13		1.11		-0.38		-0.34	
100% RDF (20:80:40 kg ::N:P_2O_5:K_2O/ha)	1.38		1.34		1.23		1.21		-0.41		-0.36	
Factor II – FYM and zinc levels to the intercrop (M)												
Control	1.20		1.16		1.08		1.06		-0.36		-0.32	
FYM @ 5 t/ha	1.32		1.28		1.18		1.16		-0.39		-0.35	
Zinc @ 5 kg/ha	1.22		1.17		1.09		1.06		-0.37		-0.32	
FYM@ 5 t/ha+ zinc @ 5 kg/ ha	1.32		1.29		1.18		1.17		-0.40		-0.35	
Cropping system												
Soybean + pigeonpea intercropping	1.26		1.23		1.13		1.11		-0.38		-0.34	
Soybean sole	1.00		1.00		1.00		1.00		-		-	
Pigeonpea sole	1.00		1.00		1.00		1.00		-		-	
Factor	SEd	**CD(P=0.05)**	SEd	**CD(P=0.05)**	SEd	**CD(P=0.05)**	SEd	**CD (P =0.05)**	SEd	**CD (P=0.05)**	SEd	**CD (P=0.05)**
F	0.04	**0.08**	0.04	**0.09**	0.04	**0.07**	0.04	**0.08**	0.01	**0.02**	0.01	**0.02**
M	0.05	**0.09**	0.04	**0.10**	0.04	**0.08**	0.05	**0.09**	0.01	**0.03**	0.01	**0.02**
F x M	0.08	**NS**	0.09	**NS**	0.07	**NS**	0.08	**NS**	-	**-**	-	**-**
Intercropping *vs* soybean sole	0.06	**0.12**	0.06	**0.13**	0.05	**0.11**	0.05	**0.10**	-	**-**	-	**-**
Intercropping *vs* pigeonpea sole	0.06	**0.12**	0.06	**0.13**	0.05	**0.11**	0.05	**0.10**	-	**-**	-	**-**

The results of the field experiments indicate that soybean + pigeonpea intercropping system at 2:1 row ratio as replacement series under integrated nutrient management practices enhanced the biological potential of component crops, maximized the cropping system productivity and improved the land use efficiency. It also suggests that all the integrated nutrient management practices tested in intercropping system were biologically superior and economically beneficial. Integrated nutrient management practices comprising of 100 per cent RDF (20:80:40 kg::N:P_2O_5:K_2O/ha) and FYM @ 5 t per ha+ zinc @ 5 kg per ha can be successfully practiced with competitive complementarity and without too much inter-crop competition in soybean + pigeonpea intercropping system. Furthermore, the balanced application of inorganic fertilizer, organic manure and micronutrient may improve the soil fertility status, correct nutrient deficiency, maximize the yield of component crop in intercropping system and facilitate better crop and environment quality. Integrated nutrient management practices that promote better crop growth and development and yield of crops invariably enhance the resource-use efficiency.

REFERENCES

Adetiloye P O and Ezedinma F O C. 1983. A land equivalent co-efficient (LEC) concept for the evaluation of competitive and productive interactions in simple to complex crop mixtures**.** *Ecological Modelling***19**: 27-39.

Anonymous. 2012. *Agriculture Statistics at a Glance 2012*, Published by Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India.

Ali A S N, Mathews R B, Williams J H and Peacock J M. 1990. Light use, water uptake and performance of individual components of sorghum and groundnut intercrop. *Experimental Agriculture* **26**: 413 - 27.

Bhatti I H, Ahmed R, Jabbar A, Nazir M S and Mahmood T. 2006. Competitive behavior of component crops in different sesame legume intercropping systems. *International Journal of Agriculture and Biology* **8**: 165-7.

Ghosh P K, Mohanty M, Bandyopadhyay K, Painuli D K and Misra A K. 2006. Effect of nutrient management on growth, competition, yield advantage and economics in soybean/pigeonpea inter-cropping system in semi-arid tropics of India. *Field Crops Research* **96**: 90-7.

Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*, 2nd edn. John Wiley and Sons, New York, pp 680.

Halvankar G B, Varghese Philips, Taware S P and Raut V M. 2000. Evaluation of intercropping patterns of soybean (*Glycine max*) in pigeonpea (*Cajanus cajan*). *Indian Journal of Agronomy* **45**: 553- 8.

Heibsch C K and Mc Collum R E. 1987. Area x time equivalency ratio: A method for evaluating the productivity of inter crops. *Agronomy Journal* **79**: 15-22.

Imran M, Ali A, Waseem M, Tahir M, Ullah A, Shehzad Mohsin, Ghaffari A and Rehman H. 2011. Bio-economic assessment of sunflower-mungbean intercropping system at different planting geometry. *International Research Journal of Agricultural Science and Soil Science* **1**: 126-36.

Kantwa S R, Ahlawat I P S and Gangaiah B. 2005. Effect of land configuration, post monsoon irrigation and phosphorus fertilization on performance of sole and intercropped pigeonpea. *Indian Journal of Agronomy* **50**: 278-80.

Kantwa S R, Ahlawat I P S and Gangaiah B. 2006. Performance of sole and intercropped pigeonpea as influenced by land configuration, post monsoon irrigation and phosphorus fertilization. *Indian Journal of Agricultural Sciences* **76**: 635-7.

Kumar P and Rana K S. 2007. Performance of pigeonpea (*Cajanus cajan*) + greengram (*Phaseolus radiatus*) intercropped systems as influenced by moisture conservation practices and fertility levels under moisture conservation practices and fertility levels under rainfed conditions. *Indian Journal of Agronomy* **52**: 31-5.

Kumar P, Rana K S and Rana D S. 2012. Effect of planting systems and phosphorus with biofertilizer on the performance of sole and intercropped pigeonpea (*Cajanus cajan*) under rainfed conditions. *Indian Journal of Agronomy* **57**: 127-32.

Lal B, Rana K S, Rana D S, Shivay Y S, Gautam Priyanka, Ansari M A and Joshi E. 2013. Assessment of economics, energy use and yield advantage indices of Ethiopian mustard + chickpea intercropping system under dryland condition. *Research on Crops* **14**: 518-824

Mc Gilchrist G A. 1965. Analysis of competition experiments. *Biometrics* **21**: 975-85.

Mucheru-Muna M, Pypers P, Mugendi D, Kungu J, Mugwe J, Merckx R and Vanlauwe B. 2010. A suggested maize-legume intercrop arrangement robustly increases crop yield and economic returns in the highlands of Central Kenya. *Field Crops Research* **115**: 132-9.

Padhi A K, Panigrahi R K and Jena B K. 2010. Effects of planting geometry and duration of intercrops on performance of pigeonpea + finger millet intercropping system. *Indian Journal of Agricultural Sciences* **44**: 635-7.

Sarawgi S K, Chitale S, Tiwari A and Bhoi S. 2012. Effect of phosphorus application along with PSB, Rhizobium and VAM on P fractionation and productivity of soybean (*Glycine max*). *Indian Journal of Agronomy* **51**: 55-60.

Thakur R, Sawarkar S D, Vaishya U K and Singh M. 2011. Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. *Journal of Indian Society of Soil Science* **52**: 74-81.

Vishwanathan S, Koppalkar B G, Anilkumar S N, Desai B K and Naik V. 2011. Economics and yield advantages of pigeonpea and sunflower intercropping system influenced by fertilizer management. *Research Journal of Agricultural Sciences* **2**: 248-51.

Willey R W. 1979. Intercropping - its importance and research needs, Part II. Competition and yield advantages. *Field Crop Abstract* **32**: 73-8.

Soybean Research (Special Issue Number 2): 173-181: 2014

Evaluation of Intercropping of Soybean with Different Row Proportions and Weed Management Practices in Upland Rainfed Rice

K T JADHAV [1], U N ALSE[1], V P SURYAWANSHI[2] and M S SURYAWANSHI[3]
Upland Paddy Research Scheme, Vasantarao Naik Marathwada Krishi Vidyapeeth, Parbhani 431 402, Maharashtra, India
E mail: kirantjadhav76@gmail.com, jyotikiran2003@gmail.com

ABSTRACT

A field experiment on evaluation of intercropping of soybean with different row proportions and weed management practices in upland rainfed rice was conducted on medium black soil with slightly alkaline in reaction at Upland Paddy Research Scheme Farm, Parbhani. Amongst weed management practices in 2011-12 and 2012-13, pre-emergence application of pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS produced significantly higher soybean seed yield over rest of the weed management practices except two mechanical weeding at 20 and 40 DAS. Amongst various intercropping treatments sole rice crop gave significantly higher rice grain yield than rest of the rice + soybean intercropping systems during both the years. Rice + soybean (4:2) showed significantly higher grain yield over rest of the rice intercropping systems except rice + soybean at 2:1 ratio during both the years of experimentation. In 2011-12 and 2012-13, rice + soybean (3:2) gave significantly more soybean seed yield over rest of the intercropping systems. Rice + soybean (4:2) intercropping was observed to be statistically at par with rice + soybean (2:1) in both the years of investigation and both were significantly better than rice + soybean (5:1). Highest rice grain equivalent yield was recorded by pre-emergence application of pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS except two mechanical weeding at 20 and 40 DAS amongst weed management practices. Rice grain equivalent yield was significantly influenced by interaction of weed management and intercropping. Significantly higher rice grain equivalent yield was obtained with the interaction of pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS with rice + soybean at the ratio of 3:2 over rest of the interactions in both the years , however, it was at par with pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS practiced for rice + soybean at the ratio of 4:2 in both the years and combination of two mechanical weeding with rice + soybean at the ratio of 3:2 in 2012-13. Highest weed dry weight was recorded with weedy check. Amongst weed control treatments, pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS recorded significantly lowest weed dry weight in both the years at all stages of observation (30 DAS, 60 DAS and at harvest), however, this was at par with pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS at 30 DAS in 2011-12, at 60 DAS in 2012-13 and at harvest in both the years.

Key words: Rice grain equivalent, rice and soybean intercropping, upland rice, weed dry weight

---

[1]*Associate Professor;* [2]*Assistant Professor;* [3] *Senior Research Assistant*

In view of shrinkage of resources like arable land, irrigation water and energy, there is an urgent need to design and develop new methods and techniques of crop production to meet the increasing demand for food, feed and forage through effective utilization of available agricultural input resources. Rice plays pivoted role in reference to food security of Indian sub-continent. Rice production in the tune of ever increasing population will be challenging for rice growers, moreover, emerging alternative crops for rice which are more profitable that requires less water and labour (Tomar *et al*., 2012) and ever increasing cost of inputs has aggravated the task of meeting the demand of rice production at national level. Short fall in rice production leads to economical, social and nutritional insecurity in India and this has been witnessed in recent past and will be acute in future. Moreover, uncertainties of rainfall, limitation for increasing irrigation facilities towards traditional rice cultivation method, fertilizer and pesticide availability are major challenges for attaining desired rice production at state and national level. This necessitates to find out appropriate alternative and more efficient production systems such as multiple cropping (inter/relay cropping) which can ensure proper utilization of resources to obtain increased production per unit area and time on a sustainable basis (Jabbar *et al*., 2010), particularly for non-traditional areas of rice growing region of India. Legumes in association with major staple food crops like rice could be successfully introduced to enhance the productivity of the system (Arya *et al*., 2012). Similarly, weed management is big challenge in upland rice. Singh *et al*. (2005) reported reduction in grain yield by 75.8, 70.6 and 62.6 per cent under dry seeded rice, wet seeded rice and transplanted rice, respectively due to uncontrolled weeds. Dwivedi and Srivastava (2011) found reduction in weed population under cereal + legume intercropping. In accordance with this, a trial was conducted to test the performance of soybean as an intercrop in different row ratios with rice coupled with different weed management practices.

MATERIAL AND METHODS

A field experiment on evaluation of intercropping of soybean with different row proportions and weed management practices in upland rainfed rice was conducted on medium black soil with slightly alkaline in reaction at Upland Paddy Research Scheme Farm, Parbhani for consecutive two years (2011-12 and 2012-13). The experiment was laid out in split plot design with three replications. Weed management treatments carried out in main plots were pendimethalin @ 0.75 kg a.i. per ha, pendimethalin @ 0.75 kg a.i. per ha followed by one hand weeding (HW) at 25 days after sowing (DAS), two mechanical weeding at 20 and 45 DAS and an un weeded control and in sub-plots treatments different row proportions of soybean intercrop, namely, rice (20 cm row spacing), rice + soybean (2:1), rice + soybean (3:2), rice + soybean (4:2) and rice + soybean (5:1). Rice (*var*. Parag) was sown using 60 kg of seed rate and soybean (*var* JS 335) was sown as an intercrop at the seed rate of 75 kg per ha as per the treatments with recommended dose of fertilizer (80:50:50 kg::N:P_2O_5:K_2O/ha) with the row spacing of 20 cm. Pendimethalin as pre-emergence @ 0.75 kg a.i. per ha was sprayed manually after sowing as per the treatments. Soil was low in nitrogen, ferrous and zinc; medium in phosphorous and rich in potash.

RESULTS AND DISCUSSION

Rice grain yield

Weed management practices: Amongst weed management practices in 2011-12 and 2012-13, pre-emergence application of pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS produced significantly higher grain yield (2,636 and 2,895 kg/ha, respectively) over rest of the weed management practices except two mechanical weeding at 20 and 40 DAS (2,553 and 2,831 kg/ha). Lowest rice grain yield was observed with unweeded control (813 and 897 kg/ha) during 2011-12 and 12-13 (Table 1). Sinha *et al*. (2006) reported higher rice grain yield with pre emergence application of pendimethalin coupled with one hand weeding at 25 DAS under dry seeded sole rice crop.

Intercropping systems: Amongst various intercropping treatments, sole rice crop gave significantly higher rice grain yield than rest of the rice + soybean intercropping systems during both the years (Table 1). Rice + soybean (4:2) showed significantly higher grain yield over rest of the rice intercropping systems except rice + soybean at 2:1 row ratio during both the years of experimentation. Lowest rice grain yield was observed with rice + soybean (5:1). Reduction in grain yield of rice due to intercropping was also reported by Chandra *et al*. (1992), which might be attributed to lowered population of rice in intercropping system due to introduction of soybean crop.

Soybean seed yield

Weed management practices: In case of soybean seed yield amongst weed management practices, application of pendimethalin @ 0.75 kg per ha followed by one hand weeding at 25 DAS produced significantly more soybean seed yield (629 and 690 kg/ha) over rest of the treatments except mechanical weeding on 25 and 40 DAS (603 and 662 kg/ha). Unweeded control gave significantly lower soybean seed yield (230 and 254 kg/ha) over rest of the treatments during both the years (Table 1).

Intercropping system: In 2011-12 and 2012-13, rice + soybean (3:2) gave significantly more soybean seed yield (861 and 946 kg/ha) over rest of the intercropping systems (Table 1). Rice + soybean (4:2) was statistically at par with rice + soybean (2:1) in respect of soybean seed yield in both the years of investigation and both were significantly better than rice + soybean (5:1).

Rice grain equivalent yield

Weed management practices: The significantly highest rice equivalent yield amongst weed management practices was recorded by pre-emergence application of pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS (3,620 and 4,006 kg/ha) except two mechanical weedings at 20 and 40 DAS (3,497 and 3,897 kg/ha) in 2011-12 and 1012-13, respectively (Table 1). Lowest grain yield was observed with unweeded control (1,173 and 1,306 kg/ha) in both the years of experimentation.

Intercropping systems: In 2011-12 and 2012-13, rice + soybean (3:2) gave significantly more rice grain equivalent yield (3,370 and 3,815 kg/ha) over rest of the intercropping systems except rice + soybean (4:2) (3,266 and 3,620 kg/ha) in the first year of investigation and both were significantly better than rest of the intercropping systems and sole rice crop (Table 1). Rice + soybean (5:1) recorded significantly lowest rice grain equivalent yield (2,196 and 2,438 kg/ha), which was comparable with sole rice crop (2,294 and 2,523 kg/ha). Munda *et al.* (2002) reported

Table 1. Yields as influenced by weed management and intercropping of rice with soybean

Treatment	Rice grain yield (kg/ha)		Soybean seed yield (kg/ ha)		Rice equivalent yield (kg/ha)	
	2011-12	**2012-13**	**2011-12**	**2012-13**	**2011-12**	**2012-13**
Pendimethalin @ 0.75 kg a.i. /ha	2338	2602	497	546	3115	3481
Pendimethalin @ 0.75 kg a.i./ha followed by one hand weeding at 25 DAS	2636	2895	629	690	3620	4006
Two mechanical weeding at 20 and 45 DAS	2553	2831	603	662	3497	3897
Unweeded control	813	897	230	254	1173	1306
S Em (±)	62.72	71.6	13.92	15.4	81.64	82
C D (P = 0.05)	**173.59**	**197.6**	**38.53**	**42.9**	**216.68**	**230.5**
Rice (20 cm row spacing)	2294	2523	--	--	2294	2523
Rice + soybean (2:1)	2131	2341	638	702	3130	3471
Rice + soybean (3:2)	2022	2292	861	946	3370	3815
Rice + soybean (4:2)	2171	2382	700	769	3266	3620
Rice + soybean (5:1)	1807	1998	249	273	2196	2438
S Em (±)	16.48	19.68	24.01	27.0	43.24	61.25
C D (P = 0.05)	**45.65**	**54.5**	**66.45**	**74.7**	**113.53**	**121.6**

DAS- Days after sowing

higher rice grain equivalent yield under rice + soybean (4:2) intercropping system in comparison to sole crop of rice under rainfed mid-hill dry terraces of Meghalaya.

Interaction

Rice grain yield: Rice grain yield was significantly influenced due to interaction effects of weed management practices and intercropping treatments (Table 2). Significantly highest rice grain yield was obtained in pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS in sole crop of rice and it was at par with mechanical weeding at 25 and 40 DAS with sole crop of rice in 2011-12 and similar trend was observed in 2012-13. In 2011-12, amongst weed management and Rice + soybean intercropping treatments, highest rice grain yield was obtained with the combination of rice + soybean (4:2) and pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS, however, it was at par with rice + soybean (2:1) with pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS and rice + soybean (4:2) with mechanical weeding at 25 DAS and 40 DAS. Similar results were observed in 2012-13 as well.

Soybean seed yield: Soybean seed yield was significantly influenced by interaction of weed management practices and

Table 2. Interaction effect between weed management treatments and rice + soybean intercropping on rice grain yield, soybean seed yield and rice equivalent yield

Treatments	Rice (20 cm row spacing)		Rice + soybean (2:1)		Rice + soybean (3:2)		Rice + soybean (4:2)		Rice + soybean (5:1)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Rice grain yield (kg/ha)										
Pendimethalin @ 0.75 kg a.i./ha	2564	2820	2404	2650	2297	2660	2425	2660	1908	2211
Pendimethalin @ 0.75 kg a.i./ha + one hand weeding at 25 DAS	2862	3152	2703	2949	2596	2825	2724	2991	2297	2521
Two mechanical weeding at 20 and 45 DAS	2799	3077	2618	2874	2447	2831	2692	2959	2425	2436
Un weeded control	951	1047	801	887	748	823	844	929	723	801
S Em (±)	32.96	39.5								
C D (P = 0.05)	**91.23**	**108.9**								
Soybean seed yield (kg/ha)										
Pendimethalin @ 0.75 kg a.i./ha	--	--	633	695	900	990	700	770	250	274
Pendimethalin @ 0.75 kg a.i./ha + one hand weeding at 25 DAS	--	--	775	870	1120	1227	925	990	323	354
Two mechanical weeding at 20 and 45 DAS	--	--	825	890	1000	1094	875	991	315	347
Un weeded control	--	--	318	351	425	474	300	327	107	117
S Em (±)	48.2	53.99								
C D (P = 0.05)	**132.9**	**149.4**								
Rice equivalent yield (kg/ha)										
Pendimethalin @ 0.75 kg a.i./ha	2564	2820	3395	3769	3705	4554	3520	3900	2389	2652
Pendimethalin @ 0.75 kg a.i./ha + one hand weeding at 25 DAS	2862	3152	3916	4366	4349	4801	4172	4585	2802	3091
Two mechanical weeding at 20 and 45 DAS	2799	3077	3909	4291	4012	4592	4061	4554	2705	2995
Un weeded control	951	1047	1299	1452	1413	1586	1313	1475	890	989
S Em (±)	72.35	87.45								
C D (P = 0.05)	**192.64**	**217.8**								

intercropping treatments under study (Table 2). Significantly higher soybean seed yield was obtained in pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS with rice + soybean (3:2) over rest of the treatment combinations, except the treatment of mechanical weeding at 25 DAS and 40 DAS with rice + soybean (3:2) in 2011-12. This was at par with pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS with a rice + soybean at the ratio of 4:2, pendimethalin @ 0.75 kg a.i. per ha with rice + soybean at the ratio of 3:2 and the interaction of mechanical weeding at 25 and 40 DAS with rice + soybean at the ratio of 4:2 in 2011-12. In 2012-13 significantly highest soybean yield was recorded with the combination of pendimethalin @ 0.75 kg a.i. per ha followed by one hand weeding (HW) at 25 DAS and rice + soybean (3:2). The significantly lowest soybean seed yield was obtained with unweeded control and least introduction of soybean intercrop with a ratio of rice + soybean at 5:1 during both the years.

Rice grain equivalent: Rice grain equivalent yield was significantly influenced by interaction of weed management and intercropping (Table 2). Significantly higher rice grain equivalent yield was obtained with the interaction of pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS with rice + soybean at the ratio of 3:2 over rest of the interactions of weed management and intercropping of rice + soybean in both the years, however, it was at par with pendimethalin @ 0.75 kg per ha followed by hand weeding at 25 DAS practiced for rice + soybean at the ratio of 4:2 in both the years and combination of two mechanical weeding with rice + soybean at the ratio of 3:2 in 2012-13. This might be attributed to better availability of nutrients and moisture in intercropping systems with 4:2 or 3:2 rice + soybean system which supported the growth of both component crops, which resulted in higher equivalent yield of rice grain. Increase in Rice grain equivalent as a result of intercropping was also reported by Joshi (2002).

Weed studies

Major weeds encountered during experimentation were *Commelina benghalensis, Amaranthus sp, Merrimia emarginata, Euphorbia sp., Convolvulus arvensis, Parthenium sp., Xanthium strumarium, Digera arvensis, Abtulion indicum, Alternanthera philoxeroides* among broad leaved, *Echinochloa colonum, Echinochloa crusgali, Dactyloctenium aegyptium, Brachiaria eruciformis, Digitaria sanguinalis, Cynadon dactylon, Setaria tomentosa, Dinebra retroflexa* among grasses and *Cyprus rotundus in sedges.*

Highest weed dry weight was recorded with weedy check. Amongst weed control treatments, pendimethalin @ 0.75 kg a.i. per ha followed by one hand weeding at 25 DAS recorded lowest weed dry weight in both the years at all stages of observation (30 DAS, 60 DAS and at harvest). However, this was at par with two mechanical weeding at 20 and 45 DAS at 30 DAS in 2011-12, at 60 DAS in 2012-13 and at harvest in both the years (Table 3). Similar trends were reported by Singh *et al*. (2008) and Saha (2005). However, intercrop treatments and the interaction effects due to weed management and intercrop practices were non-significant.

Economic evaluation

Weed Management Practices: Significantly highest gross monetary returns were obtained with pendimethalin @ 0.75 kg a.i. per ha followed by one hand weeding at 25 DAS over rest of the practices (Table 4); however, it was on par with two hand weeding at 20 and 45 DAS amongst weed management practices in both the years of experimentation. However, significantly

Table 3. Weed dry weight as influenced by weed management and intercropping

Treatments	Weed dry weight (g/m²)					
	2011-12			2012-13		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Pendimethalin @ 0.75 kg a.i. /ha	38	94	167	33	104	156
Pendimethalin @ 0.75 kg a.i./ha followed by one hand weeding at 25 DAS	13	39	116	16	48	127
Two mechanical weeding at 20 and 45 DAS	20	49	128	24	59	132
Unweeded control	96	214	305	89	235	328
S Em (±)	2.3	2.96	4.7	2.3	3.45	5.4
C D (P = 0.05)	7.4	8.94	14.8	7.4	11.49	16.3
Rice (20 cm row spacing)	48	108	191	47	120	198
Rice + soybean (2:1)	41	98	175	40	109	184
Rice + soybean (3:2)	38	95	169	37	108	172
Rice + soybean (4:2)	36	93	172	33	105	179
Rice + soybean (5:1)	47	102	188	46	114	197
S Em (±)	1.78	3.5	6.4	1.64	3.7	7.2
C D (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction						
S Em (±)	3.2	4.8	9.4	3.5	5.6	11.2
C D (P = 0.05)	NS	NS	NS	NS	NS	NS

DAS- Days after sowing

highest net monetary returns was obtained with pendimethalin@ 0.75 kg a.i. per ha followed by one hand weeding at 25 DAS than rest of the weed management practices in both the years of experimentation followed by two hand weeding at 20 and 45 DAS.

Intercropping: Significantly highest gross and net monetary returns was noted with rice + soybean (3:2) in 2011-12 and 2012-13 and was closely followed by rice + soybean (2:1) and rice + soybean (4:2) and were at par with each other in both the years of study (Table 4).

Studies carried out in 2011-12 and 2012-13 indicated that rice + soybean intercropping at the row ratio of 4:2 or 3:2 with the pre-emergence application of pendimethalin @ 0.75 kg a.i. per ha gave better rice grain equivalent yield. Further from the study it can be concluded that there is scope to increase the profitability of upland rice crop with the introduction of suitable intercrop to assure the sustainable rice based cropping system in rainfed upland rice crop.

Table 4. Monitory returns obtained in 2011-12 and 12-13 with weed management practices and intercropping in rice

Treatments	Gross monitory returns (Rs)		Net monitory returns (Rs)	
	Year of experiment			
	11-12	12-13	11-12	12-13
Pendimethalin @ 0.75 kg a.i. /ha	36485	48785	17311	27891
Pendimethalin @ 0.75 kg a.i./ha followed by one hand weeding at 25 DAS	42076	55811	20602	32348
Two mechanical weeding at 20 and 45 DAS	40772	54391	16998	28557
Unweeded control	13757	18443	-4397	-2817
SEm (±)	881.3	1078	451	356
CD (P = 0.05)	2344	3028	1254	958
Rice (20 cm row spacing)	27546	36122	7836	13582
Rice + soybean (2:1)	36383	48365	15368	25490
Rice + soybean (3:2)	38827	52768	17612	29693
Rice + soybean (4:2)	36674	50174	15659	27299
Rice + soybean (5:1)	25929	34449	5664	13829
SEm (±)	467	805	254	394
CD (P = 0.05)	1220	2247	634	1096

REFERENCES

Chandra D, Raju A R and Singh U D. 1992. Evaluation of suitable rice and pegeonpea varieties for intercropping under upland conditions in Orissa, India. *International Rice Research Newsletter* **17**(5): 19.

Arya M P S, Srivastava B C, Behera B C and Singh S P. 2012. Intercropping models for efficient use of natural resources and family sustenance. *Extended Summaries Vol. 2: third International Agronomy Congress*, Nov. 26-30 , 2012, New Delhi, India. pp: 634-635

Dwivedi K S and Srivastava G K. 2011. Planting geometry and weed management for maize (*Zea mays*)- blackgram (*Vigna mungo*) intercropping system under rainfed Vertisols. *Indian Journal of Agronomy* **56**: 202-8.

Jabbar Abdul, Ahmad Riaz, Iftikhar Hussain B, Atiqueur-Rehman, Zaheer Abbas V and Shah N V. 2010. Effect of different rice-based intercropping systems on rice grain yield and residual soil fertility. *Pakistan Journal of Botany* **42**(4): 2339-48.

Joshi M. 2002. Dynamics of rice-based cropping systems in southern transitional zone of Karnatka, India. *International Rice Research Newsletter* **27**(1): 41-2.

Munda G C, Patel D P and Mokidul Islam. 2011. Performance of different cropping systems under rainfed mid-hill dry terraces of Meghalaya. *Extended Summaries Vol. 2: Second International Agronomy Congress*, Nov. 26-30, 2002, New Delhi, India, pp 1064-5.

Saha Sanjay. 2005. Efficacy of certain new herbicides formulation in transplanted rice under rainfed shallow lowland. *Indian Journal of Weed Science* **37**: 109-10.

Singh S, Singh G, Singh V P and Singh A P. 2005. Effect of establishment methods and weed management practices on weeds and rice in –wheat cropping system. *Indian Journal of Weed Science* **37**: 51-7.

Singh Parmeet, Singh, P. and Singh, S. S. 2008. Production potential and economic analysis of direct wet seeded aromatic rice (*Oryza sativa*) Cv. Pusa basmati 1 as influenced by fertility level and weed management practiced. *Oryza* **45** (1): 23-6.

Sinha S K P, Singh A K and Singh B K. 2006. Zero and reduced tillage technologies boost up rice crop yield in Indo-Gangetic plains of Bihar. *Abstracts in International Rice Congress,* New Delhi, India. 9-13 Oct., 2006, pp 502.

Tomar S S, Hada Neeraj and Bhaduria S S. 2012. Crop and cropping system diversion in Madhya Pradesh. *Extended Summaries Vol. 2: Second International Agronomy Congress*, Nov. 26-30, 2002, New Delhi, India, pp 415-6.

Soybean Research (Special Issue Number 2): 182-188: 2014

Weed Control Efficiency of Quizalofop Ethyl 10 EC against Grassy Weeds in Soybean

S D BILLORE[1],
ICAR-Directorate of Soybean Research, Indore 452 001, Madhya Pradesh, India
E mail: billsd@rediffmail.com

ABSTRACT

*A field experiment was conducted consecutively for two rainy seasons (*kharif *2009 and 2010) to evaluate the bio-efficacy of quizalofop ethyl 10 per cent EC against grassy weeds in soybean. The existence of weeds throughout the crop season led to maximum reduction (49.94 %) in seed yield. Significantly higher soybean yield (99.76 %) was recorded when weeds were managed by manual weeding (at 30 and 45 days after sowing) over control. Among different levels of quizalofop ethyl tried, its application either @ 45 or 37.50 g a i per ha as post-emergence yielded maximum and out-yielded over its lower level (30 g a i/ha). Both the higher levels of quizalofop ethyl were found to be as effective as check herbicides* viz., *quizalofop-p-tefuryl and fenoxaprop- p-ethyl. The physical maximum dose of quizalofop ethyl worked out to be 50.11 g per ha with corresponding yield of 1,599 kg per ha. Manual weeding maintained its supremacy over chemical weed control in limiting the weed load (weed density as well as their dry biomass) in soybean crop. Application of quizalofop ethyl 10 per cent EC was found to be effective to maintain the higher grassy weed control efficiency continuously up to 45 DAS as compared to weedy check.*

Keywords: Efficacy, herbicide, optimum dose, post-emergence, soybean

Soybean becomes a major oilseed crop in India. The crop is grown mostly on Vertisols and associated soils under rainfed conditions. Being rainy season crop, it experiences vagaries of climate, insect-pests and diseases, and suffers from co-existence of weeds, if not managed properly. The existence of weeds, depending on their type, intensity and duration of competition with crop, has been noticed to cause 35 to 70 per cent reduction in seed yield of soybean (Billore *et al*., 1999). Swell-shrink soils prohibited entry in the field during heavy rains caused ineffective management of weeds by mechanical and/or manual methods. The timely unavailability and expensiveness of labour is another factor which restricts the mechanical and manual weed management. Under the circumstances, the use of chemical herbicide is an attractive and economical alternative for the farmers. Hence, the present investigation was aimed at establishing the bio-efficacy of quizalofop ethyl 10 per cent EC against grassy weeds in soybean.

MATERIAL AND METHODS

The field experiment was conducted consecutively for 2 rainy seasons (*kharif* 2009 and 2010) to evaluate the bio-efficacy of quizalofop ethyl 10 EC against grassy weeds

[1]*Principal Scientist (Agronomy)*

in soybean at Directorate of Soybean Research, Indore. The soil belonged to fine, montmorrillonitic, isothermic family of Typic Haplusterts. It analyzed: pH 7.8, EC 0.14 dS per m, organic carbon 0.3 per cent, available phosphorus 10.1 kg per ha and potassium 280 kg per ha. The experiment was laid out in randomized block design with three replications and consisted of seven treatments, namely 3 levels of quizalofop ethyl (30, 37.50 and 45 g/ha) as post-emergence and two check herbicides (quizalofop-p-tefuryl and fenoxaprop-p-ethyl) along with two hand weeding at 30 and 45 days after sowing (DAS) and a weedy check. Soybean variety JS 95-60 was sown on 10th July and 21st June 2009 and 2010 and was harvested in the month of October. The crop was raised using recommended package of practices.

The observations on yield and yield attributes were recorded at harvest. Weed population and oven-dry weight was recorded at 30 and 60 days after sowing. The relationship between yield and levels of quizalofop ethyl was determined by using the quadratic equation, i.e. $Y= a + bx + cx^2$.

RESULTS AND DISCUSSION

Yield and yield attributes

The plant height, yield and yield attributes were significantly influenced by the weed control treatments (Table 1). The highest soybean plant height recorded was under control, which remained at par with quizalofop-p-tefuryl @ 30 g per ha. The maximum branches per plant being with two hand weeding and remained at par with all the herbicidal treatments and significantly higher than control. The pod bearing ability of soybean plant substantially improved when different weed management treatments were imparted to the crop. The highest number of pods per plant was recorded with two hand weeding (26.60), which was closely followed by quizalofop ethyl @ 45 g per ha (23.37). The seed index remained uninfluenced due to different treatments.

All the weed management treatments yielded higher (from 34 to 100 %) than weedy check (851 kg/ha); the maximum seed yield being with two hand weeding at 30 and 45 days. The seed yield achieved through weed management by two hand weeding at 30 and 45 DAS manual weeding was 33.44 per cent higher over that obtained by chemical weed control together. Among herbicidal treatments, seed yield achieved by application of quizalofop ethyl 45 g per ha was significantly superior to control and quizalofop ethyl @ 30 g per ha. The weed management treatments, in general, led to significantly higher straw yield (25.67 to 61.22 %) as compared to weedy check (1,648 kg/ha). The maximum (2,657 kg/ha) and minimum (2,071 kg/ha) straw yield was noted with two hand weeding and quizalofop ethyl @ 30 g per ha, respectively. All the weed control treatments showed significantly higher harvest index as compared to control and maximum being with two hand weeding. Significantly highest harvest index was associated with two hand weeding (51.35%) and remained at par with all the treatments except quizalofop ethyl @ 30 g a i/ha and weedy check. Kushwah and Vyas (2005) and Kumar *et al*. (2008) also stated that the soybean yield was reflective of levels of weed management.

The study of relationship ($Y= 213.78 + 552.90b - 55.164\ c^2$) between yield and levels of quizalofop ethyl showed that the physical maximum dose of quizalofop ethyl was 50.11 g per ha with yield level of 1,599 kg per ha.

Weed dynamics

During the investigation, soybean was infested mainly with *Euphorbia geniculata*,

Table 1. Effect of weed control practices on yield attributes and yields of soybean

Treatment	Plant height (cm)	Branches(No/ plant)	Pods (No/ plant)	Seed index (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Quizalofop ethyl (Sakura) @ 30 g a i/ha	43.57	2.64	19.99	12.13	1142	2071	33.60
Quizalofop ethyl (Sakura) @ 37.5 g a i/ha	43.20	3.07	21.50	12.93	1328	2309	35.52
Quizalofop ethyl (Sakura) @ 45 g a i/ha	42.74	3.10	23.37	12.62	1359	2368	35.41
Fenoxaprop-p-ethyl @ 102.3 g ai/ha	43.64	2.64	20.30	12.52	1251	2178	35.77
Quizalofop-p-tefuryl @ 30 g a i/ha	44.24	2.93	21.50	12.56	1290	2267	35.39
Two hand weeding at 30 and 45 DAS	42.04	3.14	26.60	12.81	1700	2657	37.52
Weedy check	48.67	2.62	13.80	11.80	851	1648	31.61
SEm (±)	1.72	0.17	1.27	0.48	38.51	102.04	0.78
CD (P=0.05)	**5.00**	**0.49**	**3.72**	**1.41**	**112.42**	**297.86**	**2.27**

Table 2. Effect of weed control practices on grassy weed count and their dry matter and weed control efficiency in soybean

Treatment	30 days after sowing			45 days after sowing		
	Weed count (No/m²)	Dry biomass (g/m²)	WCE (%)	Weed count (No/m²)	Dry biomass (g/m²)	WCE (%)
Quizalofop ethyl (Sakura) @ 30 g a i/ha	5.00	4.17	85.99	5.00	13.81	79.98
Quizalofop ethyl (Sakura) @ 37.5 g a i/ha	2.00	1.78	93.82	0.67	6.63	89.84
Quizalofop ethyl (Sakura) @ 45 g a i/ha	1.00	1.23	96.18	0.67	5.58	91.50
Fenoxaprop-p-ethyl @ 102.3 g a i/ha	2.33	3.33	88.69	4.34	12.27	82.30
Quizalofop-p-tefuryl @ 30 g a i/ha	2.17	2.54	91.87	3.16	10.15	85.63
Two hand weeding at 30 and 45 DAS	0.00	0.00	100.00	0.00	0.00	100.00
Weedy check	39.17	30.81	-	44.00	67.93	-
SEm (±)	6.19	4.15	-	6.55	8.78	-
CD (P=0.05)	**18.07**	**12.10**	**-**	**19.13**	**25.63**	**-**

Digera arvensis, *Eclipta alba*, *Commelina benghalensis* and *parthenium hysterophoros* among broad weed leaf weeds and *Dinebra Arabica, Digeria sanguinalis* and *Echinocloa* spp. among grassy weeds and *Cyperus rotundus* (sedges).

Weed management through two hand weeding at 30 and 45 DAS was found to be most efficient to contain weed load at both the stages of observations, *i.e.* 30 and 45 days after sowing.

Although, the level of containing monocot weeds at 30 and 60 days varied; all the weed management treatments could reduce the grassy weed load as expressed in terms of number and dry biomass over control. Quizalofop ethyl @ 45 g per ha, in general, was promising as also indicated by weed control efficiency values of 96.18 and 91.50 per cent at 30 and 60 days after sowing, respectively. Though the remaining treatments also showed more than 80 per cent weed control efficiency at both the stages of observations (Table 2).

Table 3. Effect of weed control practices on sedges weed count and their dry matter in soybean

Treatment	30 days after sowing		45 days after sowing	
	Weed count (No/m²)	Dry biomass (g/m²)	Weed count (No/m²)	Dry biomass (g/m²)
Quizalofop ethyl (Sakura) @ 30 g a i/ha	6.50	5.42	5.83	5.83
Quizalofop ethyl (Sakura) @ 37.5 g a i/ha	5.50	4.39	3.50	6.68
Quizalofop ethyl (Sakura) @ 45 g a i/ha	5.50	4.50	4.00	6.14
Fenoxaprop-–p-ethyl @ 102.3 g a i/ha	3.33	3.18	3.00	3.90
Quizalofop-p-tefuryl @ 30 g a i/ha	4.33	2.97	3.33	3.82
Two hand weeding at 30 and 45 DAS	0.00	0.00	0.00	0.00
Weedy check	3.17	2.49	3.33	4.00
SEm (±)	1.15	0.81	0.68	0.93
CD (P=0.05)	**3.35**	**2.39**	**1.98**	**2.70**

All the treatments except two hand weeding were found to be ineffective in controlling the sedges (*Cyperus rotundus)* and dicot weeds as compared to control at 30 and 60 DAS (Table 3 and 4). All treatments significantly reduced the total weed count as well as dry-biomass as compared to control at both the stages of observations and showed more or less similar values of weed control efficiency except two hand weeding at both the stage (Table 5). The weed control efficiency of all the herbicides declined with the age of crop. The higher monocot weeds control efficiency of herbicides *viz.*, quizalofop ethyl, quizalofop-p-tefuryl and fenoxaprop-p-ethyl and low for sedges, dicot and total weed control efficiency might be due to that all the three molecules are graminicide in nature which controls only grasses. The presented results are in agreement with findings of Kushwah and Vyas (2005) and Kumar *et al* (2008).

The present study brought out that for effective management of grassy weeds in soybean, quizalofop ethyl 10 per cent EC @ 37.5 or 45 g is potent post-emergence herbicide along with quizalofop-p-tefuryl @ 30 g and fenoxyprop-p-ethyl @ 102.3 g per ha.

Table 4. Effect of weed control practices on dicot weed count and their dry matter in soybean

Treatment	30 days after sowing		45 days after sowing	
	Weed count (No/m^2)	**Dry biomass (g/m^2)**	**Weed count (No/m^2)**	**Dry biomass (g/m^2)**
Quizalofop ethyl (Sakura) @ 30 g a i/ha	16.83	17.08	19.83	40.26
Quizalofop ethyl (Sakura) @ 37.5 g a i/ha	20.32	18.625	22.66	45.58
Quizalofop ethyl (Sakura) @ 45 g a i/ha	14.49	18.23	19.50	39.73
Fenoxaprop-p-ethyl @ 102.3 g a i/ha	23.82	21.485	23.65	53.00
Quizalofop-p-tefuryl @ 30 g a i/ha	16.99	18.2	24.49	47.82
Two hand weeding at 30 and 45 DAS	0.00	0	0.00	0.00
Weedy check	12.32	13.14	15.33	37.65
SEm (±)	3.35	4.28	3.04	8.92
CD (P=0.05)	**9.76**	**12.51**	**8.87**	**26.03**

Table 5. Effect of weed control practices on total weed count and their dry matter and weed control efficiency in soybean

Treatment	30 days after sowing			45 days after sowing		
	Weed count (No/m²)	Dry biomass (g/m²)	WCE (%)	Weed count (No/m²)	Dry biomass (g/m²)	WCE (%)
Quizalofop ethyl (Sakura) @ 30 g a i/ha	28.32	26.66	55.05	23.16	58.90	44.82
Quizalofop ethyl (Sakura) @ 37.5 g a i/ha	27.82	24.80	54.86	16.82	56.29	46.41
Quizalofop ethyl (Sakura) @ 45 g a i/ha	20.99	23.65	55.81	15.66	51.35	50.54
Fenoxaprop-p-ethyl @ 102.3 g a i/ha	29.48	28.55	47.35	21.49	66.17	40.60
Quizalofop-p-tefuryl @ 30 g a i/ha	23.49	25.57	54.11	22.98	60.30	41.40
Two hand weeding at 30 and 45 DAS	0.00	0.00	100.00	0.00	0.00	100.00
Weedy check	54.65	63.28	-	53.66	104.84	-
SEm (±)	6.38	8.33	-	6.48	13.15	-
CD (P=0.05)	**18.61**	**24.32**	**-**	**18.91**	**38.39**	**-**

REFERENCES

Billore S D, Joshi O P and Ramesh A. 1999. Energy productivity through herbicidal weed control in soybean. *Indian Journal of Agricultural Sciences* **69**(11): 770-2.

Kushwah S S and Vyas M D. 2005. Herbicidal weed control in soybean (*Glycine max*).*Indian Journal of Agronomy* **50**(3): 225-7.

Kumar Suresh, Angiras N N, Rana S S and Thakur Arvind Singh. 2008. Evaluation of doses of some herbicides to manage weeds in soybean (*Glycine max* L.). *Indian Journal of Weed Science* **40**(1-2): 56-61.

Soybean Research (Special Issue Number 2): 189-194: 2014

Energy Use Pattern under Soybean Cultivation in Kawardha District of Chhattisgarh

NARENDRA H TAYADE*[1], JAGDISH NIKHADE**[2], REETESH PYASI[3] and H K PATRA*[4],***
****Krishi Vigyan Kendra, Dhantewada 494 441, Chhattisgarh, India,***
*****BRSM College of Agricultural Engineering and Technology, Mungeli 495 334, Chhattisgarh, Indiaand***Indian Institute of Technology, Rootkee 247 667, Uttarakhand, India***
E mail: narentayade@rediffmail.com

ABSTRACT

The study on energy use for soybean production was undertaken 2010-11 and 2011-12 to evaluate energy inputs requirement such as labour, power and materials for production of soybean in different categories of farmers under broadcasting and line sowing methods. The 64 farmers belonging four different categories were selected for the study under different categories and interviewing the farmers through specially designed and pre-tested questionnaire. The analyses of collected data revealed that maximum energy input was 11672.2 MJ per ha under line sowing method and 10537.73 MJ per ha under broadcasting method. The maximum energy inputs was utilized in fertilizer application (31 %) whereas, the lowest energy input was in weeding operation under broadcasting method. Similarly the highest energy input was in fertilizer application (23.5%) followed by seed bed preparation (22.5 %) and lowest energy input was in weeding operation under line sowing method. The maximum energy output was72227.81 MJ per ha and 56932.75 MJ per ha under line sowing and broadcasting methods, respectively. The output input ratio was found maximum in medium category farmers 6.07 underline method and 5.39 under broadcasting method. This study revealed that soybean productivity is efficient underline sowing method. Energy productivity of soybean was found to range from 0.192 to 0.197 kg per MJ and 0.162 to 0.171 kg per MJ, respectively under line sowing and broadcasting methods.

Key words: Broadcasting, energy use pattern, soybean, line sowing

Soybean (*Glycine max*) serves as one of the most valuable crops in the world, not only as an oilseed crop and feed for livestock and aquaculture, but also as a good source of protein for the human diet and as a bio-fuel feedstock. The world soybean production increased by 4.6 per cent annually from 1961 to 2007 and reached average annual production of 217.6 million tons in 2005-06 and predicted to increase by 2.2 per cent annually to 371.3 million tons by 2030 (Pandey, 2009). The Chhattisgarh state has 13.79 million hectare geographical area, out of which 35 per cent area is under cultivation. The Chhattisgarh state has 4710 thousand ha net sown area out of which 3571.9 thousand ha is under rice which is major crop in *kharif* followed by maize (179.9 thousand ha), black gram (177.8 thousand ha) and soybean (146.3 thousand ha)(Anonymous, 2012).

Energy use in the agricultural sector depends on the size of the population

[1]*Subject Matter Specialist, Dantewada;* [2]*Assistant Professor, Mungeli;* [3]*M Tech Student, Rootkee;* [4]*Programme Coordinator, Dantewad*

engaged in agriculture, the amount of arable land and the level of mechanization. The agricultural sector is vital in the Indian economy. It is still India's largest employment provider and a significant contributing sector to GDP, imports and exports. The share of agriculture in 2010 in GDP at current prices was 11 per cent. The contribution of agricultural commodities in total exports was 10.6 per cent and more than 40 per cent of the total population was engaged in agriculture (De, 2006). Energy in agriculture is important in terms of crop production and agro-processing for value addition. Human, animal and mechanical energy is extensively used for crop production in agriculture. Energy requirements in agriculture are divided into two groups being direct and indirect. Direct energy is required to perform various tasks related to crop production processes such as land preparation, irrigation, intercultural, threshing, harvesting and transportation of agricultural inputs and farm produce.

MATERIAL AND METHODS

The Chhattisgarh state is lies in central zone of India. The state has been divided into three agro-climatic zones, namely Chhattisgarh plain, Baster plateau and Northern hill. Chhattisgarh plain is the largest among other two zones and all the major crops are grown in this zone. The districts like Bilaspur, Durg, Kawardha, Rajnandgaon are the dominant soybean production districts. The district Kawardha was selected by stratified random sampling technique. The three villages Magdhara, Kosmanda and Dullapur were selected for the study on the basis of the level of mechanization and transport facility. The village Magdhara and Dullapur are less mechanized villages and broadcasted method was mostly adopted for soybean cultivation whereas village Kosmanda was most mechanized village and seed drills were used for line sowing of soybean. Sixty four 64 farmers were selected from all three villages were survey these farmers falling in four different categories as marginal, small, medium and large.

A questionnaire was prepared pertaining energy input and output for raising soybean crop was included in addition to the basic information about resources. The question included the information on quantity of different inputs and time to complete various operations. The data was collected through personal interview of farmers separately. All the information related to their method of cultivation, time consumed per operation, sources of power, available animal power and mechanical power, type of machinery used, *etc.* were recorded from the farmers. Information on the machinery use was collected to know the level of mechanization. The data collected was processed by adopting the method suggested by Jogdand (2007). All the data collected was separated in different categories of respondents and the variables were converted to equivalent energy input and output using standard coefficient suggested by Mitral *et al.* (1985)

Total energy input and output of crops and cropping systems were estimated by using the energy equivalents (Table 1) as suggested by Dhawan and Mittal (1990) and Singh *et al.* (1997)

The energy input and output were computed as mega Joule (MJ). The energy output was calculated by accumulating the main product and by-product produced from different sowing method. Also output-input ratio, net energy gain and energy productivity was worked by using following formulae.

Energy input	=	∑ Human energy + mechanical energy + machinery energy + seed energy + fertilizer energy + chemical energy + petroleum energy + electrical energy
Energy output	=	Energy from main product + energy from by-product
Output input ratio	=	Output energy (MJ/ha) / Input energy (MJ/ha)
Net energy gain	=	Energy output (MJ/ha) – energy input (MJ/ha)
Energy productivity	=	Yield (kg/ha)/Input energy (MJ/ha)

The operation energy required for soybean cultivation was calculated for different field operation like seedbed preparation, sowing, weeding, spraying, irrigation, fertilizer application, harvesting and threshing.

Similarly the output energy after cultivation is obtained by summing the energy obtained by product (seed) and energy obtained from by products (straw).

RESULT AND DISCUSSION

The source-wise and operation-wise energy inputswere calculated by using the energy equivalents (Table 1) and data were collected by personal interview the farmers. The MPSS 7 was used for calculating the energy requirement under different operations. The total energy input at different farm operations of soybean production in Kwardha district increased with increase in farmers land holding size from marginal to small and decrease from small to medium farmers under broadcasted soybean. The total energy input were 10128.16 MJ per ha, 10537.37 MJ per ha and 10311.45 MJ per ha, respectively in marginal, small and medium category farmers. It was also observed that the highest input energy was applied through the fertilizer (31%) whereas the lowest energy input was observed weeding operation (Table 2). The total non-commercial energy input were 282.66, 273.57 and 279.59 MJ per ha under marginal, small and medium category farmers whereas 10083.20, 10528.47 and 10290.05 MJ per ha are the commercial energy input under small, medium and large category farmers (Table 3). It was concluded that the fertilizer energy (30 %) and petroleum energy (42 %) were most significant part of energy inputs whereas use of animal energy was found to be negligible.

Similarly the total energy input under line sowing technique (Tables 4 and 5) was found to be 11481.73, 11566.89 and 11672.26 MJ per ha, respectively in small, medium and large category of farmers. It was observed that the highest energy input was utilized in fertilizer application (23.5%) followed by seedbed preparation (22.5%), whereas lowest energy input was in weeding operation. Similarly the source-wise energy use was analyzed and it was observed that the petroleum energy (48 %) was among the othersources of energy due use of more mechanical power for land preparation, sowing, harvesting, threshing and transportation.

The output-input ratio was computed for broadcasting as well as line sowing methods and it was ranged from 5.09 to 6.02. The lowest output input ratio was on small farms under broadcasting method whereas highest 6.02 was observe in large category farmers under line sowing method of soybean.

Table 1. Energy co-efficient of different input and outputs

Particulars	Units	Equivalent energy, MJ
A. Input		
Human	Man-hour	1.96
Animal	Pair-hour	10.10
Diesel	Litre	56.31
Electricity	kWh	11.93
Machinery		
(i) Electric motor	kg	64.80
(ii) Other prime mover including self-propelled machine	kg	64.80
(iii) Farm machinery excluding self-propelled machine	kg	62.70
Wood	kg	18
Chemical fertilizers		
(i) Nitrogen (N)	kg	60.6
(ii) Phosphorus (P_2O_5)	kg	11.1
(iii) Potash (K_2O	kg	6.7
Chemicals	kg	120
Seed	kg	14.7
A. Output		
Seed	kg	14.7
Straw	kg	12.5

Table 2. Operation-wise energy input (MJ/ha) under broadcasting method

Operations	Marginal	Small	Medium	Large
Summer plough	1279.01	1567.40	1581.92	0
Seed bed preparation	2423.38	2915.26	2759.96	0
Sowing	1469.36	1408.39	1393.68	0
Weeding	24.65	19.41	31.47	0
Spraying	180.98	161.74	162.38	0
Irrigation	123.46	131.24	339.99	0
Fertilizer	3542.54	3233.58	2886.24	0
Harvesting	117.15	103.89	102.12	0
Bunding, loading	69.23	110.44	96.68	0
Transport	767.33	778.17	835.77	0
Threshing	131.06	108.19	121.21	0
Total Input Energy	**10128.15**	**10537.71**	**10311.41**	**0**

Table 3. Source-wise energy input (MJ/ha) in broadcasting method

Category		Marginal	Small	Medium	Large
Non - commercial	Human energy	282.65	266.00	279.59	0.00
	Animal energy	0.00	7.57	0.00	0.00
Commercial	Mechanical energy	234.84	278.11	279.13	0.00
	Machinery energy	195.17	213.93	218.54	0.00
	Seed energy	1466.75	1402.01	1388.23	0.00
	Fertilizer energy	3535.25	3225.37	2876.50	0.00
	Chemical energy	150.00	150.00	150.00	0.00
	Petroleum energy	4041.92	4810.10	4716.49	0.00
	Electrical energy	176.58	175.35	381.55	0.00
Total Non – commercial (MJ/ha)		282.65	273.57	279.59	0.00
Total Commercial (MJ/ha)		9800.51	10254.87	10010.44	0.00
Total (MJ/ha)		**10083.16**	**10528.44**	**10290.03**	**0.00**

Table 4. Operation-wise energy inputs(MJ/ha) in line sowing system

Operations	Marginal	Small	Medium	Large
Summer ploughing	0	1427.10	1480.83	1494.42
Seed bed preparation	0	2692.64	2827.28	2369.53
Sowing	0	2081.07	2173.15	2091.09
Weeding	0	50.98	32.96	48.22
Spraying	0	248.56	199.56	199.89
Irrigation	0	222.75	433.78	316.54
Fertilizer	0	2770.99	2315.09	3109.45
Harvesting	0	74.01	87.13	108.36
Bundling, Loading	0	158.63	297.09	319.11
Transport	0	1616.80	1666.70	1515.98
Threshing	0	138.20	123.65	99.67
Total input energy	**0**	**11481.73**	**11566.89**	**11672.26**

Table 5. Source-wise energy inputs (MJ/ha) in line sowing system

Category		Total energy Input			
		Marginal	Small	Medium	Large
Non-Commercial	Human energy	0.00	351.11	329.00	350.30
	Animal energy	0.00	0.00	0.00	0.00
Commercial	Mechanical energy	0.00	338.55	357.57	317.12
	Machinery energy	0.00	315.72	341.05	312.22
	Seed energy	0.00	1451.62	1571.06	1525.12
	Fertilizer energy	0.00	2754.75	2306.62	3100.75
	Chemical energy	0.00	240.00	168.75	191.25
	Petroleum energy	0.00	5720.39	6041.89	5506.06
	Electrical energy	0.00	277.54	403.14	347.74
Total Non-Commercial		0.00	351.11	329.00	350.30
Total Commercial		0.00	11098.57	11190.08	11300.26
Total		0.00	11499.68	11519.08	11650.56

REFERENCES

Anonymous 2012. *Krishi Dairy 2012 published by Indira Gandhi Agricultural University Raipur*, Chhattisgarh.

De D. 2006. Energy use pattern and future energy requirement for crop production by 2020. *Journal of Agricultural Engineering* **43**(3): 71-7.

Dhawan K C and Mittal J P. 1990. *Energy scenario of paddy and wheat production in India*. *Journal of Rural Development* **9**(4): 719-28

Jogdand S V. 2007. Investigation of energy required in agriculture and application of energy audit principle to optimize man and machine energy contribution, Unpublished *Ph D Thesis*, Guru Ghasidas University, Bilaspur, Chhattisgarh.

Mitral V K, J P Mittal and Dhawan K C. 1985. *Research Digest on Energy Requirement in Agriculture Sector*, Coordinating cell AICRP on Energy Requirement in Agriculture Sector, College of Agricultural Engineering, Punjab Agricultural University, Ludhiana, Punjab, India.

Pandey M M. 2009. *Report on Indian Agriculture-An Introduction*, Presented in fourth session of the technical committee of APCAEM, 10-12 Feb 2009. Chiang Raised, Thailand.

Singh S, S R Verma and Mittal J P. 1997. Energy requirement for production of major crops in India. *Agricultural Mechanisation in Asia, Africa and Latin America* **28**(4): 13-7.

Soybean Research (Special Issue Number 2): 195-207: 2014

Asian Soybean Rust: Eco-friendly Management Options for Indian Farmers

P V PATIL[1] and G T BASAVARAJA[2],
University of Agricultural Sciences,
Dharwad 580 005, Karnataka, India
E mail : pvpatil1@rediffmail.com

ABSTRACT

Non-chemical approaches in the management of plant diseases are gaining more importance in India. Hence, research efforts were made between 1996 and 2008 under All India Co-ordinated Research Project on Soybean at University of Agricultural Sciences, Dharwad to find out the non-chemical eco-friendly options for the management of soybean rust. Early sowing in the first fortnight of June at Dharwad and in first fortnight of May at Ugar Khurd were found to be the best in reducing rust severity and increasing the seed yields in all the genotypes. Large scale screening of soybean genotypes to rust at Ugar Khurd during kharif *2002 and 2003 has yielded only two genotypes (EC 241778 and EC 241780) to be resistant to rust. Utilising EC 241778 and JS 335 (agronomically superior, but rust susceptible), a rust resistant high yielding genotype DSb 21 was developed and released to farmers for cultivation in rust endemic areas of Karnataka. Among the commercially available plant based products, margo tricure, nimbicidine and neemgold at 0.5 per cent and neem oil and wanis at 1.0 per cent sprayed thrice at an interval of 10 days starting from the onset of disease were found promising. Among different indigenous technological knowledge, three sprays of either cow urine @ 10 per cent, vermiwash @ 50 per cent and panchagavvya @ 3.0 per cent at 10 days interval starting from onset of disease were found best Plant based product, Cristal 56 SL and indigenous technological knowledge like cow urine and cow milk sprays have improved the quality of the produce which was indicated by increased linoleic: linolenic acid ratio.*

Key words: Eco-friendly, indigenous technological knowledge, plant based products, soybean rust

Rust caused by *Phakopsora pachyrhizi* Syd. is one of the major diseases of soybean in Asia. Significant yield reductions have been reported from Australia, India, Indonasia, Nepal, Philippines, Peoples Repulic of China, Taiwan, Thailand and Vietnam (Casey, 1979; Chan and Tsaur, 1975; Hong *et al.*, 1990; Hsu and Wu, 1968; Kurata, 1960; Yang, 1977; Yeh and Yang, 1975; Yu *et al.*, 1980). In India the disease was first noticed at Pantnagar in September, 1970 and subsequently in Kalyani (West Bengal) and in low hills of Uttar Pradesh. It was more severe in 1970, 1974 and mild in 1972 and 1973 (Singh and Thapliyal, 1977). During *kharif* 1994, the disease reappeared in epiphytotic form in the main soybean growing areas of Karnataka, Maharashtra and Madhya Pradesh and caused substantial losses in susceptible varieties. Many triazole fungicides have been evaluated and recommended for the control of soybean rust (Anahosur and Patil, 1998; Gupta *et al.*, 2007). However, continuous use of these may pose the problem of

[1] *Professor (Plant Pathology);* [2] *Principal Scientist (Soybean Breeding)*

development of resistance and also environmental hazards apart from increasing the cost of cultivation. Hence, research efforts were made between 1996 and 2008 under All India Co-ordinated Research Project on Soybean at University of Agricultural Sciences, Dharwad to find out the non-chemical eco-friendly options in the management of soybean rust.

MATERIAL AND METHODS

Identification of suitable sowing period

In order to identify the suitable sowing period to reduce rust severity, field trials were conducted at Dharwad (*kharif* 1996 and 1997) and Ugar Khurd (*kharif* 2001 and 2002). At both the locations, four sowing dates (main plots) using eight genotypes at Dharwad and four genotypes at Ugar Khurd (Belgaum district) (sub plots) were evaluated in a split plot design with three replications. Trial laid out at Dharwad was under rainfed and that at Ugar Khurd was under irrigated condition. The four sowing dates at Dharwad during 1996 and 1997 were 14.06.1996, 14.06.1997, 24.06.1996, 27.06.1997, 08.07.1996, 11.07.1997, 24.07.1996, 29.07.1996 and Ugar Khurd during 2001 and 2002 were 26.05.2001, 20.05.2002, 08.06.2001, 05.06.2002, 25.06.2001, 25.06.2002, 11.07.2001, 10.07.2002. The genotypes in sub-plots at Dharwad were DSb 1, JS 80-21, MACS 124, PK 1029, MACS 13, Pusa 40, JS 335 and PK 1162, whereas genotypes at Ugar Khurd were JS 335, DSb 1, PK 1029 and DSb 5. Crop was grown as per recommended package of practices. No control measures were taken for rust and necessary insecticides were sprayed at appropriate time to manage insect-pests. Intensity of rust was recorded by following 0 to 9 scale of Mayee and Datar (1986) when the crop was 85-90 days old. For scoring the intensity of disease, ten plants were randomly selected in the central rows of the plot. Crop was harvested at and the plot yields were recorded.

Evaluation of commercial plant based products against rust

Field experiments were conducted during *kharif 2005* and 2006 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad in randomized block design with three replications to evaluate plant based products against rust using susceptible genotype, JS 335. Different commercially available plant based products namely, soldier (contents: 20 % *Lantana camera*, 20 % *Agegle marbelus*, 20 % *Ricinus communis*, 20 % *Hygrophilla spinosa*, 20 % *Laminaria*), nimbicidine, margo tricure and neem gold (contents: 0.03 % EC azadirachtin, 90.5 % neem oil, 5.0 % hydroxyl EL, 0.5 % epichlorohydrate and 3.9 % aromax), 20 per cent EC wanis, neem oil (crude neem oil) and 5.0 per cent self prepared neem seed kernel extract were utilized. Nimbicidine, neemgold, soldier and margo tricure were used at 0.5 per cent, wanis at both 0.5 and 1.0 per cent, neem oil at 1.0 per cent and fungicide hexaconazole at 0.1 per cent. Plant based products were sprayed thrice at 10 days interval and hexaconazole was sprayed twice at 15 days interval starting with the appearance of rust on the plants. Observations on rust severity and seed yield were recorded. Further per cent disease index (PDI) was calculated using the formula of Wheeler (1969).

Evaluation of indigenous technological knowledge against rust

Field experiments were conducted in a randomized block design with three replications during *kharif* 2005, 2006 and 2007 at Main Agricultural Research Station, Dharwad. Five indigenous products *viz*., cow urine @ 10 per cent (1:10), vermiwash at 1.2 and 1.5, cow milk @ 10 per cent (1:10), panchagavvya @ 3 per cent and butter milk @ 2 per cent and recommended fungicide hexaconazole @ 1 Per cent were tested against soybean rust. All the products were sprayed thrice at 10 days interval except hexaconazole which was sprayed twice at 15 days interval stating from the appearance of rust. Observations on rust severity and seed yield were recorded. Further per cent disease index (PDI) was calculated.

Evaluation of indigenous technological knowledge, plant and protein based products and chemical fungicide in an integrated approach for the control of rust

Field experiments were laid out in a randomized block design with three replications at Dharwad and Ugar khurd during *kharif* 2007. Rust susceptible soybean genotype, JS 335 was used. Three plant and protein based products (RBS 06, cristol 56 SL and neem oil), two indigenous technological knowledge (cow urine and cow milk) and a chemical fungicide (hexaconazole) were evaluated alone and in combination of spray schedule. Three sprays were given at 10 days interval plant based products and two indigenous technological knowledge were used alone or in combination with fungicidal spray schedule and two sprays at 15 days interval was given when fungicide alone was used in spray schedule. Observations on rust severity and seed yield were recorded as mentioned above in the date of sowing experiment. Further per cent disease index (PDI) was calculated. The harvested produce in each treatment from Ugar Khurd was subjected to quality analysis *i.e.,* oil and protein content and linoleic and linolenic acid composition (Sadasivam and Manickam, 1991).

Identification and development of rust resistant soybean genotypes

Soybean genotypes included in different trials (initial varietal and advanced varietal trials under All India Coordinated Research Program on Soybean), advanced breeding material and germplasm lines were screened during *kharif* 1995-2007 at both Dharwad and Ugar khurd to identify the rust resistant soybean genotypes. Further in 2004-05, efforts were made to utilize the two identified rust resistant genotypes *viz*., EC 241778 and EC 241780 in hybridization programme with agronomically superior but rust susceptible cultivars *viz*., JS 335, JS 93-05 and DSb 1 to develop the rust resistant high yielding cultivars.

RESULTS AND DISCUSSION

Identification of suitable sowing period

At Dharwad: During *kharif* 1996, significantly low intensity of rust and high yields were recorded in the crop sown during first fortnight of June compared to rest of the dates tried. Among the different genotypes tested, high intensity of rust was recorded in JS 335 (6.50), MACS 13 (6.00) and DSb 1 (5.75) and significantly low intensity of rust was observed in PK 1029 (3.50), JS 80-21 (3.58) and PK 1162 (3.68). Among the genotypes the only significant yielder was PK 1029 (1,441 kg/ha). In early sowing (first fortnight of June), JS 335 (2,827 kg/ha), PK 1029 (2,814 kg/ha), PK 1162 (2,729 kg/ha), DSb 1 (2,716 kg/ha) and Pusa 40 (2,587 kg/ha) performed superior. However the genotypes PK 1029 and JS 80-21 gave higher yields even in late sowings. Almost similar results were obtained during *kharif* 1997 also. Crop sown during first fortnight of June recorded significantly low rust intensity with higher seed yields compared to rest of the dates tried. Among the genotypes, PK 1162 and PK 1029 gave significantly higher seed yields over the other genotypes (Table 1).

At Ugar Khurd: The different sowing dates tried during *kharif* 2001 at Ugar-Khurd under irrigated condition indicated significantly low intensity of rust on early sown crop *i.e.*, during second fortnight of May (12.04 %) compared to rest of the dates tried. Highest severity of rust was recorded on crop sown during second fortnight of June (80.53 %). No incidence of rust was recorded on moderately resistant genotypes (PK 1029 and DSb 5) sown during second fortnight of May. At first date of sowing (second fortnight of May) JS 335 recorded significantly higher seed yield compared to other genotypes. Whereas at subsequent dates of sowing *i.e.,* (first fortnight of June), (second fortnight of June) and (first fortnight of July), PK 1029 recorded significantly higher seed yield. Overall crop sown during second fortnight of May recorded significantly higher seed yield compared to other dates of sowing. Almost similar results were obtained during *kharif*2002, wherein early sowing (second fortnight of May) recorded

Table 1. Effect of date of sowing on severity of rust and yield on soybean cultivars at Dharwad

Treatments	Rust severity (0 to 9 scale)			Seed yield (kg/ha)		
	1996-97	1997-98	Mean	1996-97	1997-98	Mean
Sowing dates						
First fortnight (14th June)	1.17	2.00	1.86	2617	2718	2668
Second fortnight (24th and 27th June	5.91	3.67	4.79	1179	2144	1662
First fortnight (8th and 11th July)	6.38	4.50	5.44	572	878	725
Second fortnight (24th and 29th July)	6.38	4.50	5.44	326	281	304
SEm (±)	0.12	0.07		043	061	
C D (P = 0.05)	0.44	0.25		132	189	
Genotypes						
DSb 1	5.75	3.50	4.63	1154	1426	1290
JS 80-21	3.58	2.67	3.13	1311	1512	1412
MACS 124	5.00	4.08	4.54	945	1401	1173
PK 1029	3.50	2.33	2.92	1441	1675	1558
JS 335	6.50	4.25	5.38	1155	1454	1305
MACS 13	6.00	4.25	5.13	1002	1410	1206
PUSA 40	5.08	3.67	4.38	1087	1431	1259
PK 1162	3.68	2.25	2.97	1292	1735	1514
SEm (±)	0.26	0.11		041	059	
C D (P = 0.05)	0.81	0.40		127	183	

significantly low intensity of rust with higher seed yields compared to other dates of sowing. PK 1029 recorded higher seed yield in all the dates of sowing, except when sown in second fortnight of May, whereas JS 335 recorded higher seed yields (Table 2).

The difference in severity of rust in different dates of sowing is attributed to the weather conditions. In the present investigation, both at Dharwad and Ugar Khurd early sowing (first fortnight of June and second fortnight of May, respectively), recorded low rust severity irrespective of the genotypes. Normally at Ugar Khurd (Belgaum district) and Dharwad rust appears during first fortnight of August and second fortnight of August or first fortnight of September, respectively. By this time the early maturing genotype like JS 335 may attain the stage of physiological maturity and not much loses in yield due to rust appearance at this stage are recorded. The low disease severity and increased yield in genotypes *viz.*, JS 80 21, PK 1029, PK 1162 and DSb 5 in early sowings was because of their

Table 2. Effect of date of sowing on severity of rust and yield on soybean cultivars at Ugar Khurd

Treatments	Rust severity (PDI)			Seed yield (kg/ha)		
	2001-02	2002-03	Mean	2001-02	2002-03	Mean
Sowing dates						
First fortnight (14th June)	3.08 (12.04)	4.86 (25.13)	3.97 (18.58)	2439	2627	2534
Second fortnight (24th and 27th June	6.47 (44.43)	6.32 (42.76)	6.40 (43.60)	1791	2097	1944
First fortnight (8th and 11th July)	8.36 (80.53)	8.24 (69.10)	8.30 (74.81)	1208	1292	1250
Second fortnight (24th and 29th July)	7.2 (60.10)	6.95 (48.42)	8.95 (54.26)	533	764	649
SEm (±)	0.03	0.11		045	018	
C D (P = 0.05)	0.13	0.39		139	059	
Genotypes						
JS 335	7.61 (67.58)	7.63 (59.33)	7.62 (63.46)	1438	1620	1529
DSb 3	7.48 (64.78)	7.28 (57.59)	7.38 (61.18)	1285	1449	1367
PK 1029	5.02 (31.48)	5.49 (32.32)	5.26 (31.90)	1796	1875	1835
DSB 5	5.08 (34.26)	5.98 (36.16)	5.53 (35.21)	1452	1838	1645
SEm (±)	0.02	0.13		028	012	
C D (P = 0.05)	0.12	0.44		091	041	

rust tolerance and late appearance of rust. Several reports are available in reducing the disease severity with early sowings in different crops (Anahosur *et al.*, 1982, Hundekar, 1999; Patil and Basavaraja, 2002)

Evaluation of commercial plant based products for the control rust

Rust severity: Results indicated that rust severity during both the years and also in pooled data showed significant difference among the treatments. During 2005, lowest rust severity of 59.25 per cent was recorded in check fungicide hexaconazole followed by wanis @ 1.0 per cent (67.89 %), neem gold (70.36 %), neem oil (72.83 %) and wanis @ 0.5 per cent (72.83 %), however, they were on par with each other. Margo tricure (77.77 %), nimbicidine (87.64 %) and soldier (87.65 %) were found next best and on par with each other. Maximum rust severity of 95.05 per cent was recorded in unsprayed control. Almost similar results were obtained during 2006 also. Check fungicide hexaconazole was found best in reducing the rust severity (25.92 %). Nimibicidine (40.74 %), neem oil (48.14 %), margo tricure (53.08 %), neem seed kernel extract (58.02 %) and wanis @ 1.0 per cent (70.36 %) were found next best and on par with each other. Pooled data also indicated superiority of hexaconazole over other plant based products in reducing rust severity. Neem oil (60.49 %), margo tricure (65.43 %), nimbicidine (64.19 %), neemgold (64.19 %) and wanis (69.13 %) were found on par and next best in reducing rust severity. Unsprayed control recorded highest rust severity of 96.29 per cent (Table 3**).**

Seed yield (kg/ha): Seed yield in different treatments during both the years (2005 and 2006) was found to be non-significant. However, pooled data indicated significant differences among the treatments. Highest seed yield were recorded in hexaconazole (3,123 kg/ha) followed by nimbicidine (2,921 kg/ha), margo tricure (2,905 kg/ha), neem seed kernel extract (2,818 kg/ha), which were on par with each other. Unsprayed control recorded least yield of 2,506 kg/ha) and was on par with soldier (2,676 kg/ha) and wanis at 0.5 per cent (2,740 kg/ha**)** (Table 3).

B:C ratio: The highest B:C ratio was obtained from hexaconazole (4.85) followed by neem oil (2.74) and margo tricure (1.12). Lowest B:C ratio of 0.69 was recorded in soldier followed by wanis @ 1.0 per cent (-0.52) and wanis @ 0.5 per cent (-0.31)(Table 3).

Several earlier workers have reported the effectiveness of plant based products in the control of plant diseases of different crops (Wadhwani *et al.*, 1986; Ganapathy and Narayanaswamy, 1990; Usman *et al.*, 1991; Hundekar, 1999). Fugro (2000) recommended the integrated use of organic manures, inorganic fertilizers, garlic extract and cow urine sprays in controlling foliar diseases of chilli. Jones *et al.* (1989) reported the chemical nature of neem products used as fungi-toxicants. The active principle for antifungal and antibacterial activity of *Curcuma longa* and *Azadirachta indica* was reported to be the protein part of the plant extract. Present investigation has also identified the antifungal properties in some of the commercially available plant products such as neem oil, margo tricure, nimbicidine, neem gold and Wanis. These can be certainly used for the effective eco-friendly management of soybean rust.

Evaluation of indigenous technological knowledge for the control of rust

Disease severity: Data on per cent disease index (PDI) during all the three years including pooled data was found significant. Pooled analysis data clearly indicated that

Table 3. Effect of commercial plant based products on rust severity and seed yield of soybean

Treatments	Percent disease index			Seed yield (kg/ha)			B:C ratio
	2005	2006	Pooled	2005	2006	Pooled	(Mean)
Nimbicidine @ 0.5 %	69.67* (87.64)**	39.57 (40.74)	54.62 (64.19)	2751	3091	2921	0.96
Neemgold @ 0.5 %	57.17 (70.36)	49.70 (58.02)	53.43 (64.19)	2778	2915	2846	0.50
Soldier @ 0.05 %	69.67 (87.65)	52.63 (62.95)	61.15 (75.30)	2497	2855	2676	-0.69
Wanis @ 0.5 %	58.80 (72.83)	63.73 (80.24)	61.27 (76.54)	2789	2691	2740	-0.31
Wanis @ 1.0 %	55.50 (67.89)	57.13 (70.36)	56.32 (69.13)	2837	2799	2818	-0.52
Margo tricure @ 0.5 %	61.90 (77.77)	46.77 (53.08)	54.33 (65.43)	2806	3005	2905	1.12
Neem seed kernel extract @ 5.0 %	77.00 (92.58)	49.63 (58.02)	63.32 (75.32)	2615	3101	2858	0.67
Neem oil @ 1.0 %	58.77 (72.83)	43.90 (48.14)	51.33 (60.49)	2888	3158	3023	2.74
Hexaconazole @ 0.1 %	50.40 (59.25)	30.47 (25.92)	40.43 (42.59)	2964	3296	3130	4.85
Untreated control	79.27 (95.05)	84.73 (97.52)	82.00 (96.29)	2568	2444	2506	-
SEm (±)	3.31	2.95	2.16	100	249	138	-
C D (P = 0.05)	**9.82**	**8.69**	**5.97**	**NS**	**NS**	**381**	-

**Arcsine transformed values ; ** Original percentage values ; NS = Non-significant; Cost of grains @ Rs 13.00/kg; Labour charges@ Rs 125/ha for one spray; Quantity of spray solution used - 1st spray 625 liters/ha, 2nd and 3rd spray 750 liters/ha; Cost of plant based pesticides and fungicide(Rs/litre): nimbicidine (Rs 200), neem gold (Rs 200), soldier (Rs 560, wanis (Rs 340), margo tricure (Rs 175), neem oil (Rs 60), neem seed (Rs 5/kg), hexaconazole (Rs 700)*

hexaconazole @ 0.1 per cent was found significantly superior over all the other treatments in reducing rust severity. Next best treatment, which reduced rust severity is cow urine (1:10) followed by cow milk (1:10), vermiwash (1:2) and cristol 56 SL @ 1.0 per cent, which were on par with each other. Highest PDI of 81.88 was recorded in butter milk, which was on par with *T. viride* @ 1.0 per cent, panchagavvya @ 3.0 per cent and $MnSO_4$ @ 0.5 per cent (Table 4).

Seed yield: Pooled analysis data for seed yield was found significant. Highest seed yield of 3,048 kg per ha was recorded in hexaconazole spray treatment which was significant over remaining treatments. Next best treatment which has recorded higher seed yield was cristol 56 SL (2,705 kg/ha) followed by cow milk (2,698 kg/ha), cow urine (2,669 kg/ha) and vermiwash (2,652 kg/ha) which were on par with each other. Least seed yield of 2460 kg per ha was recorded in butter milk (Table 4). Under field conditions, 1:10 dilution of cow urine was found effective in reducing the disease intensity in different crops which has been well documented by several researchers (Sridhar *et al*., 2002; Manikandan, 2005; Vijayalakshmi et *al.,* 2005). Similarly butter milk also found effective under field conditions and was also supported by many researchers (Arunkumar *et al*., 2002; Zatirim *et al*., 2005)

Evaluation of indigenous technological knowledge, plant and protein based products and chemical fungicide in an integrated approach for the control of rust

Significant differences between the various treatments with respect to per cent disease index were observed (Table 5). Least per cent disease

Table 4. Evaluation of indigenous technological knowledge against rust of soybean

Treatments	Percent disease index				Seed yield (kg/ha)			
	2005	2006	2007	Pooled	2005	2006	2007	Pooled
Cow urine (1:10)	58.90* (72.83)	51.09* (60.49)	42.46* (45.67)	50.84* (59.66)	2356	2887	2764	2669
Vermiwash (1:2)	58.77 (72.56)	48.94 (56.79)	45.35 (50.61)	51.02 (59.99)	2398	2823	2735	2652
Vermiwash (1:5)	61.89 (77.77)	64.37 (80.24)	51.06 (60.49)	59.11 (72.83)	2291	2645	2671	2536
Cow urine (1:20) + vermiwash (1:15)	65.89 (82.71)	58.78 (72.83)	48.20 (55.08)	57.51 (70.21)	2176	2768	2607	2517
Cow milk (1:10)	55.54 (67.89)	45.33 (50.61)	46.78 (53.08)	49.22 (57.19)	2500	2860	2733	2698
$MnSO_4$ @ 5 % @1 %	79.28 (95.05)	52.77 (62.96)	52.48 (62.96)	61.51 (73.65)	2010	2796	2635	2480
Cristol 56 SL @ 1%	67.37 (85.18)	48.27 (55.55)	40.73 (42.67)	52.12 (61.13)	2399	2967	2748	2705
Panchagavvya @ 3 %	79.28 (95.05)	60.27 (75.30)	57.14 (70.36)	65.56 (80.24)	2139	2738	2517	2465
Butter milk @ 2 %	71.93 (90.11)	71.93 (90.11)	54.19 (65.43)	66.02 (81.88)	2165	2624	2593	2460
Tricoderma viride @ 1 %	69.65 (87.65)	70.10 (87.64)	55.52 (67.89)	65.09 (81.06)	2256	2596	2596	2483
Hexaconazole @ 1 %	51.16 (60.49)	38.13 (38.27)	34.48 (32.09)	41.26 (43.62)	2931	3309	2906	3048
Unsprayed control	-	-	65.54 (82.71)	-	-	-	2409	-
SEm (±)	3.71	3.87	2.34	1.70	143	114	041	052
C D (P = 0.05)	10.82	11.31	6.82	4.70	418	332	119	144

**Arcsine transformed values*

Table 5. Evaluation of indigenous technological knowledge, plant and protein based products and chemical fungicides against rust of soybean

Treatments	Per cent disease index			Seed yield (kg/ha)		
	Dharwad	Ugar Khurd	Pooled	Dharwad	Ugar Khurd	Pooled
RBS 06 (three sprays at 10 days interval)	38.52* (38.81)	48.19 (55.55)	43.36 (47.18)	2642	1370	2006
Cristal 56 SL @ 1 % (three sprays at 10 days interval)	30.40 (25.62)	42.44 (45.56)	36.42 (35.59)	2833	1427	2130
Cow urine @ 10 % (three sprays at 10 days interval)	35.52 (33.86)	45.35 (50.61)	40.43 (42.23)	2714	1390	2052
Cow milk @ 10 % (three sprays at 10 days interval)	35.92 (34.43)	40.95 (42.98)	38.44 (38.71)	2726	1412	2069
Neem oil @ 1% (three sprays at 10 days interval)	31.46 (27.31)	38.52 (38.80)	34.99 (33.06)	2845	1462	2154
Hexaconazole @ 0.1 % (Two sprays at 15 days interval)	22.36 (14.50)	29.77 (24.69)	26.07 (19.59)	3011	1522	2267
RBS 06 @ 1% (first spray) + Hexaconazole @ 0.1 % (second spray) at 15 days interval	24.03 (16.60)	36.00 (34.56)	30.01 (25.58)	2916	1454	2185
Cristal 56 SL @ 1 % (first spray) + Hexaconazole @ 0.1 % (second spray) + Cristal 56 SL @ 1 % (third spray) at 15 days interval	23.28 (15.65)	32.15 (28.39)	27.71 (22.02)	3095	1545	2320
Cow urine @ 10 % (first spray) + Hexaconazole @ 1 % (second spray) + Cow urine @ 10 % (third spray) at 15 days interval	27.07 (20.74)	33.71 (30.86)	30.39 (25.80)	2928	1513	2221
Cow milk @ 10 % (first spray) + Hexaconazole @ 1% (second spry) + Cow milk @ 10 % (third spary) at 15 days interval	24.41 (17.12)	30.56 (25.92)	27.49 (21.52)	2904	1627	2266
Neem oil @ 1 % (first spray) + Hexaconazole @ 0.1 % (second spray) + Neem oil @ 1 % (third spary) at 15 days interval	26.64 (20.12)	32.95 (29.64)	29.80 (24.88)	3107	1525	2316
Control	45.25 (50.44)	55.50 (67.89)	50.38 (59.16)	2478	1280	1879
SEm (±)	**1.06**	**1.33**	**0.85**	**029**	**036**	**025**
C D (P = 0.05)	**3.10**	**3.91**	**2.50**	**086**	**106**	**074**

**Arcsine transformed values*

Table 6. Effect of ITK's, plant and protein based and chemical fungicides on seed oil, protein, linoleic and linolenic acid contents of soybean as influenced by rust

Treatments	Oil content (%)	Per cent increase over control	Protein content (%)	Per cent increase over control	Linoleic acid (%)	Lino-lenic acid	Linoleic: linolenic acid ratio
RBS 06 (three sprays at 10 days interval)	19.08	1.47	35.19	0.28	10.417	1.763	5.910
Cristal 56 SL @ 1 % ((three sprays at 10 days interval)	19.11	1.62	36.25	3.20	10.231	1.678	6.116
Cow urine @ 10 % (three sprays at 10 days interval)	19.23	2.24	35.62	1.49	10.263	1.722	5.960
Cow milk @ 10 % (three sprays at 10 days interval)	19.39	3.04	35.73	1.79	10.392	1.654	6.285
Neem oil @ 1% (three sprays at 10 days interval)	19.53	3.74	35.96	2.42	10.368	1.794	5.780
Hexaconazole @ 0.1 % (Two sprays at 15 days interval)	19.62	4.18	36.83	4.72	10.433	1.768	5.904
RBS 06 @ 1% (first spray) + Hexaconazole @ 0.1 % (second spray) at 15 days interval	19.33	2.74	36.15	2.93	10.425	1.732	6.019
Cristal 56 SL @ 1 % (first spray) + Hexaconazole @ 0.1 % (second spray) + Cristal 56 SL @ 1 % (third spray) at 15 days interval	19.76	4.86	36.80	4.65	10.380	1.730	6.011
Cow urine @ 10 % (first spray) + Hexaconazole @ 1 % (second spray) + Cow urine @ 10 % (third spray) at 15 days interval	19.38	2.99	36.48	3.81	10.504	1.721	6.104
Cow milk @ 10 % (first spray) + Hexaconazole @ 1% (second spry) + Cow milk @ 10 % (third spary) at 15 days interval	19.61	4.13	36.51	3.89	10.311	1.801	5.745
Neem oil @ 1 % (first spray) + Hexaconazole @ 0.1 % (second spray) + Neem oil @ 1 % (third spary) at 15 days interval	19.35	2.84	36.58	4.08	10.333	1.725	5.991
Control	18.80		35.09	-	10.232	1.781	5.726
SEm (±)	0.16		0.24		0.051	0.028	0.098
C D (P = 0.05)	**0.65**		**0.96**		**0.207**	**0.112**	**0.384**

index of 22.36 and 29.77 per cent was recorded in two sprays of hexaconazole @ 0.1 per cent at 15 days interval after appearance of rust at both Dharwad and Ugarkhurd, respectively. Spray schedule of cow milk @ 10 per cent followed by hexaconazole @ 0.1 per cent and cow milk @ 10 per cent, cristol 56 SL @ 1.0 per cent followed by hexaconazole @ 0.1 per cent and cristol 56 SL @ 1.0 per cent, and neem oil @ 1.0 per cent followed by hexaconazole @ 0.1 per cent and neem oil @ 1.0 per cent at 15 days of interval were found next best in reducing the rust intensity. Maximum seed yield of 2,320 kg/ha was recorded in cristol 56 SL @ 1.0 per cent followed by hexaconazole @ 0.1 per cent and cristol 56 SL@ 1.0 per cent. The treatments next in order were neemoil @ 1.0 per cent followed by hexaconazole @ 0.1 per cent and neem oil @ 1.0 per cent (2,316 kg/ha), and cow milk @ 10 per cent followed by hexaconazole @ 0.1 per cent and cow milk @ 10 per cent (2,266 kg/ha) spray schedules. The oil and protein contents were significantly influenced by different treatments. The treatments involving the spray schedules of cristol 56 SL @ 1.0 per cent followed by hexaconazole @ 0.1 per cent and cristol 56 SL @ 1.0 per cent recorded highest oil (19.76 %) and protein (36.80 %) contents in seeds. Regarding linoleic: linolenic acid ratio (Table 6), the treatment involving three sprays of cow milk @ 10 per cent at 10 days interval recorded higher value (6.285) than unsprayed control (5.726). Most of the treatments were on par with cow milk alone spray schedule. Similar views were expressed by Hundekar (1999) in soybean rust. The higher acid ratio in cow milk spray schedule is an indicative of increasing the shelf life of the oil (Eskin *et al*., 1996).

Identification and development of rust resistant soybean genotypes

Soybean genotypes, EC 241778 EC 241780 EC 391160 have shown resistant reaction and genotypes namely, SL 428, PK 1284 DSb 5, JS 95 65, TS 99 12, TS 99 76, PK 1024, Ankur, PK 1162, PK 1314, DS 228, TS 2000 20, VLS 2, EC 325115, EC 251378, EC 241760, EC 333917, EC 389149, EC 432536, VLS 63, MACS 993, PS 1437, KDS 167-9 MAUS 295, RCS 9, TS 13, DS 23-09, VLS 67 and EC 230970 were found moderately resistant or less susceptible to soybean rust. Many earlier workers have identified few soybean genotypes as resistant and moderately resistant to rust in India (Singh and Thapliyal, 1997; Patil and Basavaraja, 1997; Gupta *et al*., 1999; Patil *et al.,* 2004).

The hybridization programme involving rust resistant soybean genotypes *viz.* EC 241778 and EC 241780 with agronomically superior, but rust susceptible cultivar *viz.,* JS 335, JS 93 05 and DSb 1 has yielded 500 advanced breeding lines. The screening of these lines to rust under glass house conditions with artificial inoculation has yielded one line *viz.,* DSb 21 (a cross derivative of JS 335 x EC 241778), which showed resistant reaction to rust. Highly resistant reaction of DSb 21 tested under natural epiphytotic condition with higher seed yield at Dharwad and Ugar Khurd during rainy seasons of 2008-2011 was also confirmed by Basavaraja *et al*. (2012).

Based on the above results it can be concluded that the following non-chemical approaches like growing of rust resistant genotype, sowing in the second fortnight of May in irrigated areas, in first fortnight of June in assured rainfall areas and spraying either neem oil or cristol @ 1 per cent at the onset of disease can help soybean growers for good and safe management of rust.

REFERENCES

Anahosur K H and Patil P V. 1998. Soybean rust and its integrated management. *The Soybean Processors Association Digest* **7**: 15-33

Anahosur K H, Patil S H and Naik S T. 1982. Effect of date of sowing on the incidence of sorghum rust. *Indian Phytopathology* **35:** 247-50

Arunkumar R, Bhansali R and Mali O C. 2002. Response of bio-control agents in relation to acquired resistance against leaf curl virus in chilli. *In: Asian Congress on Mycology and Plant Pathology,* p 266.

Basavaraja G T, Shamarao Jahagirdar, Hosmath J A, Patil R H, Athoni B K and Somnath Agasimani. 2012. DSb 21-Apromising Soybean Rust Resistant Genotype in India. *Soybean Research* **10**: 104-6

Casey P S. 1979. The epidemiology of soybean rust (*Phakopspora pachyrhizi* Syd.). *Ph D Thesis,* 203 pp. University of Sydney, Australia

Chan K L and Tsaur W L. 1975. Investigation of soybean yield loss due to rust. *Annual report of Dry Land Food Crops Improvement* **16**: 206-8.

Eskin N A M, Macdonald B E, Przybylski R, Malcomson L J, Scarth R, Mag T, Ward K and Adolphe D. 1996. Canola oil, Chapter-1. *In Bailey's Industrial Oil and Fat products*. Fifth Ed,H Vol.2, John Wiley and Sons, N. Y.,pp.1-95.

Fugro P A. 2000. Role of organic pesticides and manures in the management of some important chilli diseases. *Mycological Plant Pathology* **30**: 96-7.

Ganapathy T and Narayanaswamy P. 1990. Effect of plant products on the incidence of major diseases of groundnut. *International Arachis Newsletter* **7:** 20-1.

Gupta G K, Ansari M M, Karmakar P G, Husain, S M and Ramteke, R. 1999. Resurrection of soybean rust (*Phakopsora pachyrhizi* Syd. & P.) in India. *Proceedings VI World Soybean Research Conference*. Chicago, Illinois. pp. 617.

Gupta G K, Kurundkar B P, Khot G G, Raut V M and Sharma S K. 2007. Epidemiology and race scenario of soybean rust in India. *Sopa Digest* **4**(7): 12-6.

Hong N X, Long T D and Dan N T. 1990. Soybean rust management in Vietnam. *Food legume-Course Grains Newsletter* **14**: 14-45.

Hsu C M and Wu L C. 1968. Study on soybean rust. *Scientific Agriculture* **16(**5-6**):** 186-8.

Hundekar A R. 1999. Studies on some aspects of soybean rust caused by *Phakopsora pachyrhizi* Syd. *Ph D Thesis,* University of Agricultural Sciences, Dharwad (India).

Jones P S, Ley S V, Morgan E D and Santafianos D. 1989. *The Chemistry of the Neem Tree. The Neem Tree, Focus on Phytochemical Pesticides,* M Jacobson (Ed), *CRS Press,* Florida, pp 19-45.

Kurata H. 1960. Studies on fungal diseases of soybean in Japan. *Bulletin of the National Institute of Agricultural Sciences No.12*: 1-154.

Manikandan G. 2005. *Organic Methods of Pest and Disease Management*, Centre for Indian Knowledge System, Chennai, p.18.

Mayee C D and Datar V V. 1986. Phytopathometry, *Technical Bulletin-I (Special Bulletin-3)*. *Marathwada Agricultural University, Parbhani*, p.95.

Patil P V and Basavaraja G T. 1997. A prospective source of resistance to soybeab rust. *Karnataka Journal of Agricultural Sciences* **10(**4): 1241-43

Patil P V and Basavaraja G T. 2002. Soybean rust scenario in Karnataka. Abstract: *Proceedings of. Indian Phytopathological Society- Annual Meeting and National Symposium on Plant Disease Scenario in Southern India*. December 19-21, 2002, UAS, Bangalore

Patil P V, Basavaraja G T and Hussain S M. 2004. Two genotypes of soybean as promising sources of resistance to rust caused by *Phakopsora pachyrhizi* Syd. *Soybean Research* **2:** 46-7

Sadasivam S and Manikam A. 1991. *Biochemical Methods for Agricultural Sciences*. Wiley Eastern Limited, New Delhi.

Singh B B and Thapliyal P N. 1977. Breeding for resistance to soybean rust in India. *In*: *Rust of Soybean – The Problems and Research Needs,* R E Ford and J B Sinclair (Eds), INTSOY series No. 12 Illinois, pp. 62-5.

Sridhar S, Arumugasamy S, Saraswathy H and Vijaylakshmi K. 2002. *Organic Vegetable Gardening,* Centre for Indian Knowledge Systems, Chennai, p. 39.

Usman M R, Jaganathan R and Dinakaran D. 1991. Plant disease management of groundnut with naturally occurring plant products. *Madras Agricultural Journal* **78:** 152-3.

Vijaylakshmi K, Arumugasmy R and Subhashini S. 2005. *Organic Methods of Pest and Disease Management,* Centre for Indian Knowledge Systems, p.8.

Wadhawani K, Mehrotra N and Dudeja S K. 1986. The effect of some plant extracts on uredospore germination of *Puccinia helianthi. Journal of Phytopathology* **22:** 133-6.

Wheeler B E J. 1969. *An Introduction to Plant Diseases*, John Willy and Sons Ltd. London, p 301.

Yang C Y. 1977. Soybean rust in Eastern Hemisphere, *In*: *Rust of Soybean: The Problems and Research Needs,* Ford R E and Sinclair J B (Eds), University of Illinois, USA, pp. 22-3.

Yeh C C and Yang C Y. 1975. Yield loss caused by soybean rust (*Phakopspora pachyrhizi* Syd.). *Plant Protection Bulletin 17*: 7-8.

Yu Z L, Tan Y J and Liu J L. 1980. Current status of soybean rust research. *Oil Crops in China* **1:** 47-55.

Zatarim M, Cardoso A I I and Furtado F L. 2005. Effect of types of cow milk on he powdery mildew control of pumpkin under field conditions. *Horticultura Brasileira* **23**(2): 198-201.

Soybean Research (Special Issue Number 2): 208-2012: 2014

Bio-efficacy Evaluation of Leaf Extracts of Some Plant Species against Tobacco Caterpillar (*Spodoptera litura* Fab.)

S P TAWARE[1], ABOLI BADNIKAR[2] and A S UPADHYE[3]
Agharkar Research Institute, G G Agharkar Road,
Pune 411 004, Maharashtra, India
E mail: neel.t20@gmail.com

ABSRACT

*Tobacco caterpillar (*Spodoptera litura *Fab.) is a serious pest of soybean and being a polyphagous pest it attacks many crops. It sometimes occurs in epidemic form on soybean and causes losses to the extent of 80 per cent or more. Botanical insecticides are environmentally safer option of chemical insecticides and sometimes show promising results. Present studies were aimed at evaluation of bio-efficacy of leaf extracts of 25 plant species against 3rd instar larvae of tobacco caterpillar. Antifeedant activity of petroleum ether, methanol and ethanol extracts was tested by both force feeding and free choice methods. Larval mortality was recorded after 24 hof force feeding. Results indicated methanol and ethanol extracts to be more effective than petroleum ether extract for antifeedant activity using both the methods. Larval mortality was more in methanol extract than other solvent extracts. Among the plant species,* Alianthus exelsa *Roxb.,*Paramignya monophylla *Wight,* Gardenia gummifera *Linn. f. and* Croton bonplandianum *Baill. exhibited both antifeedant activity and larval mortality.*

Key words: Antifeedant activity, leaf extracts, larval mortality, *Spodopteralitura* Fab.

Soybean [*Glycine max* (L.) Merrill] is a number one oilseed crop of India covering area of 10.7 million hectares with production of 12.7 million tonnes (SOPA, 2012). Due to several biotic and abiotic stresses productivity (1.2 t/ha) islower than worldand Asian average. Among biotic stresses insect-pests are responsible for 10 to 30 per cent yield losses (Ferry *et al*., 2004). Tobacco caterpillar (*Spodoptera litura* Fab.) is a serious pest of soybean crop causing losses to the extent of 80 per cent or more when it occurs in epidemic form. Several chemical insecticides have been recommended to control this pest. However, in view of environmental safety indi-scriminate use of these pesticides is not advisable. Botanical pesticides are safer option to these chemicals to control the pests effectively. A study on bio-efficacy of leaf extracts of 25 different plant species was conducted against this pest in the present investigation.

MATERIAL AND METHODS

Plant material (leaves) of 25 plant species (Table 1) was collected from different localities of western Maharashtra. The taxonomic identity of these plant species was confirmed by using regional floras and voucher specimens were deposited in the Agharkar Herbarium of Maharashtra Association (AHMA) of Agharkar Research Institute (ARI), Pune. The material was cleaned and extracts were made by standard procedure using various solvents like petroleum ether, methanol and ethanol. Traces of solvents were removed by using

[1]*Scientist F and Soybean Entomologist;* [2]*Research Student;* [3]*Scientist C*

rotary evaporator at reduced pressure and temperature. The extracts were kept in the refrigerator at 4°C.

Larvae of tobacco caterpillar were collected from the field and fed with untreated castor (*Ricinus communis* L.) leaves. After pupation the pupae were kept in mating cage. After emergence adults were fed with sucrose solution. Fresh castor leaves were kept in the cage for egg laying by female adults. The egg masses obtained were kept date-wise in petri dishes to observe for egg hatching. The hatched larvae were fed with fresh castor leaves till completion of 2nd instar stage. The 3rd instar larvae thus obtained were used for bio-efficacy evaluation of the leaf extracts.

Antifeedant activity of the leaf extracts was tested by free choice and force feeding methods. In free choice method, castor leaf discs of uniform size were treated with leaf extracts @ 100 mg per ml and arranged randomly in the large size petri dish (15 cm diameter) along with untreated discs as control. Fifty pre-starved (24 h) third instar larvae were released in the petri dish. Observations were recorded on the extent of leaf damage after 24 hours. The leaf extract treated discs showing no leaf damage were considered to have antifeedant activity.

In force feeding method pre-weighed castor leaf discs of uniform size were treated with different leaf extracts @ 100 mg per ml and were kept in separate petri dishes. Five pre-starved (24 h) third instar larvae were released on each leaf disc. Observations on leaf weight consumed and larval mortality were recorded after 24 hours of release. The leaf extract is considered to be having larvicidal effect when all the five larvae became dead / moribund. Antifeedant effect of the leaf extract was considered to be positive when the weight of leaf disc consumed was significantly lower than the mean at P = 0.01 level.

RESULTS AND DISCUSSION

The results indicated both antifeedant and larvicidal effects of several leaf extracts against tobacco caterpillar larvae (Table 1). The activity of plant crude extracts is often attributed to the complex mixture of active compounds. In nature there are many such compounds in different plant parts such as leaves, roots, seeds, flowers, fruits and bark in crude forms, which are being used by local people as conventional insecticides traditionally. Preliminary screening is a good mean of exploring their bio-efficacy against pests and diseases of crops and domestic animals.

Antifeedant activity

As many as 59 leaf extracts out of 75 extracts evaluated under present study by free choice and force feeding methods exhibited antifeedant activity against 3rd instar tobacco caterpillar larvae. In free choice method almost all methanol extracts (24 extracts out of 25) showed antifeedant activity followed by ethanol (20 extracts) and petroleum ether (9 extracts). Similar trend was observed in force feeding method except that less number of extracts showed antifeedant activity than in free choice method. Kamraj *et al*. (2008) and Koul *et al*. (2000) have also reported that methanol extracts are more effective thanthe extracts using other solvents. Earlier reports showed thatplant extracts exhibit antifeedant activity against *S. Litura* (Sahayaraj, 1998; Ulrichs *et al*., 2008; Sreelatha *et al*., 2010; Pavunraj *et al*., 2012). Elumalai *et al*. (2010) have reported antifeedant activity of medicinal plant essential oils against *S. litura*.

Larvicidal effect

Ten out of 25 methanol extracts evaluated showed larvicidal effect against

Table 1.Antifeedant and larvicidal activity of leaf extracts of different plant species

Plant species used	Antifeedant activity						Larval mortality		
	PE		ME		ETE				
	M1	M2	M1	M2	M1	M2	PE	ME	ETE
Vitex negundo L.	-	+	+	-	-	-	-	-	-
Meliadubia Cav.	-	-	+	+	+	-	-	+	+
Albizia chinensis Merr.	-	-	+	-	+	-	-	+	-
Gnidiaglauca Gilg.	+	-	+	-	+	-	-	-	-
Caesaria graveolens Dalz.	-	-	-	-	+	+	-	-	-
Sapindus laurifolius Vahl.	+	-	+	-	-	+	-	+	-
Azadirchta indica A.	+	+	+	-	+	-	-	+	+
Zanthoxy lumrhetsa Roxb.	+	+	+	-	+	+	+	-	-
Ervatamia heyneana Wall.	-	-	+	+	-	+	-	-	-
Scleicher aoleosa Oken.	-	-	+	-	+	-	-	-	-
Lepisanthus tetraphylla (Vahl.) Radlk.	-	+	+	+	+	-	-	+	-
Garcsiniata lbottii Raiz.	-	-	+	-	+	-	-	-	-
Randia spinosa (Poir.)	-	-	+	-	+	-	-	-	+
Paramignya monophylla Wight	+	+	+	-	+	+	+	+	+
Celtisti morensis Spanoghe	-	+	+	-	-	+	-	+	-
Gardenia gummifera Linn. f.	+	+	+	+	+	-	+	+	-
Annona squamosa Linn.	-	-	+	+	+	-	-	-	+
Balanitesae gyptiana (L.)	+	-	+	+	+	-	-	-	-
Croton bonplandianum Baill.	+	+	+	+	+	-	+	-	-
Vitex leucoxylon Linn.	-	-	+	+	+	+	-	+	+
*Termina liachebula*Retz.	-	-	+	-	+	+	-	-	-
Narega miaalata Wight and Arn.	-	+	+	-	+	+	+	-	-
Vitex sp.	-	-	+	-	-	-	-	-	-
*Premna obtusifolia*R. Br.	+	-	+	+	+	+	-	-	-
Ailanthus exelsa Roxb.	+	+	+	+	+	+	+	+	-
Control (untreated)	-	-	-	-	-	-	-	-	-
Control (solvent treated)	-	-	-	-	-	-	-	-	-

PE=Petroleum ether extract, ME = Methanol extract, ETE = Ethanol extract, M1 = Free choicemethod, M2 = Force feeding method, + = Activity present, - =Activity absent.

tobacco caterpillar larvae. For petroleum ether and ethanol extracts, 6 extracts of each showed larvicidal effect. Larvicidal effect of plant extracts against *S. Litura* larvae was reported by many researchers (Rathi and Gopalkrishnan, 2005; Baskar *et al*., 2011; Bhagat and Kulkarni, 2012).

Plant species

Among the 25 plant species evaluated, *Alianthus exelsa* Roxb.,*Paramignya monophylla* Wight, *Gardenia gummifera* Linn. f. And *Croton bonplandianum* Baill. were highly effective for both antifeedant and larvicidal effect. *Meliadubia* Cav., *Azadirchta indica* A. and *Vitex leucoxylon* Linn. also showed promising results for both the activities. All the three extracts of *Gnidiaglauca* in free choice method showed antifeedant activity, whereas methanol and ethanol extracts of *Albizia chinensis* Merr.,*Scleichera oleosa* Oken., *Garcsini atalbottii* Raiz., *Randia spinosa* (Poir.) and *Terminal iachebula* Retz. Exhibited antifeedant activity. In addition to the species mentioned above for larvicidal effect, petroleum ether extracts of *Zanthoxy lumrhetsa* Roxb. And *Naregamia alata* Wight & Arn.; methanol extracts of *Sapindus laurifolius* Vahl.,*Lepisanthuste traphylla* (Vahl.) Radlk. And *Celtisti morensis* Spanoghe and ethanol extracts of *Randia spinosa* (Poir.) and *Annona squamosa* Linn. Also showed larvicidal effect.

Arivoli and Tennyson (2012) have reported maximum antifeedant activity in *Z. Linonella* extracts. During the present study also all the three solvent extracts of *Z. Rhetsa* Roxb. exhibited antifeedant activity. Antifeedant activity of neem seed kernel extracts and its commercial formulations has been proved effective against many insect-pests and is used as one of the components in integrated pest management. Leaf extracts of neem (*A. indica*) exhibited antifeedant as well as larvicidal activity against *S. Litura* in the present investigation also.

From the present study, it was found that leaf extracts of many plant species have antifeedant and larvicidal activity. These extracts can be used as one of the components of integrated management of tobacco caterpillar, which will reduce the cost as well as help in reducing environmental hazards due to excessive use of chemical insecticides. Likewise, isolation of active compounds could possibly facilitate in finding new formulations for effective control of insect pests.

ACKNOLEDGEMENT

Authors are grateful to Director, Agharkar Research Institute, Pune for providing facilities.

REFERENCES

Arivoli S and Tennyson S. 2012. Antifeedant activity of plant extracts against *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). *American-Eurasian Journal of Agricultural and Environmental Sciences* **12:** 764-8.

Baskar K, R Maheshwaran, S Kingsley and Ignacimuthu S. 2011.Bioefficacy of plant extracts against Asian army worm *Spodoptera litura* Fab. (Lepidoptera: Noctuidae). *Journal of Agricultural Technology* **7:** 123-31.

Bhagat R B and Kulkarni D K. 2012. Evaluation of larvicidal and antifeedant potential of three *Jatropha* species against *Spodoptera litura* (Lepidoptera: Noctuidae) and two predators (Coleoptera: Coccinellidae). *Annals of Biological Research* **3:** 2911-6.

Elumalai K, A Krishnappa, M Anandan, Govindarajan and Mathivanan T. 2010. Antifeedant activity of medicinal plant essential oils against *Spodoptera litura* (Lepidoptera: Noctuidae). *International Journal of Recent Scientific Research* **2:** 62-8.

Ferry N, M G Edwards, J A Gatehouse and Gatehouse A M R. 2012. Plant-interaction: molecular approaches to insect resistance. *Current Opinion in Biotechnology* **15:** 155-61.

Kamraj C, A Abdul Rahuman and Bagvan A. 2008. Antifeedant and larvicidal effects of plant extracts against *Spodoptera litura* (F.), *Aedesae gypti* L. and *Culexquinque fasciatus* Say. *Parasitological Research* **103:** 325-31.

Koul O, M P Jain and Sharma V K. 2000.Growth inhibitory and antifeedant activity of extracts from *Meliadubia* to *Spodoptera litura* and *Helicovarpa armigera* larvae. *Indian Journal of Experimental Biology* **38:** 63-8.

Pavunraj M, K Baskar and Ignacimuthu S. 2012. Efficacy of *Melochia corchorifolia* L. (Sterculiaceae) on feeding behaviour of four Lepidopteran pests. *International Journal of Agricultural Research* **7:** 58-68.

Rathi M J and Gopalkrishnan S. 2005. Insecticidal activity of aerial parts of *Synedrella nodiflora* Gaertn (Compositae) on *Spodoptera litura* (Fab.). *Journal of European Agriculture* **6:** 223-8.

Sahayaraj K. 1998. Antifeedant effect of some plant extracts on Asian armyworm, *Spodoptera litura* Fabricius). *Current Science* **74:** 523-5.

SOPA. 2012. Soybean Processor's Association of India. www.sopaindia.org.

Sreelatha T, A Hymvathi, R S V Rao, P Devanand, P U Rani, M J Rao and Babu S K. 2010. A new benzil derivative from *Derris scandens*: Structure-insecticidal activity study. *Bioorganic and Medicinal Chemistry Letters* **20:** 549-53.

Ulrichs C H, I Mews, S Adhikary, A Bhattacharyya and Goswami A. 2008. Antifeedant activity and toxicity of leaf extracts from *portesiacoarctatatakeoka* and their effects on the physiology of *Spodoptera litura* (F.). *Journal of Pest Science* **18:** 79-84.

Soybean Research (Special Issue Number 2): 213-218: 2014

Evaluation of Virtako® 40 WG (Chlorantraniliprole 20 % + Thiamethoxam 20 %) against Soybean Insect Pests

D G MORE[1], K S BAIG[2], D H SARANG[3] and D T PAWAR[4],
AICRP on Soybean, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani 431 402, Maharashtra, India
E mail: daya_more@ rediffmail.com

ABSTRACT

Semilooper, girdle beetle and stem fly are causing great yield losses regularly in Marathwada region of Maharashtra. For the management of these pests, a new combination product Virtako® 40 WG (Chlorantraniliprole 20 % + Thiamethoxam 20 %) was evaluated at various doses (30, 40 and 50 g a.i. /ha) along with the checks Chlorantraniliprole 18.5 per cent SC, Thiamethoxam 25 per cent WG, Ethion 50 per cent EC and Imidacloprid 17.8 SL in a field experiment conducted during kharif *2010 at Parbhani (Maharashtra). The new combination product at levels 40 g a.i. per ha and above was found to be the most effective against semiloopers (1.56, 1.00 and 0.44 larvae per MRL at 3, 7 and 10 days after treatment application), girdle beetle (3.32 %) and Stem fly (4.48 % stem tunneling). Further, neither phytotoxicity at higher doses (100 g a.i. /ha) or any adverse effects on natural enemies was observed due to the application of the combination product.*

Key words: Bio-efficacy, chlorantraniliprole, defoliators, girdle beetle, soybean, stem fly, thiamethoxam

Maharashtra has become second largest soybean growing state in India contributing nearly 32 per cent area (3.8 million ha) and 37 per cent production (4.6 million tonnes) of the country next to Madhya Pradesh. (Anonymous, 2013). However, the productivity is more or less stable at about 1,100-1,200 kg per ha. Among different factors responsible for low productivity, incidence of insect-pests is of utmost importance. The important pests infesting soybean in Marathwada region include girdle beetle (*Obereopsis brevis*), stem fly (*Melanagromyza sojae*), tobacco leaf eating caterpillar (*Spodoptera litura*), semiloopers (*Chrysodeixis acuta, Gesonia gema*). All these pests cause severe yield losses every year.

Chechani *et al.* (1999) reported 40.27 per cent avoidable losses due to insect pests in soybean at Udaipur, Rajasthan. Gangrade (1976) observed 84.4 and 47.2 kg per ha reduction in the pod and seed yield, respectively due to girdle beetle. Venkatesan and Kundu (1994) reported that stem tunneling due to stem fly ranging from 10.0 to 20.0 per cent per plant caused a loss of 24.83 to 33.96 per cent or a grain yield loss of 2.75 to 3.81 g per plant. A yield loss of 30.37 per cent was reported by Singh and Singh (1990) due to stem fly tunneling.

Out of various methods of pest management, use of chemical insecticides is most preferred by the farmers as it gives quick visible effects. Every year more and more chemical insecticides are coming in market.

[1]*Junior Entomologist;* [2]*Soybean Breeder;* [3and4]*Senior Research Assistant*

Also, the manufacturers are bringing combination products of different insecticides from different insecticidal groups with different mode of actions. In such a situation, it becomes necessary to evaluate the bio-efficacy of these products against the targeted pests and critically inspect for their adverse effects on the natural enemies of the pests as well as on the plants.

MATERIAL AND METHODS

An experiment was carried out in randomized block design to evaluate the bio-efficacy of a new combination product Virtako® 40 WG (Chlorantraniliprole 20 % + Thiamethoxam 20 %) at three different doses (30, 40 and 50 g a.i. /ha) along with the checks Chlorantraniliprole 18.5 per cent SC, Thiamethoxam 25 per cent WG, Ethion 50 per cent EC and Imidacloprid 17.8 SL at the research farm of Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani (Maharashtra) during *kharif* 2010. Total nine treatments were replicated thrice. Soybean variety MAUS 71 was sown at 45 cm x 5 cm spacing and the plot size was 2.7 m x 5.0 m (6 rows of 5 m lengths each). All other recommended agronomical practices were followed to raise a good crop.

Observations on lepidopteron pests (*Gesonia gema* and *Chrysodeixis acuta*) and natural enemies were recorded at 3, 7 and 10 days after spraying from 3 places of 1 m row length selected at random. Per cent girdle beetle infested plants were recorded. Stem tunneling due to stem fly was recorded at physiological maturity. Soybean seed yield obtained per plot was converted to kilogram per hectare. All the data obtained is subjected to suitable transformations before statistical analysis.

Observations on phytotoxicity symptoms were recorded visually in field as per CIB guidelines (cibrc.nic.in, 2011). Effect on crop health *viz.*, yellowing, necrosis, scorching, epinasty and hyponasty were recorded 1, 3, 5, 7, and 10 days after application of spray using score as 0 = no phytotoxicity, 1=1-10 per cent, 2=11-20 per cent, 3=21-30 per cent, 4=31-40 per cent, 5=41-50 per cent, 6=51-60 per cent, 7=61-70 per cent, 8=71-80 per cent, 9=81-90 per cent and 10=91-100 per cent phytotoxicity and per cent effect was worked out.

RESULT AND DISCUSSION

During the season, incidence of *Spodoptera litura* and *Helicoverpa armigera* was not observed. Only semiloopers, *Gesonia gemma* and *Chrysodeixis acuta* were found infesting soybean crop, hence, among the defoliators, the bio-efficacy of Virtako® 40 WG was evaluated against semilooper only. The treatment application was done at 45 DAS (days after sowing). Later on, the population of semilooper was observed very low/ below ETL till the end of the season, hence only one spray was administered.

Effect on larval population of semiloopers, *Gesonia gema and Chrysodeixis acuta*

Non-significant differences among various treatments indicated an even distribution of the pest in all the plots (Table 1). At 3 days after treatment (DAT), all the treatments were found significantly superior over untreated check in reducing the semilooper population. The treatment Virtako® 40 WG @ 50 g a.i. per ha recorded lowest semilooper larval population (1.11 larvae/mrl), which was at par with Virtako® 40 WG @ 40 g a.i. per ha (1.56 larvae/mrl) and Chlorantraniliprole 18.5 per cent SC @ 30 g a.i. per ha (1.67 larvae/mrl). The next best treatment was Virtako® 40 WG @ 30 g a.i. per ha, which recorded 2.11 larvae per mrl and was at par with rest of the treatments except untreated check (4.22/mrl).

At 7 DAT also, all the treatments were significantly superior over untreated check. The treatment Virtako® 40 WG @ 50 g a.i. per ha recorded lowest semilooper larval population of 0.44 per mrl and was at par with treatments Virtako® 40 WG @ 30 g a.i. per ha (0.89 larvae/mrl), Virtako® 40 WG @ 40 g a.i. per ha (1.00 larvae/mrl) and Chlorantraniliprole 18.5 % SC @30 g a.i. per ha (1.11 larvae/mrl). Untreated check recorded highest number of semilooper larvae (3.44/mrl).

Table 1. Efficacy of Virtako® 40 WG (Chlorantraniliprole 20 % + Thiamethoxam 20 %) against semiloopers on soybean

Treatments	Pre-Count (No/mrl)	Semilooper larvae (No/mrl) Days after treatment		
		3	7	10
Untreated check	3.78 (2.06)*	4.22 (2.16)	3.44 (1.98)	2.22 (1.64)
Virtako® 40 WG @ 30 g (15 g + 15 g) a.i./ha	4.44 (2.22)	2.11 (1.61)	0.89 (1.16)	0.78 (1.12)
Virtako® 40 WG @ 40 g (20 g + 20 g) a.i./ha	3.00 (1.85)	1.56 (1.43)	1.00 (1.21)	0.44 (0.96)
Virtako® 40 WG @ 50 g (25 g + 25 g) a.i./ha	4.00 (2.11)	1.11 (1.25)	0.44 (0.96)	0.33 (0.89)
Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha	3.11 (1.89)	1.67 (1.46)	1.11 (1.23)	0.89 (1.17)
Thiamethoxam 25 % WG@ 25 g a.i./ha	3.56 (2.00)	2.67 (1.77)	1.89 (1.54)	1.11 (1.24)
Ethion 50 % EC@ 750 ml a.i./ha	4.22 (2.17)	2.33 (1.67)	1.44 (1.38)	1.11 (1.25)
Imidacloprid 17.8 SL@ 20 ml a.i./ha	3.67 (2.03)	2.56 (1.74)	1.67 (1.46)	1.33 (1.33)
SEm (±)	0.08	0.08	0.11	0.11
C D (P = 0.05)	**NS**	**0.26**	**0.36**	**0.34**

**Figures in parenthesis are square root (X + 0.5) transformed values.*

At 10 DAT as well, significant differences were observed with respect to semilooper incidence and all the treatments were found significantly superior over untreated check in reducing the population. Least number of semilooper larvae (0.33/ mrl) were recorded in the treatment Virtako® 40 WG @ 50 g a.i. per ha and it was at par with treatments virtako® 40 WG @ 40 g a.i. per ha (0.44 larvae/mrl), Virtako® 20 WG @50 g a.i. per ha (0.78 larvae/mrl) and Chlorantraniliprole 18.5 per cent SC @ 30 g a.i. per ha (0.89 larvae/mrl). The untreated check recorded 2.22 larvae per mrl. Rest of the treatments were intermediate and at par with each other.

Effect on girdle beetle (*Obereopsis brevis*)

The overall girdle beetle infestation at 60 DAS ranged from 2.82 to 10.28 per cent (Table 2). All the treatments were found significantly superior over untreated check in controlling the girdle beetle infestation. The treatment Virtako® 40 WG @ 50 g a.i. per ha recorded least infestation of 2.82 per cent and was at par with treatments Virtako® 40 WG @ 40 g a.i. per ha (3.32 %), Virtako® 40 WG @ 30 g a.i. per ha (3.65 %) and Chlorantraniliprole 18.5 per cent SC @ 30 g a.i. per ha (4.05 %). Rest of the treatments were intermediate and at par with each other except untreated check which recorded statistically highest girdle beetle infestation of 10.28 per cent.

At harvest also, more or less similar trend was observed. Least girdle beetle infested plants were observed in treatment Virtako® 40 WG @ 50 g a.i. per ha (4.16 %) and it was found at par with the treatment Virtako® 40 WG @ 40 g a.i. per ha (5.98 %). Rest of the treatments were intermediate and at par with each other. Statistically highest girdle beetle infestation of 18.45 per cent was recorded in untreated check.

Effect on stem tunnelling due to stem fly

Least stem tunnelling at physiological maturity was observed in treatment Virtako® 40 WG @ 50 g a.i. per ha (3.50 %), which was found at par with the Virtako® 40 WG @ 40 g a.i. per ha (4.88 %). Rest of the treatments were intermediate and at par with each other except treatment Ethion 50 per cent EC@ 750 g a.i. per ha which recorded 12.12 per cent stem tunnelling. Statistically significant and highest stem tunnelling was observed in untreated check (32.14 %).

Effect on beneficials

In the experimental plot, population of natural enemies like lady bird beetle predators were observed, but it was very low/ at negligible level. The differences are non-significant and the population treatment plots of Virtako® 40 WG were near about at same level suggesting that there was adverse effect of the chemical at tested doses on the natural enemies.

Effect on yield

All the insecticidal treatments recorded significantly more yield over untreated check. Highest yield of 2,530 kg per ha was recorded in treatment Virtako® 40 WG @ 50 g a.i. per ha and was at par with treatment Virtako® 40 WG @ 40 g a.i. per ha, which recorded yield of 2,217 kg per ha. The untreated check recorded significantly lowest yield of 1183 kg per ha.

The findings of the present investigation are in conformity with many earlier workers, *viz.*, Chaudhary and Meghwal (2012), who managed *Chrysodeixis acuta* Walker with rynaxypyr 20 SC @ 100 and 150 ml per ha and reported that it gave maximum seed yield of 1,106 kg per ha. Vinaykumar *et al.*,(2013) reported that rynaxypyr at 0.006 per cent was found most effective in managing *S. litura* and *H. armigera* infesting soybean in Junagadh, Gujarat. Virkar (2004) evaluated the effectiveness of different insecticides against major pests of soybean and reported that Thiamethoxam 25 WG at 100 g per ha was the most effective treatment in reducing tunnel length due to stem fly. Soybean pest management with spraying of different insecticides at different locations was reported by Patil et al. (2002), Keshbhat *et al.* (2004) and Mishra *et al.* (1995). Yadav et al. (2001) reported that combination product Chlorpyrifos 50 EC + Cypermethrin 5 EC was most effective in reducing the *Spodoptera litura* larval population population whereas the semilooper larvae were effectively managed by Chlorpyrifos 50 EC + Cypermethrin 5 EC followed by Profenofos + Cypermethrin 44 EC.

Table 2. Efficacy of Virtako® 40 WG (Chlorantraniliprole 20 % + Thiamethoxam 20 %) against girdle beetle, stem fly infestation and soybean seed yield

Treatments	Girdle beetle infested plants /mrl (%)		Stem tunnelling due to stem fly at physiological maturity (%)	Lady bird beetle (No/mrl)	Seed yield (kg/ha)
	60 DAS	At harvest			
Untreated check	10.28 (18.48)*	18.45 (25.34)*	32.14 (34.48)*	0.89 (1.17)#	1183
Virtako® 40 WG @ 30 g (15 g + 15 g) a.i./ha	3.65 (10.93)	6.80 (15.11)	7.53 (15.87)	1.11 (1.26)	2033
Virtako® 40 WG @ 40 g (20 g + 20 g) a.i./ha	3.32 (10.44)	5.98 (14.11)	4.88 (12.56)	1.00 (1.21)	2217
Virtako® 40 WG @ 50 g (25 g + 25 g) a.i./ha	2.82 (9.57)	4.16 (11.71)	3.50 (10.68)	1.00 (1.21)	2530
Chlorantraniliprole 18.5 % SC @ 30 g a.i./ha	4.05 (11.47)	7.26 (15.60)	7.08 (15.37)	0.67 (1.05)	2100
Thiamethoxam 25 % WG@ 25 g a.i./ha	5.22 (13.14)	8.86 (17.28)	9.13 (17.54)	1.00 (1.21)	1800
Ethion 50 % EC@ 750 ml a.i./ha	5.62 (13.65)	9.86 (18.21)	12.12 (20.35)	0.78 (1.09)	1683
Imidacloprid 17.8 SL@ 20 ml a.i./ha	5.11 (12.97)	7.94 (16.29)	10.26 (18.62)	0.89 (1.17)	1767
SEm (±)	1.10	1.09	1.26	0.11	110
C D (p = 0.05)	**3.34**	**3.30**	**3.83**	**NS**	**336**

**Angular transformed values; #Square root (x +0.5) transformed values.*in untreated check plot and the

Table 3. Phytotoxic effect of Virtako® 40 WG (Chlorantraniliprole 20 % + Thiamethoxam 20 %) on soybean crop after 1, 3, 5, 7 and 10 days after application*

Treatment	Yellowing	Necrosis	Scorching	Epinasty	Hyponasty
Untreated check	0	0	0	0	0
Virtako® 40 WG @ 50 g (25 g + 25 g) a.i./ha	0	0	0	0	0
Virtako® 40 WG@ 100 g (50 g + 50 g) a.i./ha	0	0	0	0	0

** mean of all observation*

Phytotoxicity effect of Virtako® 40 WG (Chlorantraniliprole 20 % + Thiamethoxam 20 %) on soybean crop

On the basis of per cent crop health and score, results indicated that no phytotoxic symptoms were observed in the plot treated with Virtako® 40 WG @ 50 and 100 g a.i. per ha (Table 3).

ACKNOWLEDGEMENT

Authors are thankful to M/s. Syngenta India Ltd., Pune for providing the chemical insecticides for evaluation of bio-efficacy against soybean insect-pests.

REFERENCES

Anonymous. 2013. http.// www.sopa.org

Chaudhary H R and Meghwal H P. 2012. Bioefficacy of rynaxypyr and spinosad against green semilooper, *Chrysodeixis acuta* Walker on soybean. *Indian Journal of Entomology* **74**(4): 323-5.

Chechani V K, Joshi F L, Meena V R and Sharma U S. 1999. Assessment of losses caused by insect pests of soybean, *Glycine max* (L.) Merrill. *Indian Journal of Applied Entomology* **13**: 65-9.

Gangrade G A. 1976. Assessment of effect on yield and quality of soybean caused by major arthropod pests. *Terminal Technical Report on the Project*, JNKVV, Jabalpur, Madhya Pradesh, pp.143.

Keshbhat S S, Bidgire U S and Suryawanshi D S. 2004. Field efficacy of different insecticides against stem fly, *Melanagromyza sojae* Z. and girdle beetle, *Obereopsis brevis* S. on soybean, *Glycine max* (L.) Merrill. *Journal of Oilseeds Research* **21**(1): 202-3.

Mishra B K, Mandal S M A and Mishra P R. 1995. Chemical control schedule for soybean green semilooper, *Chrysodeixis acuta* (Walker) and leaf miner, *Biloba subsecivella* Zeller. *Journal of Insect Science* **8**(1): 73-5.

Patil A K, Teli V S and Patil B R. 2002. Evaluation of insecticides against girdle beetle infesting soybean. *Journal of Maharashtra Agricultural Universities* **27**(3): 321-2.

Singh O P and Singh K J. 1990. Seasonal incidence and damage of *Melanagromyza sojae* (Zehntner) on soybean. *Indian Journal of Plant Protection* **18**(2): 271-5.

Venkatesan T and Kundu G G.1994. Yield-infestation relationship and determination of economic injury level of stem fly, *Melanagromyza sojae* (Zehnt.) infesting soybean. *Journal of Entomological Research* **18**(3): 265-70.

Vinaykumar M M, Raghvani K L, Naik L Krishna, Biradar Abdul Khadar and Chandrashekar G S. 2013. Management of *Spodoptera litura* (Fabr.) and *Helicoverpa armigera* (Mats.) in soybean with newer insecticides. *International Journal of Green and Herbal Chemistry* **2**(3): 665-74.

Virkar A R. 2004. Studies on chemical control and economics of major insect pests of soybean (*Glycine max* L.) *M Sc(Agri.) Thesis* (Unpub.), MAU, Parbhani.

www.cibrc.nic.in. 2011. Guidelines for regiatration of chemical pesticides.

Yadav M K, Matkar S M, Sharma A N, Billore M, Kapoor K N and Patidar G L. 2001. Efficacy and economics of some new insecticides against defoliators and stem borers of soybean [*Glycine max* (L.) Merrill.] *Crop Research* **21**(1): 88-92.

Soybean Research (Special Issue Number 2): 219-224: 2014

Optimization and Standardization of Process Technology for Preparation of Soycoffee

ABHIMANNYU A KALNE[1*], K ALAM KHAN[1], N A GHURDE[2] and V B KALMEGH[3]

Agro Produce Processing Division, Central Institute of Agricultural Engineering, Nabibagh Berasia Road, Bhopal 462 038, Madhya Pradesh, India

E-mail: abhikalne7@rediffmail.com

ABSTRACT

Over the years, a wide variety of plants were used to prepare coffee substitutes. Conventional coffee contains caffeine and methyl xanthine, which leads to nervous in-coordination, disturbs sleep and gives rise to many chronic diseases. Soybean coffee (soycoffee) can avoid the harmful effects of conventional coffee. Customarily, soycoffee can be prepared by preconditioning the beans, roasting and then grinding. Roasting of soybean is the most critical process which affects the overall acceptability and quality of soycoffee. Looking to non-availability of suitable roaster in market, existing popcorn machine was modified with necessary changes in roasting pan and agitator with provision of temperature control switch for selecting wide range of temperature. Different trials of soybean roasting (plain roasting and roasting with sand) were conducted using modified roaster in temperature range of 150-220 ^{0}C, with interval of 10 ^{0}C. For plain roasting, time required was observed as 42 min at 150 ^{0}C and 8 min at 220 ^{0}C. Sand roasting of beans was performed with bean to sand ratio 1:7 and 1:10 by weight and required roasting time at 150 ^{0}C was 31 min and 26 min, respectively, and at 220 ^{0}C it was observed as 8 min for both the ratios. Treatments were judged by method of sensory evaluation. Maximum value of consumer index (C I) was observed to be 0.88 for combination of 210 ^{0}C and 9 minutes with 1:7 beans to sand ratio and 0.83 for 210 ^{0}C and 9 min with 1:10 ratio. In case of plain roasting C I was 0.80 for 210 ^{0}C and 9 min.

Keywords: Consumer index, roaster, soycoffee, sand roasting, sensory evaluation

Day dawns of high-class society with a warm cup of coffee. Even business sector people as well intellectuals also prefer a cup of coffee to release the stresses and mental fatigue. Customarily, it is being served at various functions also. But most of them are unaware of what harmful ingredients they are taking in. Coffee contains caffeine and methyl xanthine, which leads to nervous in-coordination, disturbs sleep and gives rise to many chronic diseases. Not only these disadvantages but partial addiction also results due to continuous consumption. Nkondjock (2009) reviewed relation between coffee consumption and cancer. Author described that habitual coffee drinking has been associated with a reduced risk of mortality and chronic diseases, including cancer. Further author described that habitual coffee consumption has been associated with a substantially lower risk of mortality as well as degenerative, progressive and chronic

Research Associate, CIAE, Bhopal; [2and3]M Tech Student and Associate Professor respectively, Dr PDKV, Akola, Maharashtra

diseases, including Alzheimer's disease. Coffee contains many compounds which are known to affect human body chemistry. The coffee bean itself contains chemicals which are psychotropic for humans as a by-product of their defense mechanism. These chemicals are toxic in large doses, or even in their normal amount.

Over the years a wide variety of plants have been used to prepare coffee substitutes. In many cases, substitutes were developed in response to high price or non-availability of coffee itself. There is also, however, a desire by some consumers to avoid caffeine, while some coffee substitutes, such as a soybean provides the benefits of soy with analogues coffee taste. Soybeans provide all eight of the essential amino acids not manufactured by the body (Anonymous, 2013).

Answer to combat these problems, there is a need to find out which will give better substitute to coffee. Nature has served to mankind in various ways and in many forms. Looking deep into natural resources, 'soybean' is a magic capsule, which has all the potential to provide a better substitute for coffee, when subjected to little processing operations. It not only satisfies the human need for coffee, but also supplements with nutritious ingredients. As soy products are low in starch, soycoffee is beneficial for diabetic people due to presence of diabetic fiber and isoflavones. It also promotes healthy and strong bones and joints. In India, soybean crop has tremendous potential to be used in diet as well as for value addition (Ali *et al.*, 1988).

Properly dried beans of any variety when roasted and prepared, makes an excellent coffee substitute. During the civil war soybean was used rather extensively in the southern states as a coffee substitute. In some parts of Europe specially Switzerland, Japan and southern Russia soybean coffee is prepared and put in small packages in the market. This product has ground very fine and has much the appearance of coffee essence. Prepared as coffee, soybean gives the liquid of the same color and aroma as coffee, but it has got somewhat the flavor of a cereal beverages. Those who are fond of cereal drinks pronounce the soybean beverage to be the best (Kale, 1985). Stewart *et al.* (2003) conclude that soybeans dried using forced convective drying at a temperature of 60°C contained acceptable low levels of trypsin inhibitor activity, making them adequately processed for food purposes.

Customarily, soycoffee can be prepared by preconditioning the beans, roasting and then grinding. While roasting in baking oven, many problems were associated such as lack of stirring mechanism, unloading arrangement, inspection window *etc.* As elevated temperature is required, over roasting and burning of kernels are unavoidable. All these factors, ultimately results into poor quality of product and results into decrease in overall acceptance (Khorgade and Jawanjale, 2003). The present study thus deals in optimizing the process conditions for making soycoffee using a developed roaster. Product quality was also assessed by sensory evaluation.

MATERIAL AND METHODS

Raw material preparation and pre-conditioning

Soybeans of variety JS 335 collected from the farm of a local farmer. Any impurities/ foreign materials were removed by cleaning and only graded soybeans were used for further experiment. 100 g of graded soybeans were boiled in water (1:3 beans to water ratio) for 05 min with 1 per cent $NaHCO_3$. This treatment softens the beans and inactivates the enzyme called "lipoxygenase". Blanching usually refers to the immersion of foods in boiling water or steam for a short period of time, and is typically applied to legumes after soaking for reasons of microbial safety (Gowen *et al.*, 2007).

Excess moisture was drained out and the beans were spread for approximate 30 min to evaporate excess surface moisture. The splitted beans were separated and only whole beans were subjected to roasting. Mendonca *et al*. (2008) focused the negative aspects of defective coffee beans as they impart to the quality of the roasted and ground coffee used for beverage preparation and consumption. Roasting process of whole beans was carried out as plain roasting and with sand roasting (1:7 and 1:10 beans to sand proportion by weight) in a developed soycoffee roaster. Nicholas Pintauro (1999) described that roasting of coffee beans is essentially a process of exposing the beans to a warming process that is sufficiently fast to drive off the free and bound moisture and the dry bean residue is heated to more than 180 ^{0}C. At this temperature thermal decomposition and chemical changes occur within the bean.

Preparation of soy coffee powder

Whole beans were roasted using the developed roaster at a temperature of 150 ^{0}C to 220 ^{0}C with the interval of 10 ^{0}C. The roasting time was judged by change of soybean color from initial color to dark golden brown color. The roasting time required was recorded for each temperature level and roasted beans were then cooled and ground in domestic grinder to form soycoffee powder. The powder formed is then packed in polyethylene bags of 200 gauges. Fig. 1 shows flow diagram of soycoffee preparation.

Sensory evaluation of soy coffee powder

The pleasant taste soy coffee drink was prepared by boiling 125 ml of milk, with 15 g of sugar and 10 g of soycoffee powder for 5 min. On filtering, the drink was served to panel of 05 judges with score sheet. Sensory evaluation of soycoffee drink roasted at each roasting temperature level was carried out for colour, flavour and aroma of soycoffee tasted by a panel of 05 judges using a 9-point hedonic scale (Amerine, 1995). The nine point hedonic scale has value of 09 for liked extremely and 01 for disliked extremely. Consumer index was computed from score sheet of each judge using formula,

Consumer index (C I) = Total score/27

Total score was the sum of scores of nine point hedonic scale for colour, flavour and aroma. The denominator 27 comes as 9 (For 9 point hedonic scale) multiplied by 3 (3 parameters for which sensory evaluation carried out, *viz*, colour, flavour and aroma).

RESULTS AND DISCUSSION

Roasting is one of the most important parameter on which quality of soycoffee depends. To study the effect of different roasting temperature on quality of soycoffee, initially roasting temperature of developed roaster was set at 150 ^{0}C and gradually it increases in steps of 10 ^{0}C up to 220 ^{0}C. Temperature above 210 ^{0}C was not considered for study because it results in uneven burning of soybeans which lowers the aroma and overall quality of soy coffee.

Fig. 2 shows time required for optimized roasting using plain roasting and using sand roasting at two different bean to sand ratio by weight *viz*. one part of soybean and seven parts of sand (1:7) and one part of soybean and ten parts of sand (1:10) at different temperature levels of developed soycoffee roaster. Consumer index of soycoffee at respective roasting temperature was also calculated according to the formula given above (Table 1).

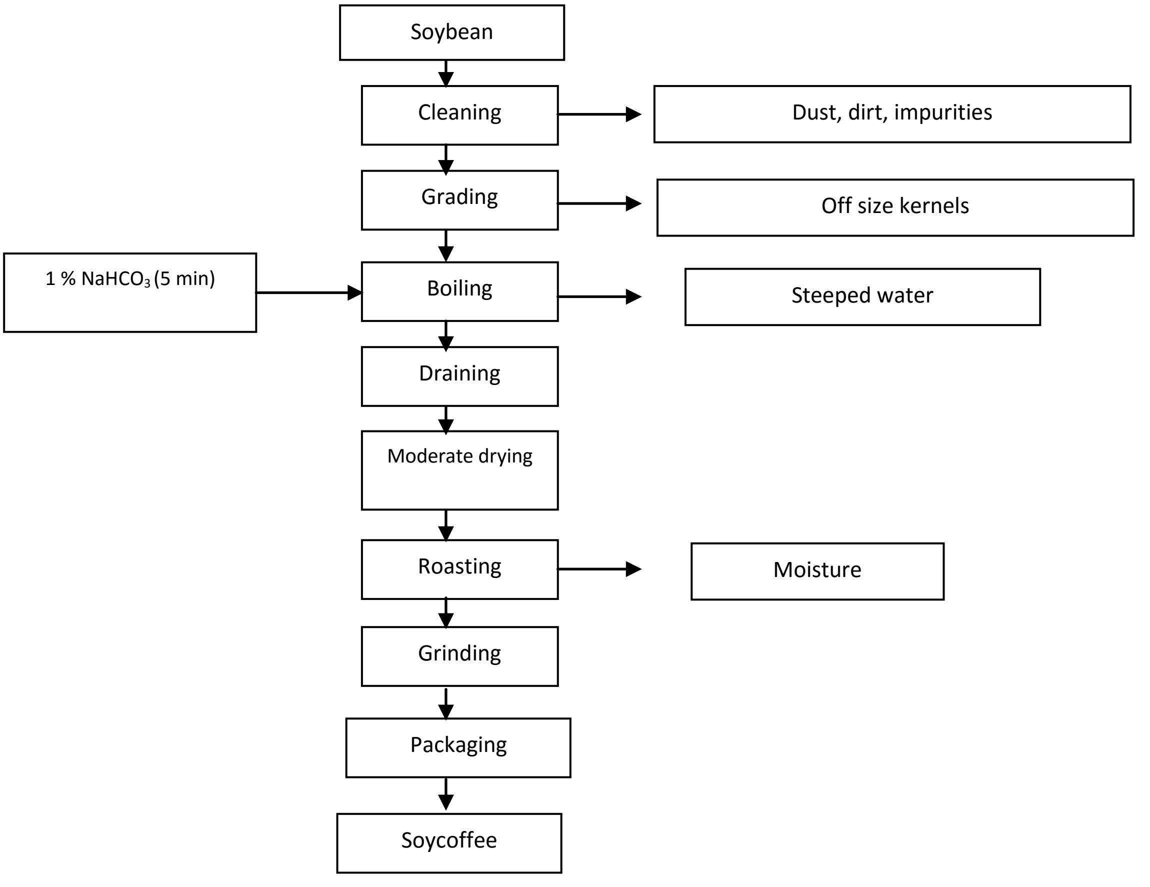


Fig. 1. Flow diagram for preparation of soycoffee

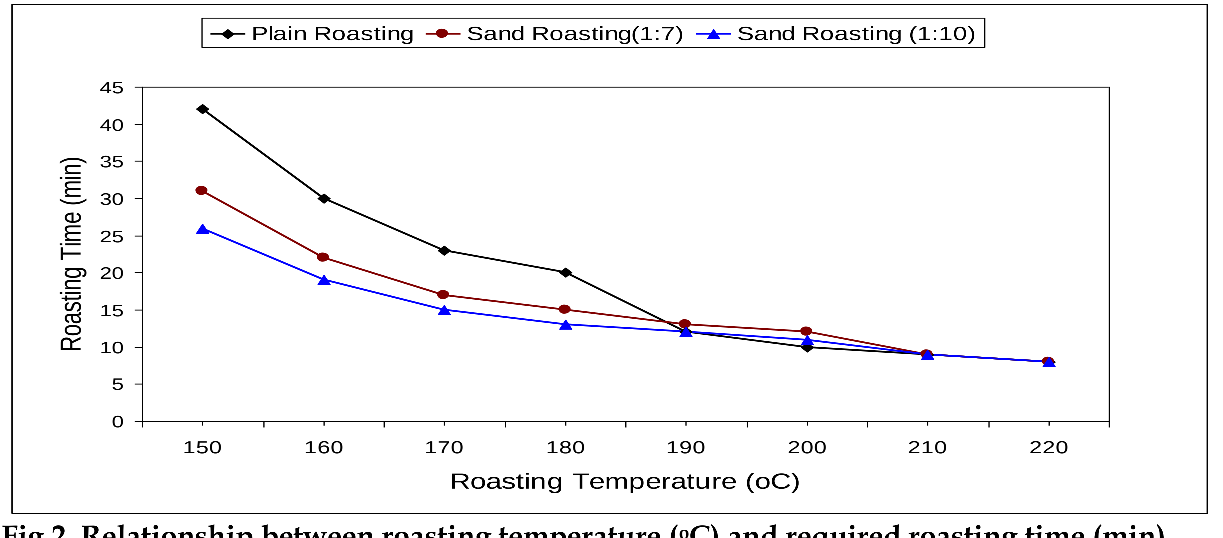


Fig 2. Relationship between roasting temperature (°C) and required roasting time (min)

Table 1. Effect of roasting temperature on C I (plain and sand roasting)

Roasting temperature (^0C)	Consumer Index		
	Plain Roasting	Sand Roasting (1:7)	Sand Roasting (1:10)
150	0.71	0.78	0.75
160	0.69	0.77	0.73
170	0.77	0.85	0.70
180	0.79	0.86	0.77
190	0.73	0.85	0.76
200	0.78	0.83	0.79
210	0.80	0.88	0.83
220	0.74	0.81	0.78

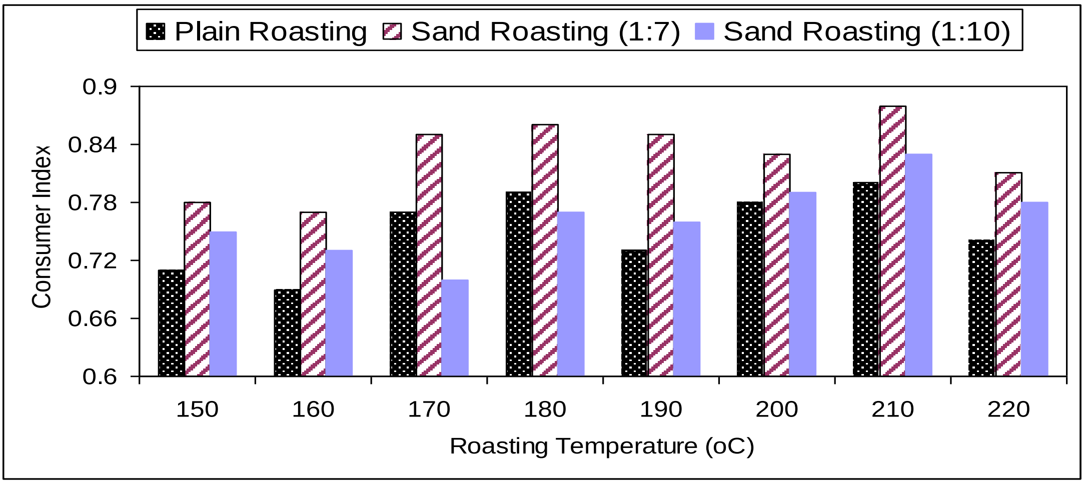


Fig. 2. Effect of roasting temperature (^0C) on consumer index of soycoffee

From the fig. 2 it was clear that as roasting temperature for preconditioned whole soybeans increases the time required for roasting decreases gradually. When temperature was set at 150^{0}C, optimized roasting time was recorded as 42 min whereas a minimum roasting time was noted as 8 min for temperature level of 220 ^{0}C for plain roasting.

Though at 220^{0}C roasting temperature, minimum roasting time of 8 min was noted, the corresponding consumer index was recorded as 0.74 only. As consumer index (C.I.) is an indicator of overall acceptability of prepared soy coffee drink, roasting temperature and time of 210^{0}C and 9 min was suggested for preparation of soycoffee powder. In case of sand roasting, maximum required roasting time was observed to be 31 minutes and 26 minutes for temperature of 150^{0}C in case of 1:7 and 1:10 ratio respectively. Whereas minimum roasting time required was noted as 8 minutes for both ratios of bean to sand roasting at temperature of 220⁰C. Similarly the relationship between roasting temperature for plain as well as sand roasting and consumer index of soycoffee prepared by respective roasting method is shown in table 1 and Fig. 3.

From the above data, the effect of temperature and roasting methods on overall acceptability of soycoffee could be discussed. It was observed that highest value of C.I. *i.e.*, 0.80 was recorded at temperature level of 210⁰C for plain roasting which requires roasting time of nine minutes. Values of consumer index (C.I.=0.88) was found for 1:7 beans to sand ratio at temperature of 210⁰C which takes nine minutes roasting time. Second highest C.I. *i.e.*, 0.83 was noted for 1:10 bean to sand ratio at temperature of 210⁰C which also require nine minutes roasting time. Consumer index, which is a measure of produce quality, has remained mostly unaffected due to bean to sand ratio. However, it is a complex function of temperature and time parameter and each combination affects the quality factors such as color, flavor and taste. The variation in C.I values represents the true picture of that complex phenomenon.

Thus it may be concluded from the present study that, soycoffee a novel soft drink can be prepared from soybeans by preconditioning, roasting and grinding process. A developed roaster could be used to roast the soybeans for preparation of soycoffee. After assessing the product quality by sensory evaluation, it may be concluded that the maximum value of C.I was observed to be 0.88 for combination of 210⁰C and 9 minutes with 1:7 beans to sand ratio and 0.83 for 210⁰C and 9 min with 1:10 ratio and 0.80 for 210⁰C and 9 min for roasting without sand.

REFERENCES

Ali Nawab, A P Gandhi and Ojha T P. 1988. Soybean processing and utilization in India. *Proceedings of the National Seminar on Soybean Processing and Utilization in India*. Held at Central Institute of Agricultural Engineering during 22-23 November 1986.

Amerine M A, Pangbornand R H and Roessler E B. 1995. *Principles of Sensory Valuation of Food*, Academic Press, New York, pp. 1-5.

Anonymous, 2013. Advantages and benefits of soy coffee. Available on www. /answers.yahoo.com/question/index?qid=1006012505561 Accessed on 25th November 2013.

Gowen A, Abu-Ghannam N, Frias J and Oliveira J. 2007. Influence of pre-blanching on the water absorption kinetics of soybeans. *Journal of Food Engineering* **78**: 965-71.

Kale F S. 1985. *Soybean Coffee for Dietetic People, Soybean*, International Books and Periodicals Supply Services, pp 334.

Khorgade P C and Jawanjale S D. 2003. Development of process technology for soy coffee. *B.Tech. (Agricultural Engineering) unpublished Thesis*. College of Agricultural Engineering and Technology, Dr. PDKV, Akola.

Mendonca J C F, Franca A S, Oliveira L S and Nunes M. 2008. Chemical characterization of non-defective and defective green Arabica and robusta coffees by electrospray ionization-mass spectrometry (ESI-MS). *Food Chemistry* **111**, 490-497.

Nicholas Pintauro. 1999. *Soluble Coffee Manufacturing Processes*, NDC Park Ridge, New Jersey, USA, pp.1-3.

Nkondjock André 2009. Coffee consumption and the risk of cancer: An overview. *Cancer Letters* **277:** 121-5.

Stewart O J, Raghavan G S V, Orsat V and Golden K D. 2003. The effect of drying on unsaturated fatty acids and trypsin inhibitor activity in soybean. *Process Biochemistry* **39**: 483-9.

Soybean Research (Special Issue Number 2): 225-235: 2014

Effect of pH on the Protein-Lipid Film Properties of Soy Milk

M SIVASHANKARI[1], AKASH PARE[2], B K YADAV[3] and A SANTHAKUMARAN[4],
Indian Institute of Crop Processing Technology,
Ministry of Food Processing Industries (Government of India),
Thanjavur 613 005, Tamil Nadu, India
Email: sivashankari_pfe11@iicpt.edu.in

ABSTRACT

The effect of various concentrations of sodium hydroxide (alkali) on the pH of soymilk, protein-lipid film formation yield, chemical composition and boiling resistance was studied. Film yield increased as the pH of the soymilk increased above its natural pH (6.5). Film yield was found to be more at 0.4 (v/v) and 0.5 (v/v) per cent of NaOH concentration in the soymilk than at 0.1, 0.2 and 0.3 per cent. Maximum protein incorporation was found at 0.2, 0.3 and 0.4 per cent levels of alkali incorporation than at 0.1 and 0.5 per cent. Whereas, the fat incorporation was less at 0.2, 0.3 and 0.4 per cent than at 0.1 and 0.5 per cent due to the less holding capacity of protein towards non-polar lipids at higher pH. Carbohydrates and minerals were also higher as the protein has the capacity to hold more polar groups at higher pH. Boiling resistance of protein-lipid films decreased as the percentage of alkali incorporation into the soymilk increased.

Key words: pH, protein-lipid film, soy milk

Soybeans have been an important source of protein, fat and flavor for oriental people for thousands of years. Soybean protein is unique among plant proteins by virtue of its relatively high biological value (Schroder *et al.*, 1973; Liener, 1972). It has been the subject of extensive investigation as a source of protein for the human diet. Direct use of soybean products as human food is a more efficient way of utilizing the highly nutritional soy protein as compared to feeding animals and then eating the animal products.

The use of soy protein as a food source is increasing due to its functional, nutritional, and nutraceutical properties (Liu, 2000). Soy protein used in the food industry is classified as soy-flour, concentrate, or isolate based on the protein content. Soy-flour contains 50–59 per cent protein and is obtained by grinding defatted soy flakes. Soy-protein concentrate contains 65–72 per cent protein and is obtained by aqueous liquid extraction or acid leaching process. Soy-protein isolate contains more than 90 per cent protein and is obtained by aqueous or mild alkali extraction followed by isoelectric precipitation (Soy Protein Council, 1987). Soy-protein also is used in infant formulas (soy-protein formulas account for a quarter of infant formula sales) and in baked, meat, and dairy products (Witherly, 1990). However, despite its high protein quality, low cost, and plentiful supply, currently only a small percentage of soy- protein is used as food ingredient, and is thus an underutilized product. Protein is a good source for edible film formation and therefore the application of the film could be suggested (Nemet *et al.*, 2010).

[1]*Research Scholar;* [2,3]*Assisstant Professor;* [4]*Professor*

Protein lipid film is one of the most important food products made from soybean milk. The protein-lipid film is formed during heating of the soymilk (Wu and Bates, 1973). It is an endothermic polymerization of protein or lipoprotein monomers on the liquid surface promoted by surface dehydration (Wu and Bates, 1972a). It can be produced in either of two ways: surface film formation on heated soymilk or film formation from solutions of soy-protein isolate (Gennadios and Weller, 1991). It is a kind of traditional soybean food which is delicious and of high nutritional value (Liu, 1997). The protein digestion rate of protein-lipid film is almost 100 per cent (Han *et al*., 2005). Protein and lipids are the main components in protein-lipid film with carbohydrates and ash being present in smaller amounts. A typical composition(w/w, dry basis) of protein lipid film consists of 50.5 per cent protein, 28 per cent lipids, 10.2 per cent carbohydrates and 0.2 per cent ash (Wu and Bates, 1972b).

Organoleptically, soy-protein-lipid film itself is rather bland. It is normally used as an ingredient in many food dishes, as a wrapping film for other materials such as meat, and as a starting material for the fabrication of a wide range of oriental simulated meat products or meat analogues with improved texture and flavour (Wu and Bates, 1975). Dehydrated soy-protein-lipid film has to be reconstituted into a pliable product for these purposes. The application of these films to food processing is not new. Among protein-based materials, those from soybean have been used as: (i) coatings of fruits, vegetables, cheese, pre-cooked meats, fried foods, and other food products, (ii) as carriers of antioxidant agents, flavors and antimicrobial compounds, and (iii) for encapsulation and stabilization of flavors and medicines (Gennadios and Weller, 1991; Petersen *et al*., 1999; Park *et al*., 2002).

Protein film formation is pH dependent, (Park *et al.,* 2002). Soy-protein films can be formed under both alkaline and acidic conditions. A soymilk of pH value around nine maximized the film yield and protein incorporation into films (Wu and Bates, 1972a; Sian and Ishak, 1990). Dispersion pH is one of many variables in film formation, and also has a considerable influence on the denaturation process. Soy-protein film formation has been achieved within pH 1-3 and 6-12. No film formation occurred near the protein isoelectric point (pH 4.5), also the effect of pH of the film solutions were investigated on solubility, molecular and structural properties of soy protein films (Mauri and Amin, 2006). Chemical treatments with acid, alkali or cross-linking agents have been extensively used to improve the properties of films (Bourtoom, 2009). For film to form, the proteins must be dissolved completely by adjusting pH or by selecting suitable solvents (Okamato, 1978). Traditional methods of film formation as performed in the orient consist of heating soymilk in shallow pans and periodically removing the films manually when their strength so warrants (Wu and Bates, 1975). The conventional heating method of producing protein-lipid film is water bath heating, in which it is difficult to control the heating temperature. Ohmic heating of food products is regarded as a potential alternative to conventional heating (Lei *et al*., 2007). Also ohmic heating holds advantages in producing safe, wholesome and nutritious food for consumers (Manvell, 1997) and recently ohmic heating technology has been applied in food production successfully. Ohmic heating is a new method in the production of protein-lipid film of higher quality from soymilk, (Lei *et al*., 2007). Thus, it seemed desirable to study the effect of varying levels of alkali on the pH of soymilk, protein-lipid film formation yield, chemical composition and boiling resistance of the films produced by ohmic heating technology.

MATERIAL AND METHODS

Soybeans (*Glycine max*) were obtained from the local market in Coimbatore, Tamil nadu and same variety of soybean was used throughout the study. They were stored at refrigerated temperature before protein-lipid film production. A batch type ohmic heating setup developed at IICPT, Thanjavur was used for the study.

Extraction of soymilk

Extraction of soybean milk with a bean-to-water ratio of 1:10 was carried out. Soybeans were washed and soaked in tap water for 12 h at refrigerated temperature (4-8 °C). The hydrated beans were drained and ground with tap water (ten times bean weight), using a soymilk grinder/extractor plant [Pristine Plants India (Pvt.) Limited, Faridabad, India] installed at IICPT, Thanjavur. The grinder/extractor, equipped with grinder, de-odorizer and filter, could separate soymilk from the residue okara. The volume and solids content of the collected soymilk were measured and maintained uniform throughout the study. It was recommended that the concentration of total solids in soymilk be less than 9 per cent as higher concentrations caused gelation and thickening of the system upon heating (Wu and Bates, 1973). The flowchart (Fig. 1) for the whole process is given.

Heating of soymilk

The percentages of alkali (5 N NaOH) used for the film formation were 0.1 (v/v), 0.2 (v/v), 0.3 (v/v), 0.4 (v/v) and 0.5 (v/v) per cent, where the soybean milk did not curdle and films could form on the surface during heating. In each case, soybean milk was added with desired quantity of alkali and the pH change was noted down. The pH change of soymilk was found to be 7.6, 8.2, 9.5, 9.7 and 10.6, respectively. The soymilk with the varied pH was then used for the film formation using ohmic heating setup developed at IICPT, Thanjavur (Fig. 2). Triplicate 500 ml samples of soymilk after varying the pH were poured into the acrylic ohmic heating tray of dimension (15 cm L x 15 cm W x 5 cm H) with the two stainless steel electrodes placed at two opposite ends and was attached to a control panel where the voltage was fixed to be 150 V. A data acquisition system for temperature showing was used, from which the heating temperature of soymilk could be read directly. The temperature was monitored using a T-type thermocouple, which connected with the stainless steel electrodes and data acquisition system. The soymilk was heated using a low frequency alternating current from the public utility supply (50 Hz, 200 V). The milk was heated to and maintained at a temperature of about 95 °C.

Separation of film

During heating, the films formed on the milk surface were loosened, picked up with a plastic L-rod at 10 min interval on an average. The separated films were numbered according to the sequence of removal and were air dried for 48 h at 25 °C, and the weight of films were recorded as film yield. Film formation was continued until film could not fully form at that voltage. The dried films from each batch were ground using mortar and pestle and thoroughly mixed. All chemical analyses and experiments were carried out using the ground samples.

Estimation of film properties

Films obtained from each interval for

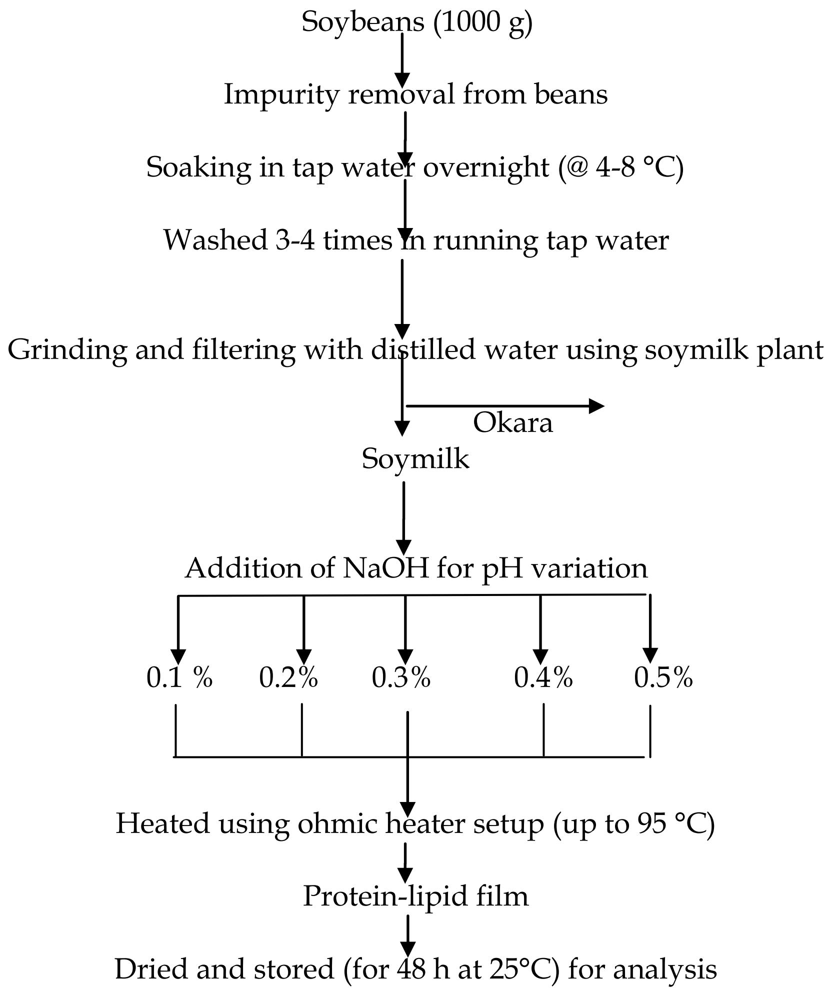


Fig. 1. Flow diagram for manufacturing protein-lipid film

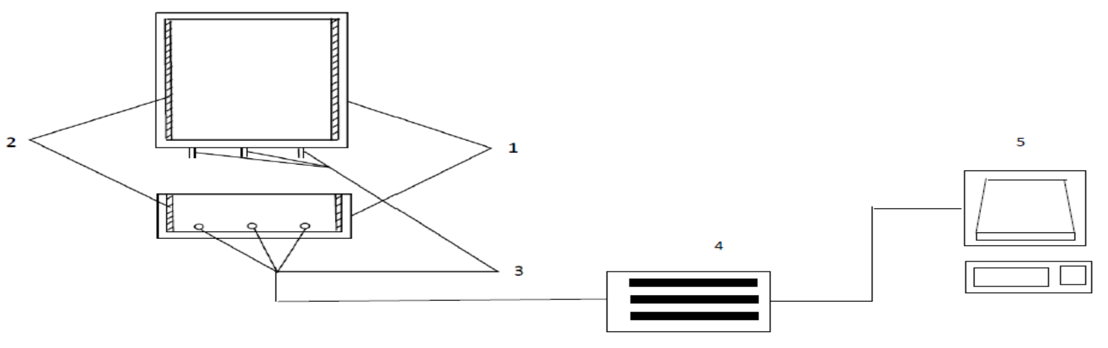


Fig. 2. Details of the ohmic heating trough: 1, teflon tray; 2, stainless steel electrodes all along the width; 3, thermocouple ports; 4, data logger; 5, computer

every different percentage of alkali were ground and stored (after determination of color values) for determination of protein, fat, moisture and ash contents (AOAC, 1975). The carbohydrate content was calculated by difference. Boiling resistance of the film formed at different level of pH was expressed as the amount of protein leached into boiling solution. Yield referred to the protein-lipid film yield of every 100 mL soymilk, while film formation rate referred to the protein-lipid film yield every 10 min. They were calculated as follows:

$Y = M/G*100$ and $V = M*10/T$

Where Y and V were the yield (g/100 ml) and film formation rate (g/10 min) of protein-lipid film respectively; M is the total protein-lipid film obtained (g); G is the volume of soybean milk for film formation (ml); T is the total time (min) used before ending film recollection.

RESULTS AND DISCUSSION

Film yield

Protein concentration of soymilk has some effects on protein-lipid film yield and film formation rate. Some factors other than protein concentration of soymilk were also important for the yield of protein-lipid film, (Shen *et al*., 2009).

The effect of incorporation of different concentrations of NaOH to the soymilk on the properties of protein-lipid film formed was investigated. The film yield was found to be more at 0.3 (v/v) and 0.5 (v/v) per cent levels of alkali incorporation to the soymilk, whereas it was less in 0.1 (v/v), 0.2 (v/v) and 0.4 (v/v) levels. It can be said that alkaline pH favoured film formation as at this pH the incorporation of protein will be more in the film thereby increasing the film weight. It was the highest at 0.3 (v/v) per cent NaOH incorporation, followed by 0.5 (v/v) and 0.1 (v/v) per cent alkali incorporation to the soymilk. Since there was more protein available at pH 9.5 and 10.6 for protein lipid interaction and carbohydrate binding, films formed at these two pH were heavier than those at pH below 9. The film yield increased by increasing the pH of soymilk from 6.0 to 9.0 (Wu and Bates, 1973).

By adding 0.1 per cent 10 N HCl to the soymilk approaching the isoelectric range lowered its pH to 5, no film was formed and the protein coagulated. Also at soymilk of pHs higher than 10.6, protein tends to be solubilized or dissociated into its molecular subunits (Kelley and Pressey, 1966). The film yield was higher at pH 9.5 and 10.6. However, the films darkened at an alkali incorporation of 0.6 (v/v) per cent to the soymilk as the pH raised to 11. This may be due to the acceleration of destruction of sulfur-containing amino acids at alkaline pH's (Badenhop and Hackler, 1970) that caused the weights of the soy protein lipid film to decrease, and the yield was very low. At lower pH, some of the proteins coagulated and could not function in protein matrix, resulting in low film weight and yield. Therefore, the percentage alkali incorporation of choice for the maximum protein lipid film yield is 0.3 (v/v) and 0.5 (v/v) per cent levels (Fig. 3).

Proximate composition of film

Protein content: Protein is the vital component in soymilk for film formation. Maximum protein incorporation in the film was found at 0.2 (v/v), 0.3 (v/v) and 0.4 (v/v) per cent levels of alkali incorporation whereas less at 0.1 (v/v) and 0.5 (v/v) percent (Fig. 4). This showed that an optimum pH range is required for the maximum protein

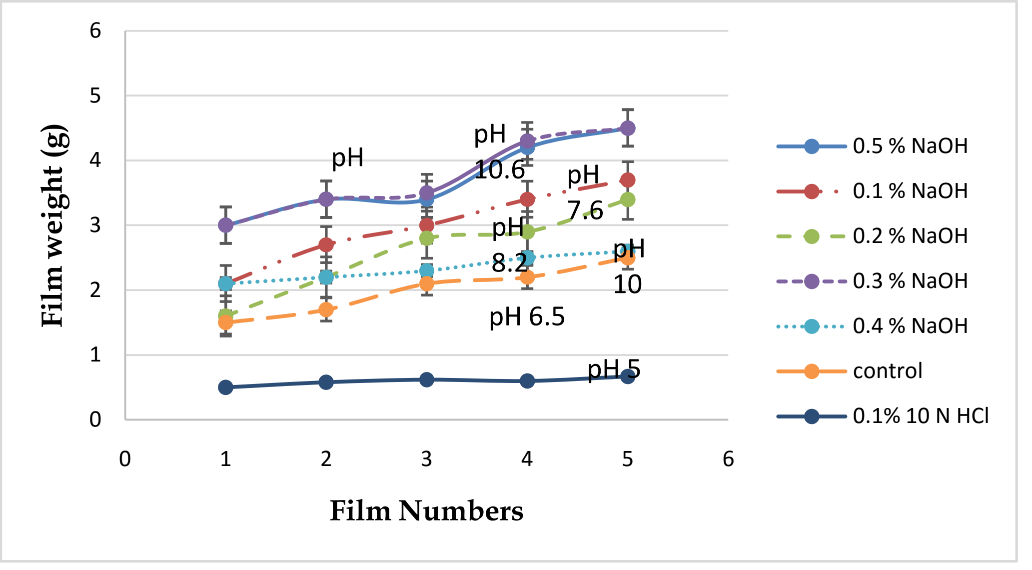


Fig. 3. Effect of pH on the soy-protein-lipid film yield

incorporation into the film. This is because the pH affects the protein charge and the degree of protein denaturation. Proteins in films maintains their native conformation at pH 8.0, and were extensively and partially denatured at pH 2 and 11, respectively (Mauri and Anon, 2008).

At very high pH, protein content of the films decreased. This may be due to the intermolecular repulsion of the highly negative charges of proteins. Similarly at lower pH, some of the proteins coagulated and could not function in protein matrix formation resulting in low film weight and yield (Okamato, 1978). At the extreme acidic or alkaline pH values, strong electrostatic repulsion of ionized group occurs in the film-forming solution, which leads to the solubilization of proteins (Hamaguchi *et al.*, 2007). This is because the unfolded proteins obtained using either acidic or alkaline solubilizing process underwent the aggregation through hydrogen, ionic, hydrophobic and covalent bondings, particularly when the water was removed (Damodaran and Paraf, 1997).

Fat content: Several researchers have reported improvements of functional and physico-chemical properties of proteins resulting from their interaction with lipids include improving the properties of soy films (Bates and Wu, 1975; Farnum *et al.*, 1976). Protein-lipid complexes are known to occur in wheat grains, peanuts, and in the oil bodies of oil seeds such as soybean, sunflower and rapeseed and in some fruits and vegetables. Soy-film consists of structure of continuous protein matrix, in which lipid droplets are dispersed. Temperature, pH and concentration are important in producing films from soymilk (Farnum *et al.*, 1976; Beckwith, 1984). Soy-films and soymilk are examples of complexes of protein and lipid; the main soybean proteins (7S and 11S) are involved in the film formation and in protein

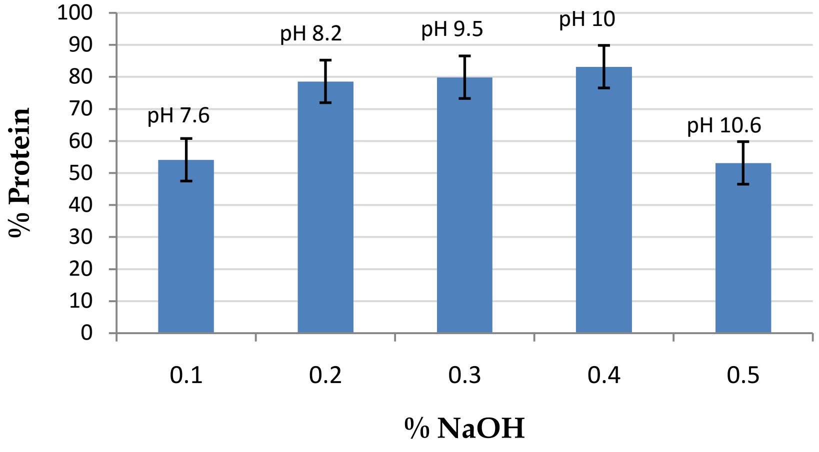


Fig. 4. Effect of pH on the protein content of protein-lipid film

-lipid complexes (Farnum *et al*., 1976; Beckwith, 1984). It was observed that at 0.2 (v/v), 0.3 (v/v), and 0.4 (v/v) per cent of alkali incorporation where the pH of soymilk was quite high (than the native pH of 6.5) protein solubility was high causes an increase in emulsifying capacity of proteins which tends to disperse fat globules more evenly in the milk, resulting in less fat at the surface and hence less fat got incorporated into the films. Fat content incorporation in the films showed a decreasing trend because of these reasons.

Also, the higher incorporation of negatively charged proteins at higher pH probably increased its capacity to hold more polar groups such as minerals and carbohydrates but less tendency to hold thenon-polar lipids (Fig. 5).

At 0.5 (v/v) per cent of alkali incorporation where the pH is very high, the protein carries a net negative charge and there is electrostatic repulsion and a reduced tendency to interact.

Carbohydrate and minerals

In all cases, soymilk protein and fat were incorporated into the films more effectively than carbohydrates (Fig. 6 and Fig. 7). Therefore, the majority of protein and lipid are incorporated into the film, and the carbohydrate and ash (minerals) are increasingly concentrated in the residual whey as well as in the sub sequentially removed films.

As mentioned earlier, the incorporation of carbohydrates and minerals are also high as the protein has the capacity to hold more polar groups such as carbohydrates and minerals. Carbohydrates accounts for almost one third of the weight of dry soy- film. The nature of the protein-carbohydrate interactions is unknown, however, in general, these constituents associate through ionic and hydrogen bonding rather than covalent or hydrophobic forces. So films with higher protein content also had high levels of carbohydrates and minerals (Fig. 7 and Fig. 8).

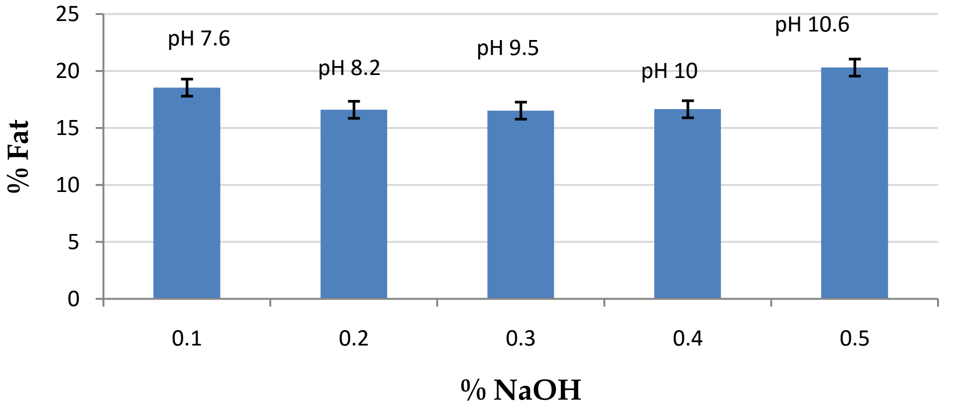


Fig. 5. Effect of pH on the fat content of protein-lipid film

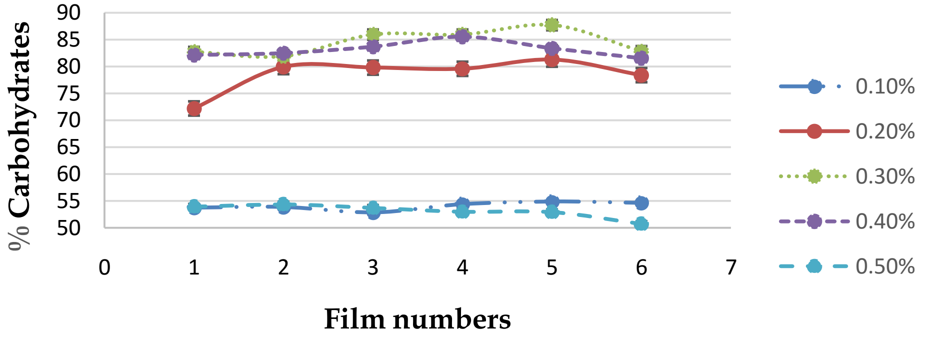


Fig. 6. Effect of pH on the carbohydrates content of protein-lipid film

The differences in the incorporation efficiencies of the major components (percentage in films based on total amount in soymilk) among five soymilks was probably due to pH. In the soymilk with extreme alkaline or acidic pH, protein content of the films decreased slightly more than films at higher pH. This decrease is due to the solubilization or dissociation of soybean protein into its molecular sub-units.

Also the presence of highly charged protein molecules caused less hydrophobic but more hydrophilic and ionic interactions; thus fat content decreased, while ash and carbohydrate content increased. At extremely acidic pH, protein contents of the films were the lowest, probably due to the precipitation of the acid-sensitive protein and formation of insoluble complexes past the isoelectric point. Thus, fewer proteins were present at the surface, and less fat globules are trapped. On the other hand, the percentage of ash and carbohydrates increased relatively (Sian and Ishak, 1990).

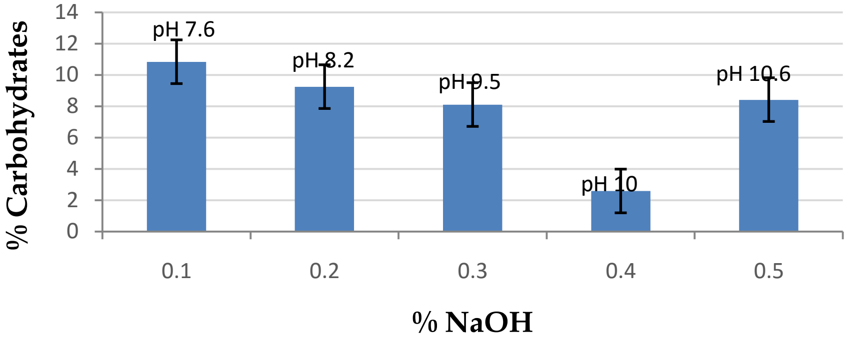


Fig. 7.Effect of pH on the carbohydrates content of protein-lipid film

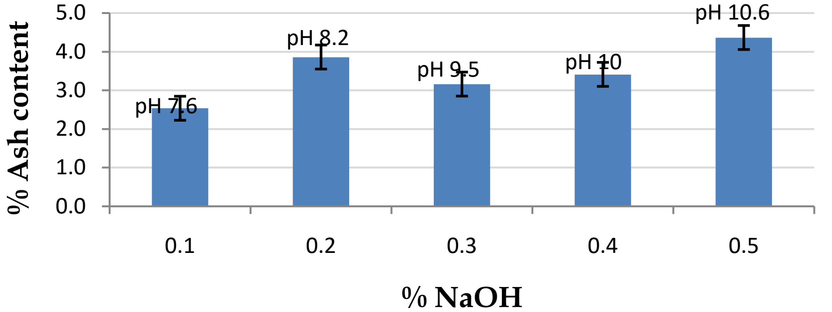


Fig. 8.Effect of pH on the ash content of protein-lipid film

Film formation rate

The natural pH of soymilk is about 6.5. Film formation is favored in alkaline pH. At pH values lower than 6.5 and near the isoelectric range of protein fractions in soymilk, film formation is impaired due to protein coagulation. On the other hand, in extremely alkaline environments, negative charges along the protein chains create repulsive forces that inhibit formation of the film protein matrix (Gennadios and Weller, 1991).

Film formation rate was maximum at 0.2 (v/v) per cent followed by 0.1 (v/v), 0.3 (v/v), 0.4 (v/v) and 0.5 (v/v) per cent of alkali incorporation in soymilk (Fig. 9). This was well correlated with the results observed by Wu and Bates (1972b) and Sian and Ishak (1990), where they suggested an optimum soymilk pH range for film formation between 7.0 and 9.5. Boiling resistance of the film formed at every pH was expressed as the amount of protein leached into the boiling solution. It was found to decrease as the percentage of alkali incorporation into the soymilk increased (Fig. 10).

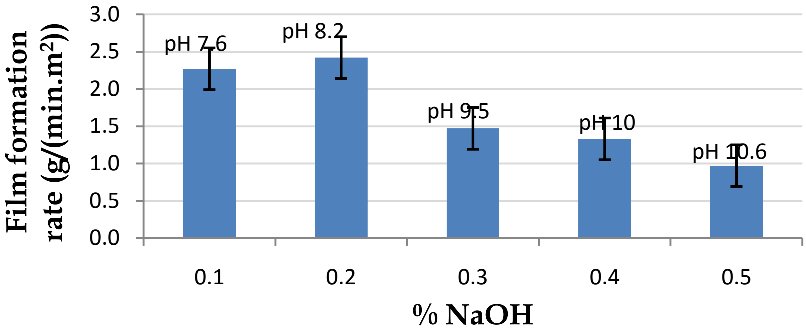


Fig. 9. Effect of pH on the Film formation rate of protein-lipid film boiling resistance

As the alkali incorporation to soymilk increased to 0.3 (v/v), 0.4 (v/v) and 0.5 (v/v) per cent, the number of negative charges increased due to the increase in pH and as a result weaker films are formed as the protein molecules tend to repel each other. This was well correlated with the results observed by Sian and Ishak (1990). Thus, the boiling resistance of protein-lipid films at high pH was found to be lower than the natural pH (6.5).

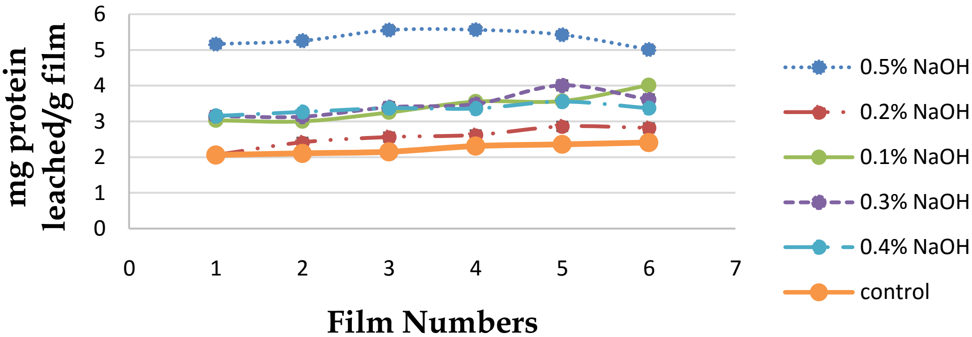


Fig. 10. Effect of pH on the boiling resistance

The studies performed allow us to correlate the chemical composition, yield, film formation rate and boiling resistance of soy protein-lipid film with the pH of soymilk. Increasing the soymilk pH by incorporating alkali in the range of 0.2 (v/v) to 0.4 (v/v) percentage is suggested for film formation with better protein incorporation and boiling resistance. The films formed at the pHs above 10.6 are not recommended due to the lower protein incorporation than the required and decreasing boiling resistance which may have possible ill effects on human health. It was observed that at extreme acidic and alkaline conditions, film formation is inhibited because of the strong repulsive forces of highly negative ($pH > 10.6$) or positive ($pH < 6.5$) charges along protein chains, which prevent protein molecules from associating and forming films.

REFERENCES

AOAC. 1975. *Official Methods of Analysis*, 12th ed. Washington, D.C. Association of Official Analytical Chemists. Section 47.021 (Modified).

Badenhop A F and Hackler L R. 1970. Effects of soaking soybeans in sodium hydroxide solution as pretreatment for soy milk production. *Cereal Science Today* **15**: 84.

Bates R P and Wu L C. 1975. Protein quality of soy protein-lipid films (yuba) and derived fractions. *Journal of Food Science* **40**(2): 425-6.

Beckwith A C. 1984. Interaction of phosphatidylcholine vesicles with soybean 7S and 11S globulin proteins. *Journal of Agricultural and Food Chemistry* **32**(6): 1397-1402.

Bourtoom T. 2009. Edible protein films: properties enhancement. *International Food Research Journal* **16**(1): 1-9.

Damodaran S and Paraf A. (Eds.). 1997. *Food Proteins and Their Applications* (Vol. 80). CRC Press.

Farnum C, Stanley D W and Gray J I. 1976. Protein-lipid interactions in soy films. *Canadian Institute of Food Science and Technology Journal* **9**(4): 201-6.

Gennadios A and Weller C. 1991. Edible films and coatings from soymilk and soy protein. *Cereal Foods World* **36**(12): 1004-9.

Hamaguchi P Y, WuYin W and Tanaka M. 2007. Effect of pH on the formation of edible films made from the muscle proteins of Blue marlin (<i>Makairamazara</i>). *Food Chemistry* **100**(3): 914-20.

Han Zhi, Takasuke Ishitani and Zaigui Li. 2005. Effects of different soymilk concentrations and depth on the formation of yuba. *NongyeGongchengXuebao (Transactions of the Chinese Society of Agricultural Engineering)* **21**(11): 179-81.

Kelley J J and Pressey R. 1966. Studies with soybean protein and fiber formation. *Cereal Chemistry* **43**(2): 195-206.

Lei L, H Zhi, Xiujin Z and Zaigui, L. 2007. Effects of different heating methods on the production of protein–lipid film. *Journal of Food Engineering* **82**(3): 292-7.

Liener I E. 1972. Nutritional value of food protein products. *In*: *Soybeans: Chemistry and Technology*, Vol. 1, Smith A K and Circle. S J (Eds), Avi Publishing Co. Inc. Westoort, CT.

Liu K. 1997. Chemistry and nutritional value of soybean components. *In*: *Soybeans* (pp. 25-113), Springer US.

Liu K. 2000. Expanding soybean food utilization. *Food Technology* **54**(7): 46–8, 50, 52, 54, 56, 58.

Manvell C. 1997. Minimal processing of food. *Food Science and Technology Today* **11**(2), 107-11.

Mauri A N and Amin M C. 2006. Effect of solution pH on solubility and some structural properties of soybean protein isolate films. *Journal of the Science of Food and Agriculture* **86**(7): 1064-72.

Mauri A N and Añón M C. 2008. Mechanical and physical properties of soy protein films with pH-modified microstructures. *Food Science and Technology International* **14**(2): 119-25.

Nemet N T, Šošo V M and Lazić V L. 2010. Effect of glycerol content and pH value of film-forming solution on the functional properties of protein-based edible films. *Actaperiodicatechnologica* **41:** 57-67.

Okamato S. 1978. Factors affecting protein film formation. *Cereal Foods World* **23**: 256.

Park S K, Hettiarachchy N S, Ju Z Y and Gennadios Aristippos. 2002. Formation and properties of soy protein films and coatings. *Protein-Based Films and Coatings. CRC, Boca Raton, FL*, 123-137.

Petersen K, Væggemose Nielsen P, Bertelsen G, Lawther M, Olsen M B, Nilsson N H and Mortensen G. 1999. Potential of bio based materials for food packaging. *Trends in Food Science and Technology* **10**(2): 52-68.

Schroder D J, Elliot J I and Jackson H. 1973. Nutritional studies on soybean curd produced by calcium sulfate precipitation of soybean milk. *Journal of Food Science* **38**(6): 1091-2.

Shen Q, Zhang X, Han Z, Li Z and Saito M. 2009. Productivity properties of protein-lipid film (Yuba) prepared from different soybean cultivars in China. *Japan Agricultural Research Quarterly* **43**(1): 25-31.

Sian N K and Ishak S. 1990. Effect of pH of yield, chemical composition, and boiling resistance of soybean protein-lipid film. *Cereal Foods World* **35**(8): 748, 750, 752.

Soy Protein Council. 1987. *Soy Protein Products: Characteristics, Nutritional Aspects, and Utilization.* Washington, DC.

Witherly S A. 1990. Soy formulas are not hypoallergenic. *American Journal of Clinical Nutrition* **51**: 705–6.

Wu L C and Bates R P. 1972a. Soy protein-lipid films. 2. Optimization of film formation. *Journal of Food Science* **37**(1): 40-4.

Wu, L C and Bates R P. 1972b. Soy protein-lipid films. 1. Studies on the film formation phenomenon. *Journal of Food Science* **37**(1): 36-9.

Wu L C and Bates R P. 1973. Influence of ingredients upon edible protein-lipid film characteristics. *Journal of Food Science* **38**(5): 783-7.

Wu L C and Bates R P. 1975. Protein-lipid films as meat substitutes. *Journal of Food Science* **40**(1): 160-3.

Soybean Research (Special Issue Number 2): 236-240: 2014

Effect of Different Roasting Temperature and Time on Mechanical Properties of Whole Soybeans

RANJIT SINGH[1*], RAHUL DEBBARMA[*2], SANDEEP SINGH RANA[3*] and KHURSHEED ALAM KHAN[4**],
****Indian Institute of Crop Processing Technology, Thanjavur, India and***
*****Central Institute of Agricultural Engineering, Bhopal, India***
E mail: ranjit_mfe12@iicpt.edu.in

ABSTRACT

This study investigates the mechanical behaviour (hardness, toughness, rupture force) of roasted whole soybeans. The geometric mean diameter of whole soybeans was measured 5.82 ± 0.07 mm with 12 per cent moisture content (db). During the experiment, maintaining steeping time (0 and 30 min), processing temperature (140 °C, 160 °C, 180 °C and 200 °C) and roasting time (60, 120 and 180 sec) revealed that hardness, toughness and rupture force decreased as temperature and time of roasting increased. Minimum hardness was 102.51 N (30 mint, 180 °C and 120 sec), maximum hardness was 253.64 N (0 mint, 140 °C and 60 sec). Minimum toughness was 71.43 N-mm (30 mint, 180 °C and 120 sec), maximum toughness was 176.86 N-mm (0 mint, 140 °C and 60 sec). Minimum rupture force 27.34 N (30 mint, 200°C and 180 sec) and maximum rupture force 115.67 N (0 mint, 140 °C and 60 sec). The best temperature and time combination for crushing or breaking of roasted whole soybeans was found 30 minute steeping, 180 °C roasting temperature and 120 second roasting time. In some of the cases minimum hardness, toughness and rupture force are found at higher roasting temperature and roasting time, but soybeans are over roasted, there is a chance of reduction in quality parameters. This information are useful in the determination of size reduction, crushing, breaking or grinding of whole soybean and designing equipment for milling, especially for soybeans crusher or grinder machine who raise livestock.

Key words: Hardness, roasting, rupture force, toughness, whole soybeans

Soybean [*Glycine max* (L.) Merrill] is a species of legume native to Eastern Asia. Among the legumes, the soybean is classified as an oilseed (Perkins, 1995). Nowadays it is used as multi-purpose crops and good source of protein and fat for human and animals all over the world. It contains 40 per cent protein and 20 per cent fat (Kulkarni, 1994). Generally soybeans are processed to be used as animal feed. One of the important processing of whole soybeans is roasting. Roasting improves flavour, texture and nutritive value of the grains and eliminates toxic effect or anti-nutritional effect of legumes (Liener, 1973). Roasted whole soybeans are an excellent source of rumen undegradable protein, but there could be variation in quality, which depends upon the roasting parameters. Roasting results in increase protein digestive value, but it varies according to temperature and time of roasting (Srivastav *et al.*, 1990). Biochemical composition of grains affects the grain hardness. Although, the effect of protein content on grain hardness is minor, it varies with crop varieties (Moss *et al.*, 1980 and Symes, 1965). Steeping time, processing temperature and roasting time dramatically

[1,3]M Tech Student; [2]Research Scholar; [4]Research Associate

affect the chemical and mechanical properties of roasted soybeans. Faldet *et al.* (1992) estimated (*in vitro*) that postruminal availability of lysine was maximized at roasting temperatures between 140 and 160 °C, given that soybeans were held at these temperatures for a minimum of 30 min with an additional 4.5 min for each 1°C below 160 °C. *In vivo* data are largely unavailable regarding the level of heating necessary to maximize both ruminal protein escape and small intestinal digestion. Reddy *et al*. (1993) demonstrated that optimum quality of roasted soybeans was achieved when the temperature was between 143 °C and 146 °C but they did not mention optimum roasting and steeping time. Nowadays, engineers are interested to design equipment for milling and size reduction of soybean like soybean crasher, grinder and oil extracting machine. There is a need to know the hardness, toughness and rupture force of roasted soybeans at particular time and temperature. Therefore, the objectives of this study were to investigate the mechanical behaviour (hardness, toughness and rupture force) of roasted whole soybeans and to find the optimum time and temperature combination for crushing or breaking of roasted whole soybeans.

MATERIAL AND METHODS

Soybeans were purchased from Thanjavur Super market, Tamil Nadu. The geometric mean diameter of whole soybeans was measured 5.82 ± 0.07 mm with the help of verniercaliper and initial moisture content of soybeans were determined by standard oven drying method at 105 ± 5°C for 24 h and was reported at 12 per cent (d.b). During the experiment, steeping time of 0 and 30 minute was maintained and after steeping soybeans were dried in hot air oven having temperature 55 ± 2 °C for 90 min, then roasting was done at four different temperatures (140, 160, 180 and 200 °C) at 30 second interval up to 180 sec. To determine the mechanical properties of soybean, a proprietary tension/compression testing machine (Instron Universal Testing Machine /SMT-5, SANTAM Company) equipped with a 500 kg compression load cell and integrator was used (Saiedirad *et al.*, 2008). The measurement accuracy was ± 0.001 N in force and 0.001 mm in deformation. The individual grain was loaded between two parallel plates of the machine and compressed along with thickness until rupture occurred as is denoted by a rupture point in the force–deformation curve. There was formation of shear band during compression. Thickness of develop shear band was 15 times bigger than mean diameter in case of mustard seed compression test (Horabik *et al.*, 2000). The rupture point is a point on the force–deformation curve at which the loaded specimen shows a visible or invisible failure in the form of breaks or cracks. This point is detected by a continuous decrease of the load in the force-deformation diagram. While the rupture point was detected, the loading was stopped. These tests were carried out at the loading rate of 5 mm per min for treatments (ASAE, 2006).

Grains having higher moisture content, rupture force on the grain will decrease, while rupture energy will increase (Tavakoli *et al.*, 2009). The mechanical behaviour of soybean grains were expressed in terms of rupture force and rupture energy required for initial rupture. Three replications were made for each test and 10 samples were used in each test. Energy absorbed by the sample at rupture was determined by calculating the area under the force–deformation curve from the following relationship (Braga *et al.*, 1999).

$E_a = F_r \times D_r/2$, where, = E_a rupture energy; = F_r rupture force; and = D_r deformation at rupture point

The results obtained were subjected to analysis of variance (ANOVA) using SPSS 20 software.

RESULTS AND DISCUSSION

The effect of roasting on mechanical properties of soybean grains was significant at 5 per cent probability level. Results obtained are discussed in detail below.

Hardness

Grain hardness is known to get affected by size, direction of applied force, moisture content, chemical composition and heat treatment (Abdelrahaman and Hoseney, 1984). Energy consumption, fineness of finished products and sieving behaviour of grains depend on grain hardness (Tran *et al.*, 1981). It was seen that hardness decrease with increase in roasting temperature and time of roasting [Fig 1(a) and 1(b)]. Minimum hardness was 84.65 N keeping 0 minute steeping time, 200 °C roasting temperature and 180 second roasting time (in case of without steeping), but after 30 minute steeping time; the hardness value is 71.65 N under the same condition.

Toughness

In case of toughness, material is known to absorb energy and plastically deform without any fracture. Toughness value of soybeans deceases with increase in roasting temperature and steeping time. Least toughness value found 60.34 N at 200 °C, 180 sec roasting time and 0 minute steeping process, but after 30 minute of steeping process toughness value was 45.07 under same condition [Fig. 2(a) and 2(b)].

Rupture force

Moisture content of roasted soybeans decreased with increase in both roasting temperature and time. At the lower moisture levels, the rupture energy was low and *vice versa*. Average rupture force decreased with increase in roasting temperature. Lowest rupture force was obtain in case of 30 minute steeping time, 200 °C and 180 second roasting temperature its value is 27.34 N [Fig. 3(a) and 3(b)].

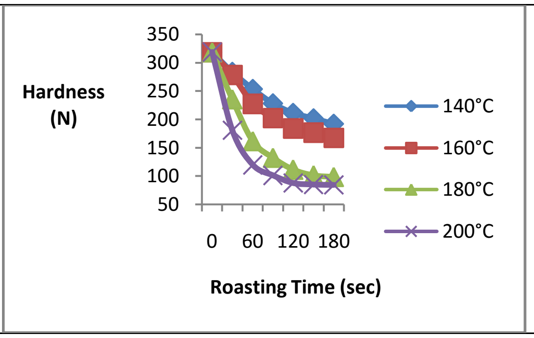


Fig. 1(a). Effect of roasting without steeping

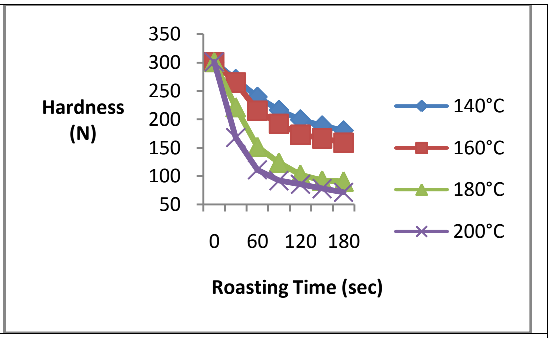


Fig. 1(b). Effect of roasting, 30 min steeping

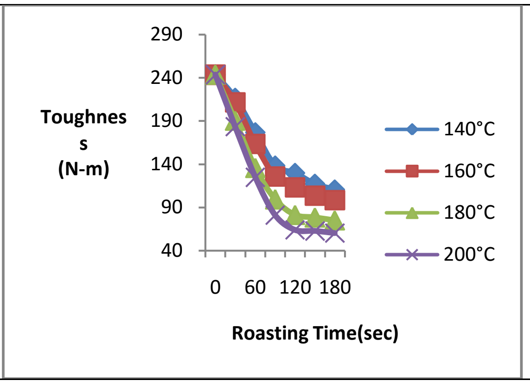


Fig. 2(a). Effect of roasting without steeping

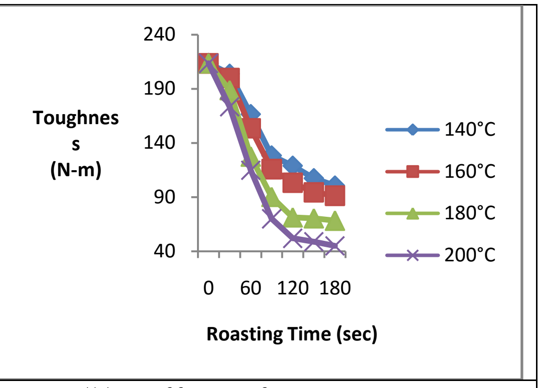


Fig. 2(b). Effect of roasting, 30 min steeping

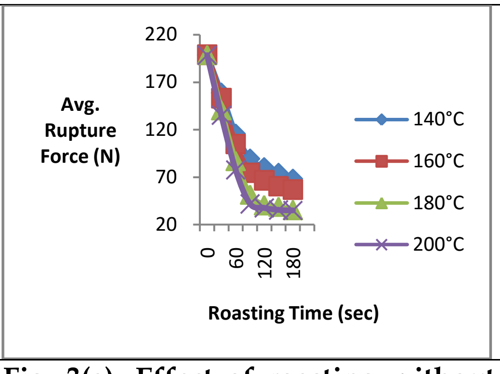


Fig. 3(a). Effect of roasting without steeping

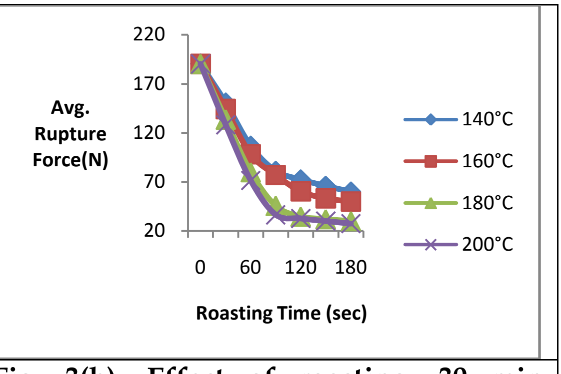


Fig. 3(b). Effect of roasting, 30 min steeping

The effect of temperature and roasting time on soybeans hardness, toughness and average rupture force is presented in non-linear polynomial regression equation (Table 1). R^2 value for hardness, toughness and average rupture force is 0.89, 0.87 and 0.84, respectively.

Table1. Analysis of variance for mechanical properties of roasted soybeans

Characteristics	**Source of variation**	**df**	**SS**	**MS**	**f-ratio**
Hardness	Temperature	2	48603	24301.5	129.51*
	Time	2	28859	14429.5	79.78*
Toughness	Temperature	2	80762	40381	61.45*
	Time	2	41260.3	20630.15	30.65*
Average rupture	Temperature	2	10590.2	5295.1	97.89*
Force	Time	2	7896.6	3948.3	59.87*

* *Means significant at 5% significance level*

Roasting of soybeans at different temperature, time and steeping process affected the mechanical properties of soybeans. It was found that steeping of soybean gives lower hardness, toughness and rupture force than without steeping soybeans. As per fig. 1, fig. 2 and fig. 3, the minimum value of hardness, toughness and rupture force is 30 minute steeping time, 200°C roasting temperature and 180 second, but in this case minimum hardness, toughness and rupture force were found at higher roasting temperature and roasting time, due to soybeans are over roasted and there is a chance of reduction in quality parameters.

This study suggested that the best temperature and time combination for crushing or breaking of roasted whole soybeans were 30 minute steeping, 180°C roasting temperature and 120 second roasting time. This information is going to be handy for engineers to design equipments (crasher, grinder and for oil extraction) for milling and size reduction for soybean.

REFERENCES

Abdelrahman A A and Hoseney R C. 1984. Basis for hardness in pearl millet, grain sorghum, and corn. *Cereal Chemistry* **61**(3): 232-5.

ASAE. 2006. Compression test of food materials of convex shape. S368.4, 609-16.

Braga G C, Couto S M, Hara T and Neto J T P A. 1999. Mechanical behaviour of macadamia nut under compression loading. *Journal of Agricultural Engineering Research* **72:** 239–45.

Faldet M A, Satter L D and Broderick G A. 1992. Determining optimal heat treatment of soybeans by measuring available lysine chemically and biologically with rats to maximize protein utilization by ruminants. *Journal of Nutrition* **122**: 151.

Horabik J, Lukaszuk J and Grochowicz M. 2000. Formation of shearband in a granular material during triaxial compression test. *International Agrophysics* **14:** 273-8.

Kulkarni S D. 1994. Roasted soybeans in cookies: influence on product quality. *Journal of Food Science and Technology* **34:** 503-5.

Liener I E. 1973. Toxic factor associated with legume proteins. *Indian Journal of Nutrition and Dietetics* **10:** 303-22.

Perkins E. 1995. Composition of soybeans and soybean products. *Practical Handbook of Soybean Processing and Utilization*, Erickson E R (Ed), AOCS Press, Champaign, IL.

Moss R, Stenvert N L, Kingswood K and Pointing G. 1980. The relationship between wheat microstructure and flour milling. *Scanning Electron Microscope* **3:** 613.

Reddy P V, Morrill J L and Bates L S. 1993. Effect of roasting temperatureson soybean utilization by young dairy calves. *Journal of Dairy Science* **76:** 1387-93.

Saiedirad M H, Tabatabaeefar A, Borghei A, Mirsalehi M, Badii F and Varnamkhasti M G. 2008. Effects of moisture content, seed size, loading rate and seed orientation on force and energy required for fracturing cumin seed under quasi-static loading. *Journal of Food Engineering* **86**(4): 565-72.

Srivastav P P, Das H and Prasad S. 1990. Effect of roasting process variables on *in-vitro* protein digestibility of Bengalgram, maize and soybean. *Food Chemistry* **35**(1): 31-7.

Symes K J. 1965. The inheritance of grain hardness in wheat as measured by the particle size index. *Australian Journal of Agricultural Research* **16:** 113.

Tavakoli H, Mohtasebi S S, Rajabipour A and Tavakoli M. 2009. Effects of moisture content, loading rate, and grain orientation on fracture resistance of barley grain. *Research in Agricultural Engineering* **55(3):** 85-93.

Tran T L, Deman J M and Rasper V F. 1981. Measurement of corn kernel hardness. *Canadian Institute of Food Science and Technology Journal* **14**(1): 42-8.

Soybean Research (Special Issue Number 2): 241-248: 2014

Magnitude of Crop Losses Due to Insect-Pest, Diseases and Weeds in Soybean – An Economic Analysis

S C MEENA[1], DEEPAK RATHI[2] and H O SHARMA[3],
Agro – Economic Research Centre, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, Madhya Pradesh, India
E mail: agrianss@gmail.com

ABSTRACT

The study analyzed the extent of physical and financial losses caused by weeds, insect-pest and diseases in cultivation of soybean in Madhya Pradesh. The relevant primary data were collected from 160 soybean growers of two major soybean producing districts (Ujjain and Raisen) of Madhya Pradesh during the year 2012 -13. The study revealed that 67.50 per cent of soybean growers were able to distinguish between the pest and disease attack by quantitative assessment followed by qualitative (15.00 %) and both (17.50 %). Out of them 96.25 per cent and 73.75 per cent households respectively reported that frequency of attack of major pests like girdle beetle and caterpillar were found to occur every year. It was also observed that the size of farms is directly proportional to pre-harvest losses over actual and normal production of soybean and adoption of control measures. Among total plant protection chemicals used by the soybean growers, average soybean grower found to invest more in insecticide (Rs 1,376/ha) followed by weedicide (Rs 1,019/ha) and fungicide (Rs 242/ha). None of the households were found to use biological method for control of insect-pest and diseases in the area. Amongst different sources of information, private input dealers were found to be most important source for seeking advice whereas, government extension agents and fellow farmers important and least important source of extension services on pest and disease control management as reported by majority of households.

Key words: Losses, magnitude, pest and diseases, soybean

The estimation of crop loss due to pests and diseases is a complex subject. It is in fact, difficult to assess the loss caused by the individual pest as a particular crop may be infested by the pest complex in the farmers' field conditions. Further, extent of crop loss, either physical or financial, depends on the type of variety, stage of crop growth, pest population and weather conditions. Nevertheless, the crop loss estimates have been made and updated regularly at global level. The worldwide yield loss due to various types of pest was estimated to be 37.4 per cent in rice, 28.2 per cent in wheat, 31.2 per cent in maize and 26.3 per cent in soybean (Oerke, 2007). At all India level, crop loss estimates due to insect -pests provided by Dhaliwal *et al.* (2010) brought out that 25 per cent losses were in rice and maize, 5 per cent in wheat, 15 per cent in pulses and 50 per cent in cotton. The crop loss has increased during post-green revolution period when compared to pre-green revolution period. The severity of pest problems has reportedly been changing with the developments in agricultural technology and modifications of agricultural practices. The damage caused by major inspect-pests in various crops has also been compiled and

[1]*Senior Research Fellow;* [2]*DeputyDirector;* [3]*Director*

reported by Reddy and Zehr (2004). Further, a number of studies have established a strong relationship between pest infestation and yield loss in various crops in India (Nair, 1975; Dhaliwal and Arora, 1994; Muralidharan, 2003; Rajeswari *et al.*, 2004; Muralidharan and Pasalu, 2006; Rajeswari and Muralidharan, 2006, Nag *et al.*, 2000, Solanki *et al.*, 2011). To estimate the crop loss, most of the existing studies have adopted experimental treatment approach (with or without pest attack through artificial infestation) or fields with natural infestation wherein half of the field is protected against the pest while the other half is not. But, the results obtained from artificial infestation or natural infestation in the selected plots/fields will not be appropriate for extrapolation over a geographical area (De Groote, 2002). It is for the reason that the estimated crop losses under these conditions may not represent the actual field conditions of farmers. Alternatively, the estimates collected directly from the farmers through sample survey may be reliable and could be used for extrapolation in similar geographical settings. However, the farmers' estimates are likely to be subjective and these should be validated with expert estimates of the state department of agriculture. Hence, the present study has been formulated to estimate the physical and financial losses caused by pests and diseases and examine the measures of pest and disease management to reduce the crop loss due to pests and diseases at farm level.

MATERIAL AND METHODS

Soybean crop has been considered for assessment of pre- and post-harvest losses in Madhya Pradesh as state have remarkable position in the area and production of the crops in India (Table 1). The primary data were collected from the selected respondents of the study area with survey method with the help of personal interview. A multistage sampling technique has been used for selection of respondents of the study.

At the first stage, Ujjain and Raisen districts from Malwa plateau and Vindhyan plateau agro-climatic regions respectively, were selected as these were found to be a true representative for soybean in Madhya Pradesh. Further, 3 villages near by the regulated market (in radius of10 km) and 3 villages far away from the regulated market (> 10 km from regulated market) have been selected for the study in second stage (Table 2).

Table 1. Present status of soybean crop in India (2010-11)

Soybean growing states	Area sown (mha)	Percen-tage to total	Yield (kg/ ha)	Percen-tage to total	Total produc-tion (mt)	Percen-tage to total
Madhya Pradesh	5.317	54.96	1051.67	103.04	5.601	57.62
Maharashtra	3.026	31.28	988.33	96.83	2.857	29.39
Rajasthan	0.724	7.48	940.67	92.16	0.702	7.22
Andhra Pradesh	0.174	1.80	1055.00	103.36	0.166	1.71
Karnataka	0.222	2.30	1021.67	100.10	0.208	2.14
Chhattisgarh	0.123	1.27	950.00	93.08	0.127	1.31
Rest of India	0.088	0.91	936.67	91.77	0.060	0.62
Grand Total	9.673	100.00	1020.67	100.00	9.720	100.00

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Agricultural Statistics at a Glance, 2012

Table 2. Selected districts and villages for the study

Agro-climatic regions	Selected districts	Selected villages	
		In radius of 10 km	> 10 km
Malwa Plateau	Ujjain	Matana	Ganvadi
		Munjakheda	Piploda
		Semaliya (nasar)	Narvar
Vindhyan Plateau	Raisen	Kotpar	Chingwara kalan
		Kamton	Arjni
		Kinagi	Tulsipar

In third stage, a list of all the farmers of the selected village has been prepared and classified them in marginal (below 2 acre) , small (2- 4 acre), medium (4-10 acre) and large (above 10 acre) categories according to their size of operational holdings and 20 farmers were selected randomly in each category for the study (Table 3).

Table 3. Number of respondents in different categories of farms in selected districts

Selected crops	Selected districts	Size of farms				Total
		Marginal	Small	Medium	Large	
Soybean	Ujjain	20	20	20	20	80
	Raisen	20	20	20	20	80
	Total	40	40	40	40	160

The collected data has been classified, tabulated and analyzed in the light of stated objectives of the study using statistical package of social science (SPSS).

RESULTS AND DISCUSSION

The incidence, magnitude of crop loss due to pests, disease and weed infestation, cost of chemical methods adopted by soybean growers of different size of farms to control pests and diseases and extension services perceived by them on pests and disease control management were observed in the present study.

Identification of pests and disease attack

The cent per cent of households able to distinguish pest and disease attack in cultivation of soybean crop revealed that majority (67.50 %) of them assess the severity of the attack by quantitative assessment. Only 15 per cent of households were able to assess the pest and disease attack by qualitative assessment in soybean crop (Table 4).

Incidence of major pests and disease

In soybean, girdle beetle and tobacco caterpillar were found very important pest of soybean in the study area as their rank of severity was found to be very important as reported by 91.25 per cent (girdle beetle) and 57.50 per cent (tobacco caterpillar) of households (Table 5).

In case of diseases in the study area, dry root rot (73.75 %), yellow mosaic (58.75 %) and fusarium wilt (50.00 %) were found to be major diseases of soybean as reported by the majority of households. The frequency of attack by yellow mosaic and dry root rot in every season was reported by 53.75 per cent and 47.50 per cent of households, while that of fusarium wilt was reported to be once in a two season (48.75 %) as reported by the majority of households. But the losses occurred by these diseases were not found more than 5 per cent as reported by the more than 85 per cent of households.

Table 4. Identification of pests and disease attack

Description		Percentage of HHs
House -holds able to distinguish pests and disease attack		*100*
Assessment about the severity of the attack	Quantitative assessment	67.50
	Qualitative assessment	15.00
	Both	17.50

As regards to the infestation of weeds in cultivation of soybean; *Samel, Dudhi, Motha and Krishaneel* were found to be very important weeds of the as soybean reported by 63.75 per cent, 77.50 per cent, 92.50 per cent and 60 per cent, respectively of the study area. The frequency of all these weeds was found to be every season but the production losses were found to be less than 5 per cent as majority of the households were using the weedicides to control these weeds in soybean field.

Magnitude of crop loss due to pests, disease and weed infestation

The magnitude of crop losses due to insect-pests, diseases and weeds infestation in soybean observed revealed that on an average size of farm 13.39 per cent and 11.75 per cent losses were recorded over actual (1,381 kg/ha) and normal (1,563 kg/ha) production, respectively. the losses due to insect-pests, diseases and weeds infestation were found to be directly proportionate to the size of holdings or scale of operation of the farm, which is clear from the table mentioned below that losses among different size of holdings found to increase from 10.11 to 16.51 per cent and 9.18 to 14.17 per cent over actual and normal production of soybean, respectively.

Cost of chemical methods adopted for insect-pests and disease control

The control of weeds is the major problem in cultivation of soybean. As soybean is a rainy season crop, various types of weeds infested the soybean fields. Chemical control (weedicide) was found to most popular and only method to control weeds in the area under study. As hand weeding is not possible due to excess moisture in the soil (black cotton soil). An average household invested Rs 1,019 per ha to control weeds in soybean. The cost of weedicide was found to increase with the size of farms from Rs 974 per ha (marginal) to Rs 1,039 per ha (large).

Incidence of insect-pest in soybean was found to be very common in study area and all the farmers used insecticide to control them. An average household found to invest Rs 1,376 per ha in insecticide. Medium farmers (Rs 1,410/ha) were found to use more on insecticides as compared to marginal (Rs 1,342/ha), small (Rs 1,351/ha) and large (Rs 1,400/ha). The seed treatment with fungicide was also found to be common in the study area in cultivation of soybean. An average household invested Rs 242 per ha in fungicide.

The cost of seed treatment was found to be somewhat more in medium (Rs 260/ha) followed by large (Rs 252/ha), small (Rs 234/ha), and marginal (Rs 221/ha) farms (Table 7).

Table 5. Incidence of major pests and disease (percentage of households)

Name of the pest/disease/weed	Rank of severity*			Frequency of attack**			Production loss***				
	1	2	3	1	2	3	1	2	3	4	5
Major insect-pests											
Girdle beetle	91.25	6.25	2.50	96.25	3.75	0.00	11.25	78.75	3.75	3.75	2.50
Tobacco Caterpillar	57.50	27.50	15.00	73.75	26.25	0.00	85.00	3.75	6.25	3.75	1.25
Major diseases											
Fusarium Wilt	50.00	42.50	7.50	31.25	48.75	20.00	88.75	7.50	1.25	2.50	0.00
Yellow Mosaic	58.75	28.75	12.50	53.75	32.50	13.75	86.25	11.25	2.50	0.00	0.00
Dry Root Rot	73.75	5.00	21.25	47.50	16.25	36.25	91.25	7.50	0.00	1.25	0.00
Major weeds											
Samel	63.75	13.13	23.13	100.00	0.00	0.00	91.25	6.25	2.50	0.00	0.00
Dudhi	77.50	8.75	13.75	98.75	1.25	0.00	88.75	8.75	2.50	0.00	0.00
Motha	92.50	6.25	1.25	100.00	0.00	0.00	95.63	4.38	0.00	0.00	0.00
Krishnneel	60.00	36.25	3.75	73.75	22.50	3.75	100.00	0.00	0.00	0.00	0.00

Very important = 1, important = 2, not important = 3; ** Every season = 1, once in two seasons = 2, once in three seasons = 3 ; * < 5% = 1; 5-10 % = 2; 10-25 % = 3; 25-50 %= 4; >50 % = 5*

Table 6. The magnitude of crop loss in soybean due to pests, disease and weed infestation across different size of holdings

Description	Marginal	Small	Medium	Large	Total
Actual production (kg/ha) with attack	1613	1366	1230	1317	1381
Normal production (kg/ha) without attack	1776	1512	1430	1534	1563
Loss of output (kg/ha)	163	146	200	217	182
Loss over actual production (%)	10.11	10.67	16.27	16.51	13.39
Loss over normal production (%)	9.18	9.64	13.99	14.17	11.75

Table 7. Cost of chemical methods adopted in soybean for pests and disease control

Particulars	Marginal	Small	Medium	Large	Total
Per cent households adopted control measures	87.50	90.00	100.00	100.00	94.38
Weedicide					
Sprays/ha (Rs)	2.27	2.32	2.47	2.47	2.38
Cost of chemical (Rs)	795.86	838.15	869.93	883.99	846.98
Labour charges (Rs)	176.31	187.87	162.40	152.13	169.68
Total Cost	974.44	1028.34	1034.81	1038.59	1019.04
Insecticide					
Sprays/ha (No)	3.26	3.48	4.82	5.38	4.24
Cost of chemical (Rs)	1054.69	1078.38	1124.89	1141.71	1099.92
Labour charges (Rs)	284.05	269.55	280.00	253.00	271.65
Total cost (Rs)	1342.00	1351.41	1409.70	1400.09	1375.80
Fungicide					
Sprays/ha (No)	0.30	0.32	0.35	0.35	0.33
Cost of chemical (Rs)	151.29	155.61	172.90	172.90	163.17
Labour charges (Rs)	69.16	77.81	86.45	79.04	78.11
Total cost (Rs)	220.74	233.74	259.70	252.29	241.62

Biological methods adopted for pests and disease control

None of the households followed the biological method for control of insect-pest and diseases in the area under study.

Extension services on pests and disease control management

The data related to extension services on insect-pest and disease control management for selected crop brought out that only 77.50 per cent households were found seeking advice related to control of pest and disease for soybean. Private input dealers constituted most important source of seeking advice on insect-pest and disease control management as reported by 71.77 per cent of households followed by fellow farmers (21.77 %) and agricultural university/ Krishi Vigyan Kendras (11.29 %), while Fellow Farmer were found to be important source of seeking advice as reported by 45.97 per cent of households followed by private input dealers (15.32 %), TV/radio service/news paper (15.32 %) and agricultural university/ Krishi Vigyan Kendras (8.87 %) It is also observed that government extension agent was found to be least important for seeking advice to control on pest and disease.

Hence, it can be concluded that private input dealers were found to be most important whereas, government extension agent and fellow farmers were found to be important and least important source of extension services on insect-pest and disease control management as reported by majority of households of study area.

Table 8. Extension services on pests and disease control management

(Percentage of households)

Particulars				**Soybean**
Households seeking advice				77.50
Rank of sources				
Sources of advice	***Most important***	***Important***	***Least important***	***Details of advice***
Government extension agent	4.03	4.03	91.94	Plant geometry, soil testing, inputs
Private input dealer	71.77	15.32	12.90	Proper plant protection measures, seeds
Fellow farmers	21.77	45.97	32.26	Fertilizer and manure application
TV/Radio service/Newspaper	0.00	15.32	84.68	Government schemes for agriculture
Agricultural University/KVK	11.29	8.87	79.84	Varietals and machinery information
Any other	0.00	0.00	0.00	

REFERENCES

Oerke E C. 2007. Crop losses to animal pests, plant pathogens, and weeds, *In*: David Pimental (Ed), *Encyclopedia of Pest Management*, pp 116-20, CRC Press, USA.

Dhaliwal G S, Jindal Vikas and Dhawan A K. 2010. Insect pest problems and crop losses: Changing trends. *Indian Journal of Ecology* **37**(1): 1-7.

Dhaliwal G S and Arora Ramesh. 1994. *Trends in Agricultural Insect Pest Management*, Commonwealth Publishers, New Delhi.

De Groote H. 2002. Maize yield losses from stem borers in Kenya. *Insect Science and its Application* **22**(2): 89-96

Muralidharan K, Krishnaveni D, Rajeswari N V L and Prasad A S R. 2003. Tungro epidemics and yield losses in paddy fields in India. *Current Science* **85**(8): 1143-7.

Muralidharan K and Pasalu I C. 2006. Assessments of crop losses in rice ecosystems due to stem borer damage (Lepidoptera: Pyralidae). *Crop Protection* **25**: 409-17.

Nag S K, Nahatkar S B and Sharma H O. 2000. Post-harvest losses of chickpea as perceived the producers of Sehore District of Madhaya Pradesh. *Agricultural Marketing* **43** (3): 12-16.

Nair M R G K. 1975. *Insects and Mites of Crops in India*, Indian Council of Agricultural Research, New Delhi.

Rajarajeswari N V L and Muralidharan K. 2006. Estimates of farm yields and district production loss from blast epidemics. *Journal of Mycology and Plant Pathology* **36**(2): 115-24.

Rajarajeswari N V L, Dinaker C and Muralidharan K. 2004. Assessing injury to grain filling and yield losses from Tungro virus epidemics. *Indian Journal of Plant Protection* **32**(1): 73-9.

Reddy K V S and Zehr Usha B. 2004. Novel strategies for overcoming pests and diseases in India. *In*: *New Directions for a Diverse Planet*, Proceedings of the 4th International Crop Science Congress, 26 September-1 October 2004, Brisbane, Australia.

Solanki B S, Singh Rajesh, Meena S C and Niranjan H K. 2011. An analytical study of post–harvest losses of soybean as perceived by the producers of Rewa District (M.P.). *Flora and Fauna* **17**(1), (Special Issue): 190–4.

Soybean Research (Special Issue Number 2): 249-255: 2014

Area-wide E-Pest Surveillance for Soybean in Maharashtra

NIRANJAN SINGH[1*], S VENNILA[2*] and P JEY KUMAR[3**],
****National Centre for Integrated Pest Management,,***
Indian Agricultural Research Institute Campus, New Delhi 110012 and
*****National Institute of Plant Health Management,***
Rajendranagar, Hyderabad 500 030, Andhra Pradesh, India
E mail: attri.ns@gmail.com

ABSTRACT

Soybean crop is grown in an area of 3.1 million ha in Maharashtra state of India. The Lepidopteron defoliators viz., *semilooper (*Chrysodeixis acuta*) and tobacco caterpillar (*Spodoptera litura*) are the major pests of soybean across the state. The infestation of* S. litura *coupled with other leaf eating caterpillars on soybean in Vidharba region of Maharashtra during 2008-09 caused severe yield losses in an area of 0.75 million ha (Dhaliwal and Koul, 2010). Epidemics of* S. litura *again occurred during 2009-10 in an area of 1.46 million ha and caused production loss of 0.085 million tons, which led to the need of systematic area wide pest monitoring. Since regular and wide area pest monitoring is the cornerstone for pest management through which epidemic situations can be avoided by detecting damage prior to establish at a higher pest population. So to automate the process of pest monitoring and issuing timely advisories to the farmers, a web based pest surveillance system was developed and implemented for effective and regular pest monitoring in soybean in Maharashtra since 2009 by integrating the potential technical and administrative stakeholders of State and Central machinery involved in plant protection. Use of internet technologies helped in providing prompt and reliable pest reports to the concerned agencies and thus confirmed the operation of effective monitoring.*

Key words: E-surveillance, insect-pests, soybean

E-pest surveillance is basically an internet-based system of capturing pest information from fields and producing instant and customized pest reports to the plant protection experts to advise the State agriculture agencieswho further advise the concerned farmers. Same information is also available for agricultural policy planners. The term 'E-pest surveillance system' encompasses computer-based storage, transfer, retrieval, sharing, and reporting of pest data for appropriate and timely decision-making for better pest management.

Why internet for pest surveillance?

The internet has become a very powerful information providing system for dissemination of pest management information. The internet has the potential for improving effectiveness and efficiency of pest management programmes being carried out across the country. Its ability to allow quick transfer of information and its ready access as well as the knowledge base assist the plant protection workers in advising farmers appropriately so as to save the crop from pest damage and economic losses by judicious use of timely intervention and relevant pest management inputs.

[1]*Senior Scientist;* [2]*Principal Scientist;* [3]*Principal Scientist*

The goal of using internet technology for pest surveillance is to capture the pest information from farmer's field, transferring it to a centralized database, compilation, reporting and dissemination of data to different stakeholders using internet. In fact, pest surveillance provides field-specific information on pest incidence and crop injury leading to appropriate selection and dissemination of pest management strategies/options by pest management professionals. The success of the recommended pest management procedures depends on the accurate and timely completion of all the pest surveillance activities. So, the use of internet technologies facilitates reporting of pest situations for different locations at a click of mouse and plays an important role in pest management decision making.

Status of internet based surveillance

Internationally, internet is widely being used for pest surveillance and modeling for forecasting in many counties such as Integrated Plant Protection Center (IPPC) of Oregon State University which has several online interactive resources including near real-time daily weather data, various degree-day products (calculators, phenology models, maps, and map calculator), and weather-based phenology models for pest management decision-making in the four Northwestern U.S. states (http://uspest.org/). Another example is the Codling Moth Information Support System (CMISS) (http://ipmnet.or/codlingmoth/) which contains various knowledge bases, databases, phenology models, and links to worldwide resources on codling moth.

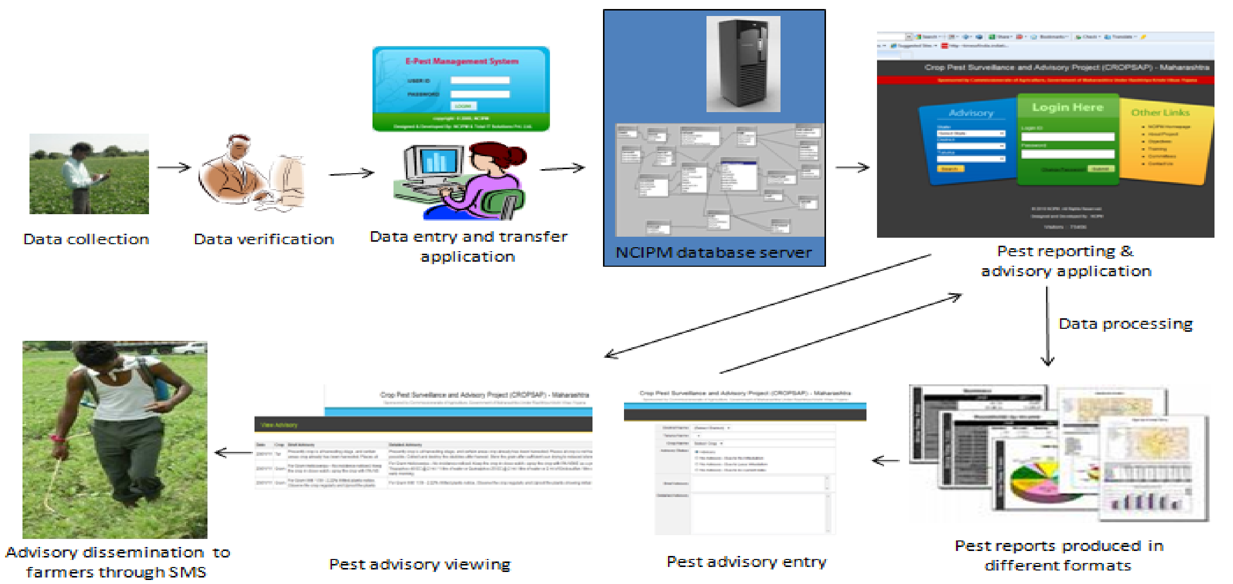
Decision support systems for interactive pest modeling and market information are being rapidly developed by many countries and made available on the internet *e.g.,* the Pacific Northwest IPM Weather Data and Degree-Days Website. At this site, daily temperature and precipitation data are gathered from 380 public and private weather stations and linked directly to pest phenology models for 22 insects, 2 diseases, and 2 crop species. Plant production information system developed by the Danish Agricultural Research and Advisory Organizations for pest and disease warnings based on weather data-driven forecast models is available. Decision support systems and expert systems have been developed in the field of pest management but no system existed for Internet Based surveillance system in the country. NCIPM took the initiative in collaboration with Maharashtra State Department of Agriculture in developing an internet based surveillance system for Soybean and Cotton from 2009 and its success has been demonstrated.

MATERIAL AND METHODS

Preparations for pest surveillance

An elaborate preparation is necessary for successful pest surveillance and thus it improves the efficiency of the activity. Preparation included training of pest scouts, field selection, sampling plan and materials required such as data books, set of guidelines, electronic devices, software, *etc.* Before starting scouting, a well thought sampling plan was prepared which to include crop distribution in the area, field selection, field size, route through the fields, selection of spots in the field and finally the number of plants to be surveyed from different spots. The sample plan outlined the procedure to draw a sample to estimate the population of different pests or the crop damage. Pest scout was given access to published information and portable handouts on guidelines for crop pest surveillance. Completely randomized plan for pest surveillance was adopted so that each spot in a field had equal chance of scouting. The scouts were educated about the identification of pests and their sampling plan and its execution. A well thought time schedule for taking pest observations was made considering pest biology and crop growth. Each filed selected was under surveillance once a week. Information such as crop variety, agronomic practices, pesticides applied, *etc*. was also to be recorded. Better preparation helps to anticipate and measure the economic significance of pest problems and comprise the baseline information of future planning.

Development of internet based surveillance system



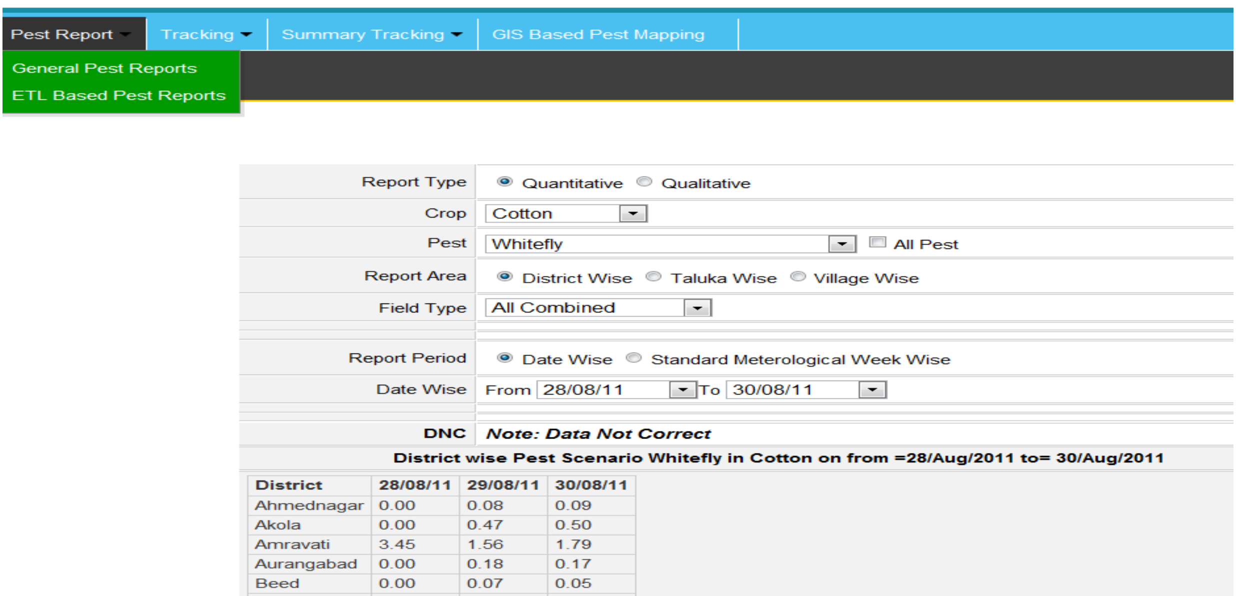
Schematic representation of internet based pest surveillance system

Different software components of internet based surveillance system were developed to acquire pest data from fields and to analyze the data for reporting of pest status in turn for issuing advisory for pest management using internet. A three tier architecture based system consisting of database for information storage; an offline application for pest data capture and data upload into database; an online application for pest reporting and advisory was developed. The different reports such as present and past pest situations could be viewed by experts. The State Agricultural Universities issued real time pest advisory for different locations for further spread it to the farmers. The information flow chart shown depicts the Internet Based surveillance system implemented in Maharashtra.

Database: The database was designed and developed for storage of interrelated pest information using SQL Sever 2000. The database consisted of 120 data fields to store data on various parameters. Various tables and views were created for different domain-specific information. Relationships were established among these tables for data normalization. Various stored procedures were generated in the database to execute different tasks.

Data entry and uploading module: Login details were created for data entry operators and pest monitors. The application is a standalone application for entry of details of fields, crop pests and other information. Data is uploaded after verification and subsequently transferred to centralized database through XML.

Pest reporting and advisory module:



The main purpose of pest reporting is to communicate immediate or potential danger. Immediate or potential danger normally arises from the occurrence, outbreak or spread of a pest. The provision of reliable and prompt pest reports confirms the operation of effective surveillance. Pest reporting allowed necessary pest management requirements and actions to be taken. Pest reports contain information on the identity of the pest, location, pest status, and nature of the immediate or potential danger. Online application is developed using ASP.net technology as user interface which provides plant protection experts the reports for issuing advisories to different stakeholders. System generates pest reports in different formats such as tabular, graphical or GIS maps. Both current as well as temporal pest reports are produced. The system has provision for producing pest reports for village(s)/taluka(s)/district(s) having pest(s) population above or equal to the pest ETL during selected dates that require/s attention of pest management experts. On the basis of pest situation of a particular location, pest experts feed the advisory for state agencies to further spread it to the farmers for making appropriate and timely decisions for pest management, if required. Accurate information on pest status facilitates technical justification of measures and helps to minimize losses due to pest incidence, thereby reducing the fears of their serious buildups.

RESULTS AND DISCUSSION

Impact of e-pest surveillance system– a glimpse

Constant and timely watch over pest scenario of the crop with the help of E-Pest Surveillance System aided in identifying the pest hot spots across the state. Staff of state agriculture department was geared up to manage epidemic situations through awareness creation and supply of critical pest management inputs. Table 1 indicates the quantum of data inputs by the field monitoring staff through the pest monitoring units of each division and the advisories issues based on the ETL for different pests of soybean and other crops for the year 2012-13. The quantum of advisories shows the effective flow of pest management advisories to farmers in the target crops (Table 1).

Table 1. Data entries and pest management advisories for soybean and other crops (2012-13)

Division	Data entries (Nos)		Pest management advisories (Nos)	
	Pest scouts	Pest monitors	Issued by SAUs	Sent to farmers
Amravati	158959	10786	15168	5501374
Aurangabad	69401	4571	4087	3553576
Kolhapur	27104	2859	2752	4472977
Latur	96501	10274	7052	3801373
Nagpur	111066	9444	21186	4166152
Nasik	84127	5083	5793	5481458
Pune	31001	3775	4659	7661055
Thane	48912	3980	1818	1352864
Total	**627071**	**50772**	**62515**	**35990829**

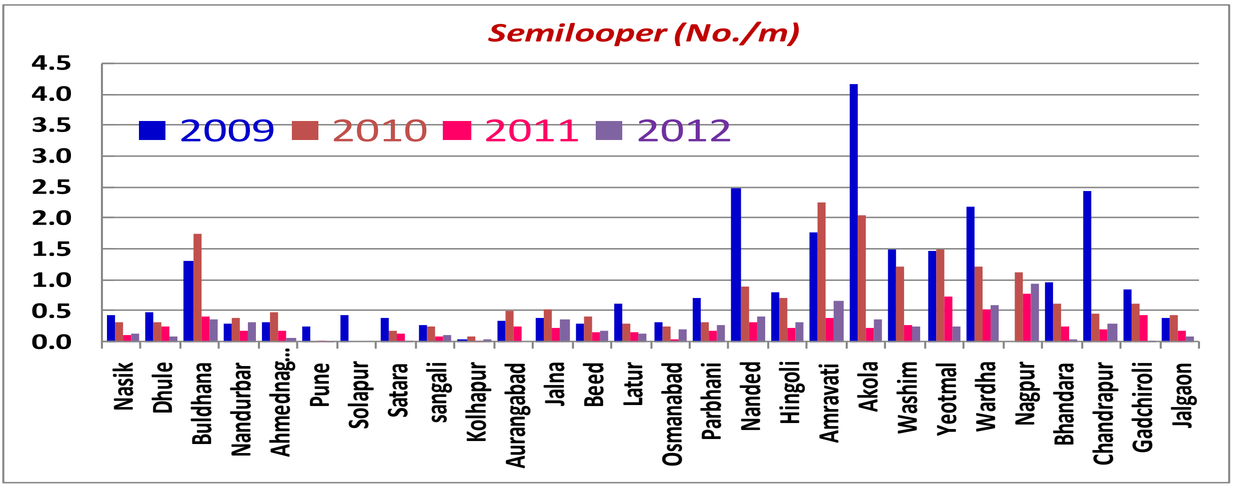


Fig.1 Spatio-temporal status of semilooper on Soybean at Maharashtra

ICT based surveillance resulted not only knowing the current pest status and issuance of real time need based pest management options but also in elucidating the pest scenario over seasons and across locations. Comparison of scenario of mean incidence of *semi* looper across districts over 4 year period indicated decreasing levels (2009>2010>2011 and 2012) after the epidemic year of 2008 (Fig.1).

Area wide coverage facilitates record of pest affected area in relation to the cultivated area under the crop and also makes possible the plant protection inputs used against the pests. The pest affected area in soybean under pest surveillance gets implemented with scientifically based pest management practices over wider area which in turn aids in increased production and productivity of the crops *per se* in the region (Table 2). The database also provides potential utility for development of prediction rules and models.

Table 2. Scenario of crop yields during the CROPSAP implementation seasons

Crop	Production (Lakh MT)			Productivity (kg/ha)		
	Normal (03-04 to 07-08)	2011-12	2012-13	Normal (03-04 to 07-08)	2011-12	2012-13
Soybean	27.01	39.69	46.90	1204	1319	1531

(Source: SDA, Maharshtra)

While the technological inputs relating to crop production inclusive of crop protection are yield enhancing, the information and communication technology (ICT) tools aid in rapid dissemination of information related them facilitating their adoption at the growers' level. CROPSAP has been the first successful programme at the National level demonstrating the area wide (statewide) implementation of plant protection in the context of Integrated Pest Management (IPM). It has integrated not only the pest management options in respect of the target crops for an effective and efficient plant protection over space and time but also brought personnel of research, extension and farmer communities under the same umbrella where the information flow is across all directions in a quicker pace. Such a programme once implemented the uses are of multiple type for the researchers and planners alike while the farmers continue to get the real time pest based management advisories for use at field level creating exemplified opportunities for increasing and improving the production and productivity of the crops at regional level.

ACKNOWLEDGEMENTS

Authors and NCIPM acknowledge the funding provided by the State Department of Agriculture (SDA) (Maharashtra), and all other stakeholders of ICAR and State Agricultural University who are all part of the programme. Ultimate outcome of information on pest scenario and production estimates entirely the rights of SDA, Maharashtra.

REFERENCES

Antonopoulou E, Karetsos S T, Maliappis M, Sideridis A B. 2010. Web and mobile technologies in a prototype DSS for major field crops. *Computers and Electronics in Agriculture* **70** (2): 292–301.

Dhaliwal G S and Koul O.2010. *Quest forPest Management: From Green Revolution to Gene Revolution*, Kalyani Publishers, and New Delhi.

Grant Jennifer, Ferrentino Gerard and Neal Joseph. 2006. Pest Monitoring:A Key to IPM for Turfgrass. In Fact Sheet, Audubon International, Cornell University.

http://uspest.org/

http://ipmnet.org/codlingmoth/

International Standards for Phytosanitary Measures (ISPM) No 6 Guidelines for Pest Surveillance 1997. FAO, Rome

Guidelines for Pest Surveillance 1997. FAO, Rome. International Standards for Phytosanitary Measures (ISPM) No17 Pest Reporting 2002, FAO, Rome.

SDA, Maharshtra

Xia Yulu, Guru Shalini, VanKirk James. 2009. Pestmapper-An Internet-Based Software Tool for Reporting and Mapping Biological Invasions and Other Geographical and Temporal Events. *Computers and Electronics in Agriculture* **69**(2): 209–12.

Soybean Research (Special Issue Number 2): 256-262: 2014

Machine Learning for Diagnosis of Soybean Diseases

ALKA ARORA[1*] AND RAJNI JAIN[2**]
****Indian Agricultural Statistics Research Institute and***
*****National Centre for Agricultural Economics and Policy Research,***
New Delhi 110 012, India
E mail: alkak@iasri.res.in, alka27@yahoo.com

ABSTRACT

Classification consists of examining the features of a newly presented object and assigning it to a predefined class. The classification task is characterized by the well-defined classes, and a training set consisting of pre-classified examples. In this paper we attempt to build machine learning models for diagnosis of soybean diseases. The dataset for soybean diseases containing 683 cases has been taken from UCI machine learning repository. Machine learning techniques namely decision trees, logistic regression, random forest and multi-layer perceptron neural network have been used. Ten fold cross validation experiments were used for evaluation of various machine learning techniques. The results suggested all these classifiers identify the soybean diseases at the accuracy level of more than 90%. Decision tree not only resulted in providing good results at the same time it facilitated in characterization of soybean diseases with the help of significant variables and better interpretability.

Key words: Classification, decision tree, logistics, machine learning, multilayer perceptron, soybean diseases

With the advent of computers, the development of accurate forewarning systems for incidence of crop diseases has been increasingly emphasized. Correct diagnosis of crop diseases will not only reduce yield losses but also alert the stakeholders to take effective preventive measures. Recently, several machine learning techniques such as decision tree induction, rough sets, soft computing techniques, neural networks, genetic algorithms *etc*., are gaining popularity for predictive modelling. These techniques are widely used in medical research for disease diagnosis. Recently researchers have been using them for disease diagnosis in crops. Jain *et al.* (2009) have used machine learning algorithms for forewarning powdery mildew of mango disease and concluded that predictive accuracy was much better than other traditional approaches.

Machine learning deals with construction and study of system that can learn from data [http://en. wikipedia. org/wiki/Machine_learning]. Machine learning methods are popular in comparison to statistical methods as they are not concerned with underlying assumption of data. Classification refers to supervised learning which deals with analyzing the input data (training set) and to develop an accurate description or model for each class using the attributes present in data (Han and Kamber, 2000). The model is then used to classify the test data for which class

[1]*Senior Scientist;* [2]*Principal Scientist*

labels are not known. Decision tree, neural network and logistics are popular classification techniques which are used in variety of applications.

Soybean popularly known as wonder crop is known for its benefits. Soybean is cheapest and easy source of quality protein and is used widely in food products and industries. Soybean is largest source of vegetable oil (20 %) and protein (40 %). It also contains a good amount of minerals, salts and vitamins. Soybean flour mixed with wheat flour is used for making high protein and nutritional food like biscuits, chaps, breads, chapati, sweets *etc*. It is also used as fodder for livestock and poultry. Soybean is widely used in industrial production of antibiotics (http://www.pnbkrishi.com/soybean.htm). Considering importance of soybean crop, timely diagnosis of soybean disease can play a significant role in enhancing the productivity and production of good quality crop.

Arora *et al*. (2008, 2009) has presented the approach for generating description for soybean diseases. Their approach is purely based on clustering and Rough Set Theory (RST). The major aim was to demonstrate the applicability of their approach for generating disease clusters and then to study the disease characteristics in absence of disease class variable (Arora *et al.*, 2008; 2009)

In this paper machine learning techniques are applied on soybean disease dataset from UCI repository to classify the soybean diseases (Bache and Lichman, 2013). Popular techniques of classification J48 decision tree, random forest tree, multilayer perceptron neural network and simple logistics function are used to classify the soybean disease dataset.

Experiment has been conducted using open source software Waikato Environment for Knowledge Learning (WEKA) (http://www.cs.waikato.ac.nz/ml/weka/).

***J48*:** J48 decision tree is an open source Java implementation of C4.5 algorithm in WEKA. C4.5 algorithm developed by Quinlan creates decision tree from training set using the concept of information gain (http://en.wikipedia.org/wiki/C4.5_algorithm; Quinlan, 1996). At each node of the tree, algorithm selects the attribute which most efficiently splits the data is said to have highest information gain. Attribute with highest normalized information gain (difference in entropy) is selected to make the decision. The process continues until complete decision tree is created giving description of all the class instances based on which test instances are classified.

***Multilayer perception*:** A multilayer perceptron is a feed forward artificial neural network with one or more hidden layers which maps set of data into appropriate output (http://en.wikipedia.org/wiki/Multilayer_perceptron; Hassoun, 1999). Basically there are three layers; input layer, hidden layer and output layer. Each neuron (node) in each layer is connected to every neuron (node) in adjacent layers. The training or testing vectors are connected to the input layer and further processed by the hidden and output layers (Zak, 2003).

Simple logistics: Let class variables are of 0-1 type. To handle the task of classification (Hastie *et al.*, 2009) in logistic regression approach, the probability of membership in the first group, p1(x), is modelled directly as in equation (1) for the two categories problem where α and β are the parameters (Hastie *et al.*, 2009).

$$p_1(x) = \frac{e^{\alpha+\beta' x}}{1+e^{\alpha+\beta' x}} \quad (1)$$

Random forest tree: The random forest algorithm was developed by Leo Breiman (2001) (Breiman, Leo, 2001; Pater Nathan, 2005). Random forests, a meta-learner comprised of many individual trees, was designed to operate quickly over large datasets and more importantly to be diverse by using random samples to build each tree in the forest. This algorithm combines multiple random trees that votes/outcome on a particular outcome. In random forest tree algorithm each vote is given equal weight. The forest chooses the classification that contains the most votes.

MATERIAL AND METHODS

Experimental details

Dataset Description: Soybean disease dataset is considered for this experiment from UCI machine learning repository (Bache and Lichman, 2013). Dataset consist of 683 instances from 19 diseases classes (Diaporthe stem canker, charcoal rot, Rhizoctonia root rot, Phytophthora rot, brown stem rot, powdery mildew, downy mildew, brown spot, bacterial blight, bacterial pustule, purple seed stain, anthracnose, Phyllosticta leaf spot, Alternaria leaf spot, frog eye leaf spot, Diaporthe pod and stem blight, cyst nematode, 2, 4-d injury, herbicide injury). There are 35 categorical attributes, some nominal and some ordinal. The values for attributes are encoded numerically. Dataset consist of missing values for some of attributes. It is learnt from data that last four disease instances are unjustified by the data as most of the attribute values are missing for these diseases. Therefore these disease instances are removed from the dataset and 630 instances consisting of 15 diseases are considered for experiment. Diseases information from dataset is provided in table 1.

Experiment description: Waikato environment for knowledge learning (WEKA) software is used for carrying out this experiment. WEKA is an open source, free software which is widely used for machine learning algorithms. WEKA has many algorithms for classification grouped in different categories of functions, trees, rules *etc.* (Witten and Frank, 2005; http://www.cs.waikato.ac.nz/ml/weka/). Steps for applying classification techniques in WEKA are given below.

Step 1: Run WEKA explorer. In the preprocess tab, select open file to open the soybean disease dataset which is available in WEKA data folder.

Step 2: Classification algorithms are hierarchically organized in different categories under classify tab. J48 and random forest algorithms are available under tree category in classifier. Multilayer perceptron and simple logistics is available under function category in classifier. Experiment is run with default parameter settings for these classifiers. In majority of cases default setting results in obtaining good performance. Help on these parameters are available with right click.

***Step 3*:** Experiment is performed with 10 fold cross-validation.

***Step 4*:** Click on start button to run the experiment. Results appear in the right frame. Results can be visualized in the separate window also by selecting the option.

***Step 5*:** Experiment is run on machine with Intel Pentium (i5) processor with 8 GB RAM.

Table 1. Information about soybean disease dataset

Disease name	# of Instances	Attributes
Alternaria leaf spot	91	Date, plant-stand, precipitation, temperature, hail, crop history, area-damaged, severity, seed-treatment, germination, plant growth, leaves, leafs pots halo, leaf spots margin, leaf spot size, leaf shread, leaf malformation, leaf mild, stem, lodging, stem-cankers, canker lesion, fruiting bodies, external decay, mycelium, internode discolor, sclerotia, fruit pods, fruit spots, seed, mould growth, seed discolor, seed size, shrivelling, roots
Anthracnose	44	
Bacterial blight	20	
Bacterial pustule	20	
Brown spot	92	
Brown stem rot	44	
Charcoal rot	20	
Diaporthe stem canker	20	
Downy mildew	20	
Frog eye leaf spot	91	
Phyllosticta leaf spot	20	
Phytophthora rot	88	
Powdery mildew	20	
Purple seed stain	20	
Rhizoctonia root rot	20	

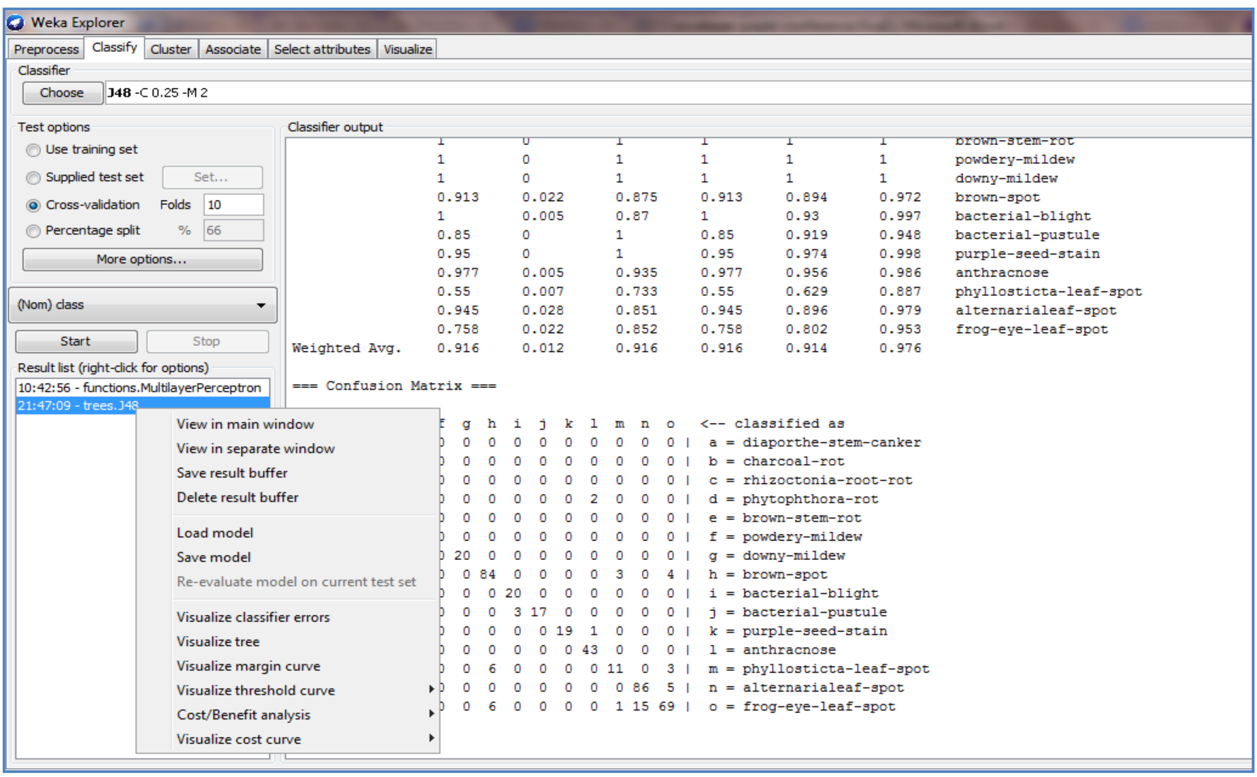


Fig. 1. Screen shot of WEKA software

RESULTS AND DISCUSSION

Comparison of different classifiers on soybean disease dataset is presented in table 2. Parameters considered are accuracy and time to build the model. Accuracy is defined as the number of instances correctly classified. It is observed that, all the classifiers are giving more than 90 per cent accuracy. Logistics and MLP performed better than all the classifier but time taken to build the MLP model is very high as compared to others.

Tree classifiers are taking less time in building the model and at the same time it results in tree like structure which can be easily understood by the users. Decision tree is created based on the principal of information gain and the attribute which results in higher information gain is selected for splitting the dataset and the process is

Table 2. Comparisons of different classifiers

Name of Classifier	Accuracy	Incorrectly classified Instances	Time to build the model
MLP	92.06	50	26.02 sec
Simple Logistic	92.22 %	49	4.76 sec
Random forest tree	90.63 %	59	0.03 sec
J48 decision tree	91.58 %	53	0.01 sec

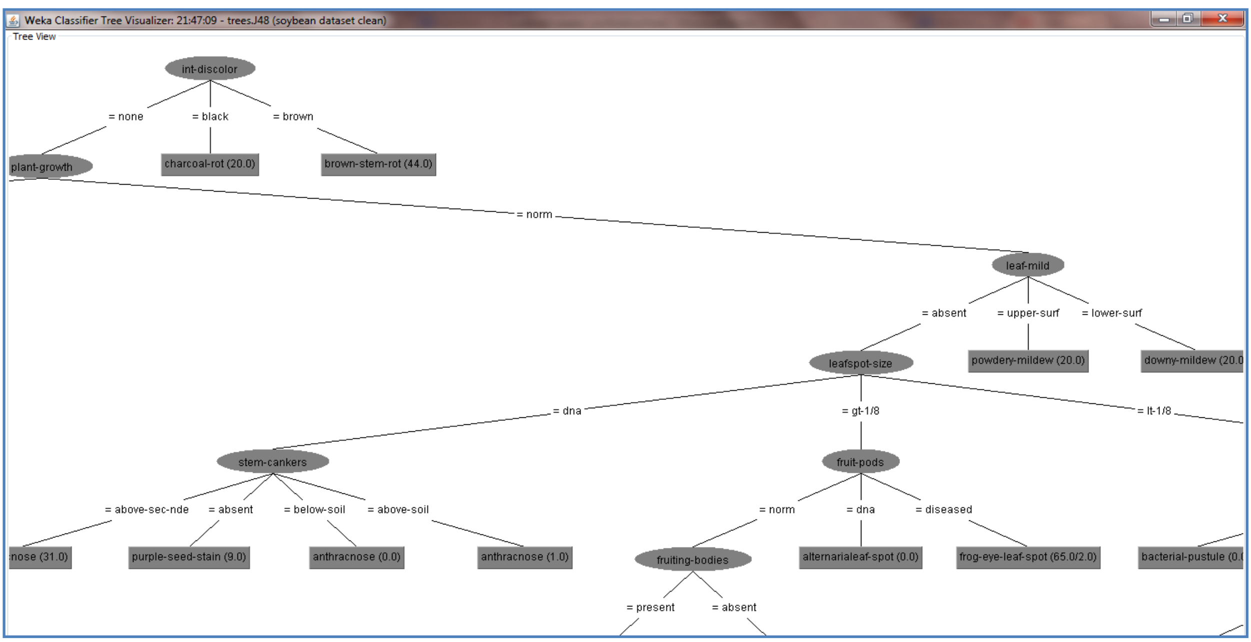


Fig. 2. J48 Decision tree in WEKA

repeated till complete dataset is divided into different classes. In this regard, it also shows the importance of attribute in classifying the class. Decision tree leads to generation of rules which can be widely used in expert systems and easily understood by common users and experts. Figure 2 presents the portion of decision tree generated by J48 decision tree. It is clear from the figure that some diseases are correctly classified with the help of 2-3 attributes out of 35 attributes. For example, all the instances of disease brown stem rot (44) are correctly classified by int-discolor='brown' and all the instances of charcoal rot (20) are classified by int-discolor='black'. Similarly, if (Pant growth = 'norm' and leaf mild='upper-surf' then disease (powdery-mildew).

The overall classification accuracy is comparable for all the classifiers. We also evaluated different classifiers on classifying different diseases. Comparison of different classifiers using the evaluation parameters true positive (TP) and precision for different diseases are given in table 3. TP is defined as the number of instance correctly labeled as belonging to the defined class. False positive (FP) is defined as the instances incorrectly labeled as belonging to that class. Precision is defined as the ratio of TP/(TP+FP).

Table 3. Comparison of classifiers on different disease

Disease name	J48		MLP		Simple Logistics		Random Forest Tree	
	TP	Precision	TP	Precision	TP	Precision	TP	Precision
Diaporthe stem canker	1	0.90	1	1	1	1	1	1
Charcoal rot	1	1	1	1	1	1	1	1
Rhizoctonia root rot	0.90	1	1	1	1	1	0.95	1
Phytophthora rot	0.97	0.97	1	1	1	1	1	0.93
Brown stem rot	1	1	1	1	1	1	1	1
Powdery mildew	1	1	1	1	1	1	1	1
Downy mildew	1	1	1	1	1	1	1	0.95
Brown spot	0.91	0.87	0.91	0.89	0.92	0.91	0.93	0.86
Bacterial blight	1	0.87	1	0.83	1	0.83	0.90	1
Bacterial pustule	0.85	1	0.80	1	0.80	1	0.85	.94
Purple seed stain	0.95	1	1	1	1	1	1	1
Aanthracnose	0.97	0.93	1	0.97	1	1	0.93	1
Phyllosticta leaf spot	0.55	0.73	0.65	0.76	0.75	0.78	0.6	0.80
Alternaria leaf spot	0.94	0.85	0.86	0.80	0.87	0.83	0.89	0.77
Frog eye leaf spot	0.75	0.85	0.79	0.85	0.75	0.80	0.71	0.86

Simple logistics and MLP has resulted in highest correctly classifying diseases nine and eight, respectively (Table 3). There is difference of only one instance. MLP is a black box approach which considers input data, learns the model from data and gives results. MLP is known for its accuracy but does not provide any additional information. Decision tree algorithms too in this case have given comparable results. These results can easily be interpreted by experts and non experts. In these approaches one can target any individual disease and study its characteristics (rules) and it gives fair idea about significant variables.

REFERENCES

Arora Alka, Upadhyaya Shuchita and Jain Rajni. 2008. Reduct based variable selection and knowledge discovery for disease clusters. *Soybean Research* **6**: 56-67.

Arora Alka, Upadhyaya Shuchita and Jain Rajni. 2009. Post processing of clusters for pattern discovery: Rough set approach. *Journal Indian Society of Agricultural Statistics* **63**(2): 181-88.

Bache K and Lichman M. 2013. *UCI Machine Learning Repository* [http://archive.ics.uci.edu/ml], Irvine, CA: University of California, School of Information and Computer Science.

http://en.wikipedia.org/wiki/C4.5_algorithm

http://en.wikipedia.org/wiki/Machine_learning

http://en.wikipedia.org/wiki/Multilayer_perceptron

http://www.pnbkrishi.com/soybean.htm

Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*, Morgan Kaufmann.

Hassoun M H. 1999. *Fundamentals of Artificial Neural Networks*, Cambridge, MA: MIT Press.

Hastie T, Tibshirani R, Friedman J. 2009. *The Elements of Statistical Learning: Prediction, Inference and Data Mining*, 2nd edition. Springer-Verlag, New York.

Jain Rajni, Sonajharia Minz and RamaSubramanian V. 2009. Machine learning for forewarning crop diseases. *Journal of the Indian society of Agricultural Statistics* **63**(1): 97-107.

Leo Breiman. 2001. Random Forests.

Pater Nathan. 2005. Enhancing Random Forest Implementation *In*: *Weka*, *Machine Learning Conference*, Paper for ECE591Q. November 28, 2005.

Quinlan J R. 1996. Improved use of continuous attributes in c4.5. *Journal of Artificial Intelligence Research* **4**:77-90.

Witten Ian H and Frank Elbe. 2005. *Datamining Practical Machine Learning Tools and Techniques*, Second Edition, Morgan Kaufmann, San Fransisco.

Zak S H. 2003. *Systems and Control*, NY: Oxford University Press.

Weka: Data Mining Software in Java (http://www.cs.waikato.ac.nz/ml/weka/).

Soybean Research (Special Issue Number 2): 263-270: 2014

Intelligent Soybean Disease Tutor System

SAVITA KOLHE[1] and G K GUPTA[2],
Directorate of Soybean Research, Indian Council of Agricultural Research, Indore 452 001, Madhya Pradesh, India
E mail : savita_dakhane@yahoo.com

ABSTRACT

Intelligent Soybean Disease Tutor System is developed using ASP .NET as a sub-system of Expert System of Soybean Diseases at Directorate of Soybean Research. The dynamic knowledge base is implemented using SQL server. This paper presents the development of Intelligent Tutor System for Soybean Diseases. The methodology used for development of the system is discussed. The importance of the system as an effective training tool for different clientele is described. The functionality of the system is explained with the help of user interface for better understanding of the system. This system can augment the conventional educational methodologies in specific courses in plant pathology. The current tutor system will pave a way to transfer the disease management technology in user-friendly manner.

Key words: Intelligent tutor, knowledgebase, knowledge acquisition, soybean disease and training tool

Soybean crop suffers from several diseases caused by bacteria, fungi, viruses, physiological disorders. Annual yield losses due to these diseases are in the tune of 12 per cent of total production (Gupta and Chauhan, 2005). Information on management of all the major diseases of soybean crop is needed by different clientele like students, research scholars, research workers, extension personnel, disease trainers, entrepreneurs and farmers. Therefore, Intelligent Soybean Disease Tutor System is developed to provide the information in different easy-to-understand ways.

Intelligent Soybean Disease Tutor System is a sub-system of Expert System of Soybean Diseases developed at Directorate of Soybean Research. It serves as an audio-visual soybean disease training tool. It provides information on useful disease aspects like pathogen, geographic distribution, economic impact, favourable climatic conditions, detection methods and effective integrated management practices. It is a useful and interactive audio-visual training tool for providing pathological trainings with the help of multimedia effects, colour pictures, videos, texts, and graphics with capability of text-to-voice interface.

MATERIAL AND METHODS

Intelligent Soybean Disease Tutor System is developed using the system architecture (Fig. 1.) consists of i) disease knowledge base, ii) knowledge acquisition system, iii) audio-visual ools and iv) teaching parameters. It facilitates provision of pathological training services to different clientele. Knowledge engineers with the help

[1]*Senior Scientist (Computer Applications);* [2]*Principal Scientist (Plant Pathology)*

of domain knowledge provided by disease experts and using knowledge acquisition system forms the disease knowledge base. This knowledge base provides all the knowledge for giving training to the end users. Tutor can use audio, videos, disease photographs and text-to-speech conversion tools to provide training in attractive manner.

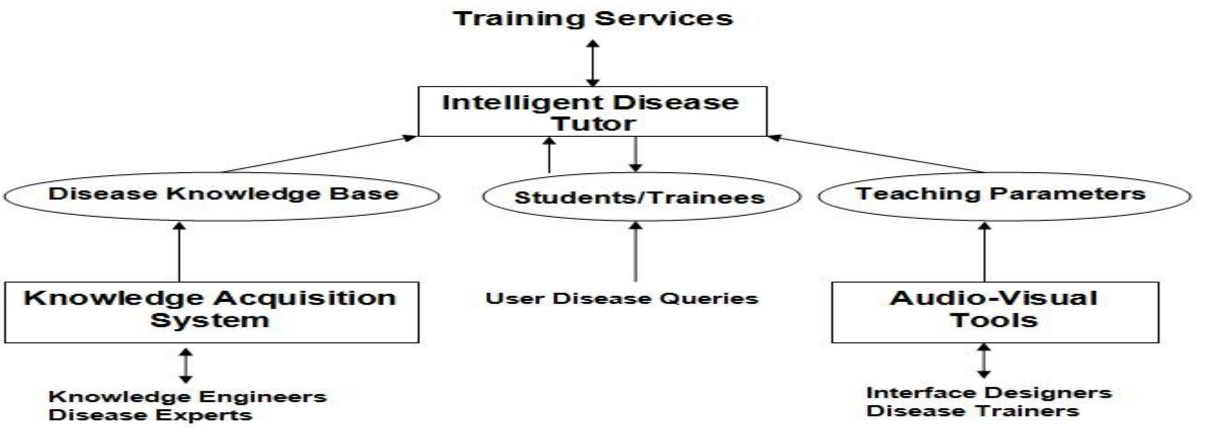


Fig. 1. Intelligent disease tutor system architecture

Software development

The system contains the disease knowledge about twenty five soybean diseases. The development of multimedia intelligent interface was done as follows.

Software selection

The interface is developed using the ASP .NET and C# for development of the system (Harvey *et al.,* 2001; MacDonald, 2005) as the concepts of text-to-speech translation can be easily used with applications built using the Microsoft .NET framework using 3-tier web architecture.

The dynamic knowledge base is implemented using SQL server. Fig. 2 explains pictorially how our intelligent tutor system employs the three-tier web architecture using .Net technology (Active server pages) and SQL server. The .NET software development platform is based on virtual machine based architecture. The entire .NET programs are independent of any particular operating system and physical hardware machine. They can run on any physical machine, running any operating system that contains the implementation of .NET Framework.

Database contains thirty-one database tables. The tables store facts and knowledge required for the knowledge base. A part of the database relationship diagram is shown in fig. 3.

Software Modules

The tutor system contains different modules for – (i) disease detail, (ii) disease comparison, (iii) new user registration, (iv) disease picture gallery and (v) disease video gallery.

The Disease detail module helps the user to view detail information on different aspects of soybean diseases. The user can compare different soybean diseases on multiple aspects for in-depth comparison of

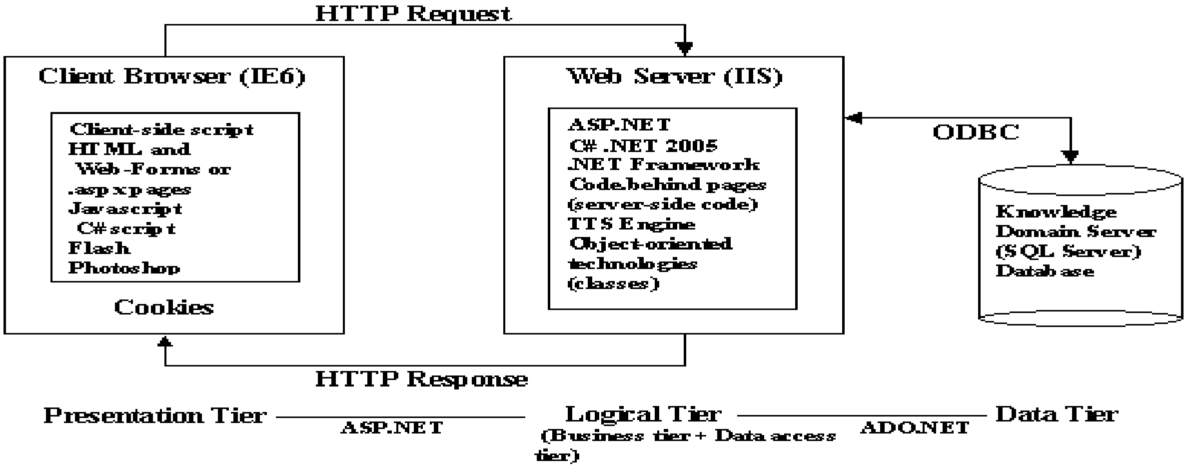


Fig. 2. Three-tier web architecture of the system (Savita *et al.*, 2011) Database Design

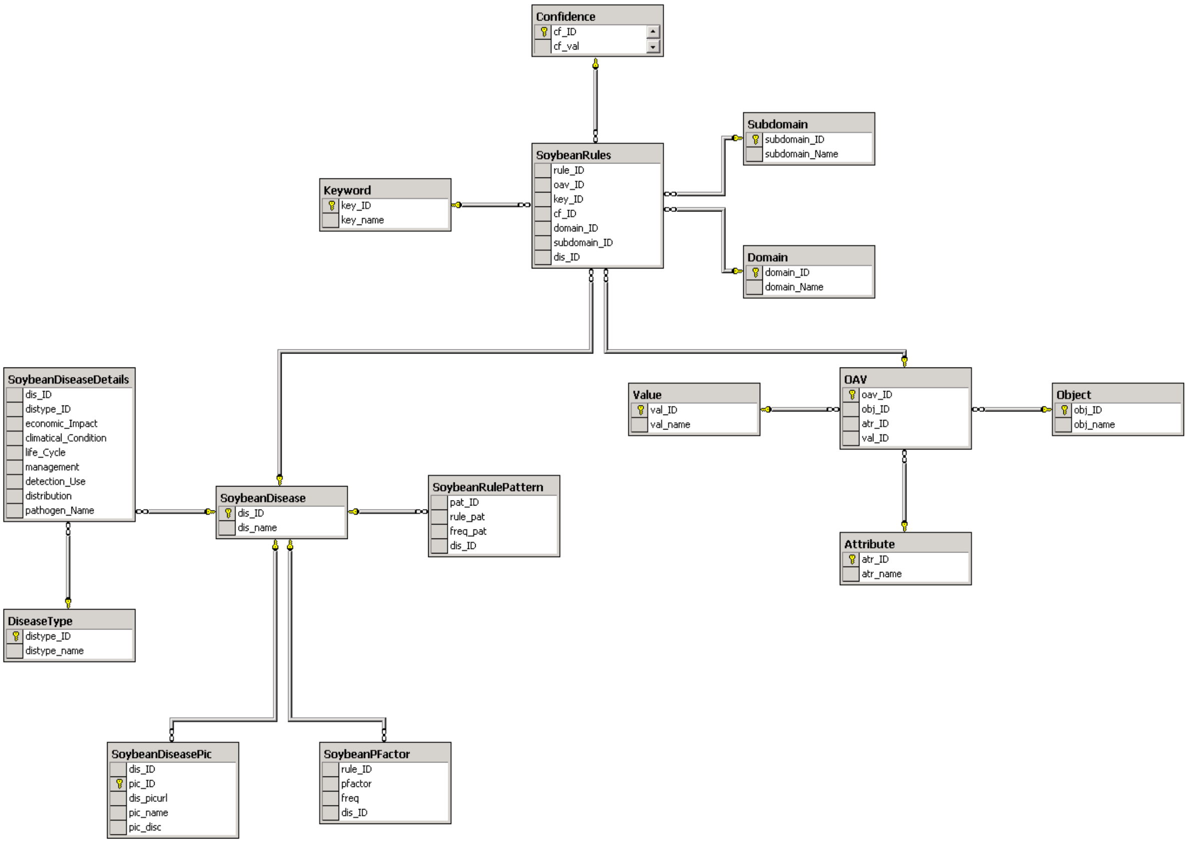


Fig. 3. A part of the database relationship diagram showing relationship between different database tables

different diseases by using disease comparison module. The new users can register for getting authorized access of the system by using new user registration module. The main users are students, research scholars, research workers, extension personnel, disease trainers, entrepreneurs and farmers. The registration is free for them for non-commercial, academic and research purpose. The users can view the pictures of different disease infection for giving correct disease symptom inputs by viewing disease picture gallery. The users can also view different disease videos by visiting disease video gallery.

Text to speech (TTS) translation

Automatic speech recognition (ASR) is commonly described as converting speech to text. The reverse process, in which text is converted to speech (TTS), is known as speech synthesis (Holmes, 2001). Speech synthesizers often produce results that are not very natural sounding. Speech synthesis is different from voice processing, which involves digitising, compressing (not always), recording, and then playing back snippets of speech. Voice processing results are very natural sounding, but the technology is limited in flexibility and is disk storage-space-intensive compared to speech synthesis.

Looking to this, our system includes the concepts of text-to-speech (TTS) translation and these features can be used comfortably with applications built using the Microsoft .NET framework.

The Microsoft Speech SDK is used to develop text to voice software applications [Microsoft speech API]. This SDK provides a collection of methods and data structures that integrate very well in the .NET 2005 framework.

Knowledge acquisition system

A web-based and interactive knowledge acquisition user interface is developed. It allows the expert to enter knowledge directly into the knowledge base, which means without an intermediary. This way of direct interaction of the expert increases the accuracy of the resulting application because errors of communication between knowledge engineers and experts are eliminated and as a result, we get a more reliable knowledge base.

The knowledge of different disease symptoms along with the knowledge on other disease related information like causal organisms, geographic distribution, economic impact, favorable climatic conditions, detection methods and effective integrated management of practices are entered using the web-based user interface of this subsystem. These are collected from literature, pathological experimental field trials, disease compendiums (Hartman *et al.*, 1999), books, scientific papers, disease bulletins (Bartaria *et al.*, 2001; Ghewande *et al.*, 2002; Gupta and Chouhan, 2005) and photographs of different diseases and interviews of plant pathologists.

RESULTS AND DISCUSSION

The interface is used by end-user by clicking menu-option "Intelligent Tutor" on the main user interface shown in fig. 4.

The user can use the system by doing login in the web form shown in fig. 5. The user gets the information in different ways by clicking menu buttons *viz.*, complete detail, disease comparison, image gallery and video gallery (Fig. 6). The user can get complete information of soybean diseases on different aspects like pathogen, geographic distribution, economic impact, favourable climatic conditions, detection methods and effective integrated management of practices

Fig. 4. Main web page of crop disease expert system

Fig. 5. Login page of intelligent disease tutor

by clicking complete detail menu button (Fig. 7). The user can compare different diseases on aforesaid aspects by clicking disease comparison menu button and by selecting desired options for comparison (Fig. 6). The disease knowledge is obtained in the form of comparison table as shown in Fig. 8. The user can view different videos and pictures to view disease expert knowledge on different diseases according to their interest and choice (Fig. 9). This helps to visualize the disease symptoms and picture-based confirmation of the diagnosed diseases.

This intelligent disease tutor system would provide real time, context-appropriate and cost-effective training enabling learners to perform appropriate disease related tasks in the right manner and at the proper time. In doing so, such an intelligent tutor system would decrease the time required to migrate learners from novice to disease expert, while increasing the number of disease trained personnel successfully reaching a more knowledgeable level. It includes complete, comprehensive disease knowledge expressed to the user effectively with the help of multimedia effects, colour pictures, videos, texts, and graphics. The users could use the system comfortably and found the working with interface satisfactory. Thus, it is a useful and interactive audio-visual training tool for providing pathological trainings. It can augment the conventional

Fig. 6 Web page for taking inputs to get complete disease details

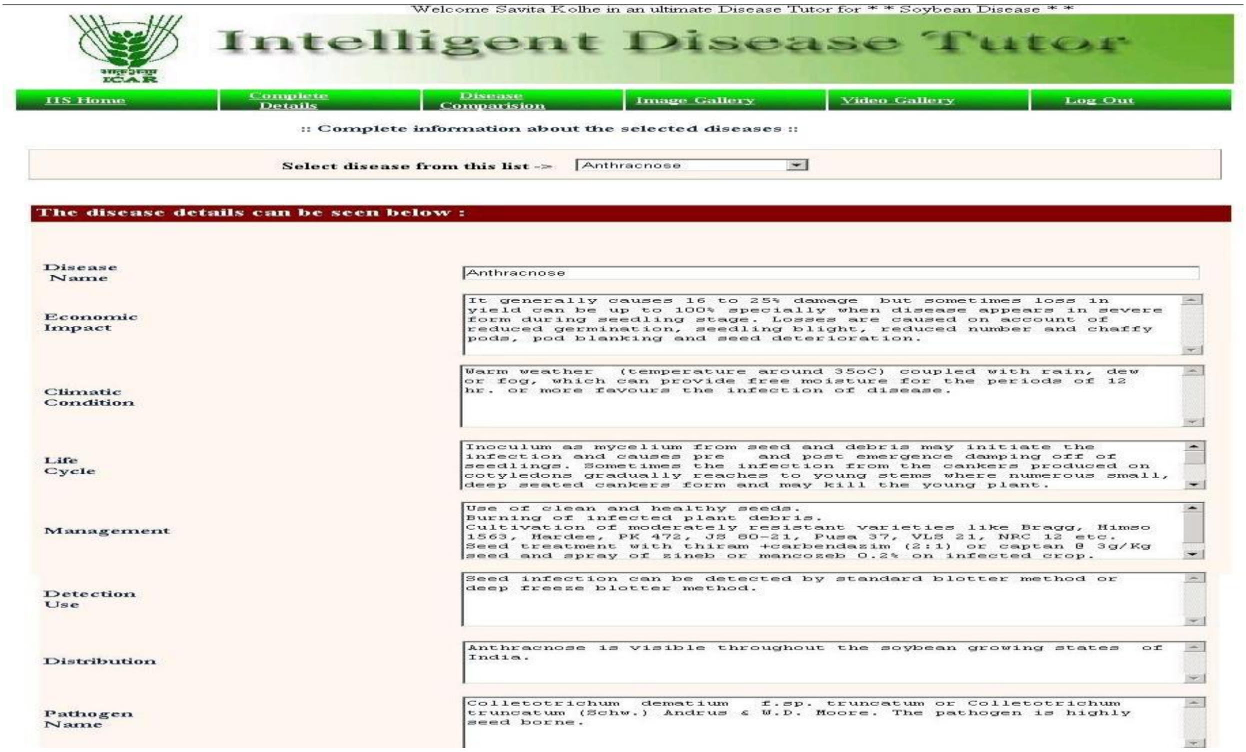
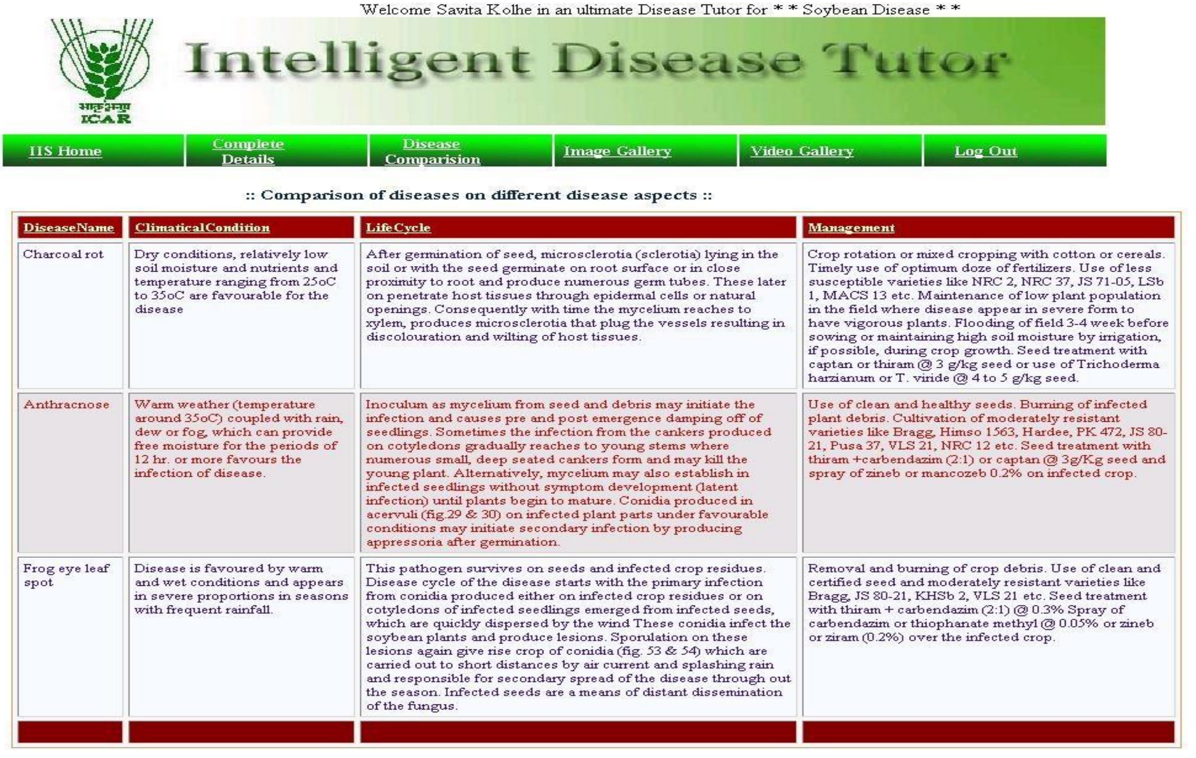


Fig 7. Web page showing complete details of the selected disease



DiseaseName	ClimaticalCondition	LifeCycle	Management
Charcoal rot	Dry conditions, relatively low soil moisture and nutrients and temperature ranging from 25oC to 35oC are favourable for the disease	After germination of seed, microsclerotia (sclerotia) lying in the soil or with the seed germinate on root surface or in close proximity to root and produce numerous germ tubes. These later on penetrate host tissues through epidermal cells or natural openings. Consequently with time the mycelium reaches to xylem, produces microsclerotia that plug the vessels resulting in discolouration and wilting of host tissues.	Crop rotation or mixed cropping with cotton or cereals. Timely use of optimum doze of fertilizers. Use of less susceptible varieties like NRC 2, NRC 37, JS 71-05, LSb 1, MACS 13 etc. Maintenance of low plant population in the field where disease appear in severe form to have vigorous plants. Flooding of field 3-4 week before sowing or maintaining high soil moisture by irrigation, if possible, during crop growth. Seed treatment with captan or thiram @ 3 g/kg seed or use of Trichoderma harzianum or T. viride @ 4 to 5 g/kg seed.
Anthracnose	Warm weather (temperature around 35oC) coupled with rain, dew or fog, which can provide free moisture for the periods of 12 hr. or more favours the infection of disease.	Inoculum as mycelium from seed and debris may initiate the infection and causes pre and post emergence damping off of seedlings. Sometimes the infection from the cankers produced on cotyledons gradually reaches to young stems where numerous small, deep seated cankers form and may kill the young plant. Alternatively, mycelium may also establish in infected seedlings without symptom development (latent infection) until plants begin to mature. Conidia produced in acervuli (fig.29 & 30) on infected plant parts under favourable conditions may initiate secondary infection by producing appressoria after germination.	Use of clean and healthy seeds. Burning of infected plant debris. Cultivation of moderately resistant varieties like Bragg, Himso 1563, Hardee, PK 472, JS 80-21, Pusa 37, VLS 21, NRC 12 etc. Seed treatment with thiram +carbendazim (2:1) or captan @ 3g/Kg seed and spray of zineb or mancozeb 0.2% on infected crop.
Frog eye leaf spot	Disease is favoured by warm and wet conditions and appears in severe proportions in seasons with frequent rainfall.	This pathogen survives on seeds and infected crop residues. Disease cycle of the disease starts with the primary infection from conidia produced either on infected crop residues or on cotyledons of infected seedlings emerged from infected seeds, which are quickly dispersed by the wind These conidia infect the soybean plants and produce lesions. Sporulation on these lesions again give rise crop of conidia (fig. 53 & 54) which are carried out to short distances by air current and splashing rain and responsible for secondary spread of the disease through out the season. Infected seeds are a means of distant dissemination of the fungus.	Removal and burning of crop debris. Use of clean and certified seed and moderately resistant varieties like Bragg, JS 80-21, KHSb 2, VLS 21 etc. Seed treatment with thiram + carbendazim (2:1) @ 0.3% Spray of carbendazim or thiophanate methyl @ 0.05% or zineb or ziram (0.2%) over the infected crop.

Fig. 8. Disease comparison on different aspects

Fig. 9. Web page displaying disease image of Anthracnose disease

educational methodologies in specific courses in plant pathology. It can prove to be a powerful means for transfer of technology of agriculture pathological technologies to practices.

Presently, the system generates knowledge in English, but in future it can be integrated with TTS engine of Hindi language also.

REFERENCES

Bartaria A M, A K Shukla, C D Kaushik, P R Kumar, and Singh N B. 2001. Major diseases of rapeseed-mustard and their management. *Technical Bulletin No. 10*, National Research Centre for Rapeseed-Mustard (ICAR), Bharatpur (Rajasthan), India, pp 34.

Ghewande M P, S Desai and Basu M S. 2002. Diagnosis and management of major diseases of groundnut. *Technical Bulletin*, National Research Centre for Groundnut (ICAR), Junagadh (Gujarat), India, pp 3-12.

Gupta G K and Chauhan G S. 2005. Symptoms, identification and management of soybean diseases, *Technical Bulletin*, National Research Centre for Soybean (ICAR), Indore (Madhya Pradesh), India, pp 92.

Hartman G L, J B Sinclair and Rupe J C. 1999. *Compendium of Soybean Diseases*, IV edition, The American Phytopathological Society, Academic Press, St. Paul, Minnesota, pp 100.

Harvey Burton, Robinson Simon, Templeman Jullan and Watson Karli. 2001. *C# Programming with Public beta,* Wrox Press Ltd. UK.

Holmes John and Holmes Wendy. 2001. *Speech Synthesis and Recognition*, 2nd Edition, Taylor and Francis Publication, UK.

MacDonald Mathew. 2005. *Pro ASP.NET 1.1 in C#: from Professional to Expert*. Apress, Berkeley, CA, USA.

Savita Kolhe, Raj Kamal, Harvinder S. Saini and Gupta G K. 2011. An intelligent multimedia interface for fuzzy logic based inference in crops. *Expert System with Applications* **38**; 34592-601.

Soybean Research (Special Issue Number 2): 271-276: 2014

Dynamics of Production and Profitability of Soybean in Madhya Pradesh

H O SHARMA[1], DEEPAK RATHI[2] and S C MEENA[3],
Agro–Economic Research Centre, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, Madhya Pradesh, India
E mail: agrianss@gmail.com

ABSTRACT

Dynamics of production and profitability of soybean has been observed in soya state of India considering variability, trend and growth of area, production, productivity, cost and profitability of soybean. The study based on secondary and tertiary data collected for the period of 30 years from 1980-81 to 2009-10. The secondary data related to area, production and productivity of soybean were collected from the Department of Farmers' Welfare and Agriculture Development, Bhopal, Madhya Pradesh, while the tertiary data related to cost and profitability of soybean in Madhya Pradesh were collected from various publications of Commission for Agricultural Costs and Prices (CACP), Ministry of Agriculture, Government of India, New Delhi. It was observed from the study that the production of soybean has increased by 11.52 per cent per annum (compound growth rate) due to combined effect of area (9.43 %/annum) and productivity (1.91 %/annum). It is also observed that the expenses related to all input variables have been found to increase by 770.64, 1372.49, 1696.90, 2153.07, and 2614.99 per cent in case of animal labour, fertilizers, seed, manure and human labour, respectively, while, expenses in case of irrigation was found to decrease by 100 per cent. The expenses on machine labour showed infinite change from Rs 0.00 (1980-81) to Rs 2534.13/ha (2009-10). With the result of increase in expenses among these input variables, the profitability of soybean has increased by 5042.92 per cent per year in the year 2009-10 over the year 1980-81. An average farmer got 12.71 per cent more benefit on investment of Rs 1.00 (benefit cost ratio) in the year 2009-10 (1:1.30) as compared to 1980-81 (1:1.15). Thus, performance of soybean was found to be quite appreciating in the state and standard of living of the farmers cultivating soybean was also enhanced during the period under study. Still immense scope is remaining to improve the productivity and as well as profitability of soybean in future.

Key words: Dynamics, Madhya Pradesh, profitability, soybean

Returns from the crop cultivation are not only important for the survival of farmers but also facilitate reinvestment in agriculture. If the flow of income from crop cultivation is not regular and adequate, farmers may not be able to repay their debts which would lead to increased indebtedness (Darling, 1925; NSSO, 2005; NSSO, 2005b; Narayanamoorthy and Kalamkar, 2005; GOI, 2007; Reddy and Mishra, 2009; Deshpande and Arora, 2010).

The increased production of soybean due to increase in area and productivity in the state enriched farmers and enhanced their standard of living. Soybean was introduced in 1970s in Madhya Pradesh. The area of soybean showed a positive and increasing trend with a magnitude of 184.85 thousand ha per year over the last 30 years. The increased

[1]*Director;* [2]*Deputy Director;* [3]*Senior Research Fellow3*

Table 1. Trend and growth in area, production and yield of soybean in Madhya Pradesh

Years	Area ('000 ha)	Production ('000 t)	Yield (kg/ha)
1980-81	237.70	96.04	404.04
1990-91	2201.50	2277.30	1034.43
2000-01	4424.58	3411.39	771.01
2001-02	4400.50	3712.69	843.70
2002-03	4148.78	2652.87	639.43
2003-04	4165.73	4623.75	1109.95
2004-05	4545.35	3736.65	822.08
2005-06	4536.50	4793.40	1056.63
2006-07	4651.90	4769.20	1025.22
2007-08	5145.80	5346.10	1038.92
2008-09	5237.60	5900.00	1126.47
2009-10	5289.80	6381.50	1206.38
b (regression coefficient)	184.85	199.15	15.28
Relative change	1420.19	2796.23	97.57
Coefficient of variance (%)	55.18	64.13	22.24
Compound growth rate (%)	9.43	11.52	1.91

area under soybean from 343.67 thousand ha (base year) to 5224.40 thousand ha (current year) showed a relative change of 1420.19 per cent with the fluctuation of 55.18 per cent (CV) and compound growth rate of 9.43 per cent per year during last 30 years. Looking to the three dimensional (area, production and yield) and tremendous growth of soybean in the state during the period under study, it is imperative to have in-depth study of change in cost incurred and profit earned by the soybean growers in the state. Hence, this particular research has been carried out to find out the reasons of three dimensional growths in soybean crop during last three decades utilizing the data of cost of cultivation survey at seven point of time covering the period from 1980-81 to 2009-10.

MATE RIAL AND METHODS

This study utilizes the data on cost of cultivation survey compiled from the various reports of the commission for Agricultural Cost and Price (CACP). Cost of cultivation survey data published by the CACP contains rich information on the cost and output of various crops on a temporal basis (Rao, 2001; Sen and Bhatia, 2004). This study covers data at seven points of time, starting from 1980-81 and ending with 2009-10.

CACP has been using seven different cost concepts. These are as follows:

Cost A1 = All actual expenses in cash and kind incurred in production by owner

Cost A2 = Cost A1 + rent paid for leased-in land

Cost A2 + FL = Cost A2 + imputed value of family labour

Cost B1 = Cost A1 + interest on value of owned capital assets (excluding land)

Cost B2 = Cost B1 + rental value of owned land (net of land revenue) and rent paid for leased-in land

Cost C1 = Cost B1 + imputed value of family labour

Cost C2 = Cost B2 + imputed value of family labour

Which is the appropriate cost that should be considered to calculate profitability of crops? Many scholars have considered cost A2 for calculating profit despite the fact that cost A2 does not cover interest on value of owned capital assets and rent for land, which would form substantial share in modern agriculture today. Moreover, there is also a growing concern that farmers should also get income for performing managerial function in agriculture, as has been followed in other professions where managing director or CEO gets hefty salary for performing managerial operations.

In this study, two cost concepts, namely cost A1 and cost C2 were considered to find out the profitability (returns over cost of cultivation) of soybean crop for the analysis. Cost A_1 covers actual expenses in cash and kind incurred in production by owner, rent paid for leased-in land. Cost C2 includes all actual expenses in cash and kind incurred in production by owner, rent paid for leased-in land, imputed value of family labour and rental value of owned land. Profit of the crop is calculated by deducting cost A1 and C2 from the value of crop output. The profit which is calculated using cost C2 should be called as 'Supernormal Profit' as that include imputed costs of various items, zero profit would mean that the farmer receives wages for family labour, *etc.* at the norm specified for this purpose (Rao, V.M. 2001). This point of view is quite correct and profit above this level would correspond to the concept of quasi rent. The same is recognized in this study.

RESULTS AND DISCUSSION

Changes in cost and profitability of soybean

The changes occurred in cost and profitability of selected crops has been observed from the tertiary data obtained from the various issues of Commission for Agricultural Costs and Prices. The changes in these parameters have been observed from 1980-81 to 2009-10 considering 5 years intervals *i.e.*, 1980-81, 1984-85, 1989-90,1994-95,1999-2000,2004-05 and 2009-10.

The expenses related to all input variables have been found to increase approximately 2000 per cent in the year 2009-10 as compared to 1980-81 (Table 2), which led to increase in the cost of cultivation of the crops by approximately 2000 per cent in the year 2009-10.

As regards to the profitability of the crop, the gross income received by the farmers has also increased by 2512.46 per cent from Rs 1109.95 per ha (1980-81) to Rs.28, 997.00 per ha (2009-10). With the results of all these the net income over the cost A_1, A_2, B_1, B_2, C_1 and C_2 also showed 2874.55, 2874.55, 1473.43, 4370.07, 1229.83 and 5042.92 per cent change, respectively in the year 2009-10 over the year 1980-81 (Table 3). The change in net return was found more than the change in cost it is due to the fact that the yield of soybean was increase three times i.e. 0.4 t per ha (1980-81) to 1.2 t per ha (2009-10). An average farmer also got 12.71 per cent more benefit on investment of Rs 1.00 (per rupee return) in the year 2009-10 (1:1.35) as compared to 1980-81 (1:1.15).

It is important to note that in United States, Brazil, and Argentina cultivated soybean varieties with growing periods of a minimum of six months. On the other hand, the most common varieties in India are grown relatively short monsoon season, and have

Table 2. Cost of cultivation (Rs/ha) of soybean based on various cost concepts, Madhya Pradesh

Particulars	1980-81	1984-85	1989 – 90	1994 - 95	1999 – 00	2004 – 05	2009 – 10	AC	RC
Seed	133.37	260.08	583.45	1017.09	1053.54	1714.64	2396.53	2263.16	1696.90
Fertilizer	44.24	114.97	246.67	521.22	575.26	687.58	651.43	607.19	1372.49
Manure	22.63	28.35	203.27	67.36	139.34	264.44	509.87	487.24	2153.07
Human Labour	175.87	389.68	634.68	1312.46	2181.25	2602.98	4774.86	4598.99	2614.99
Animal Labour	130.09	258.79	280.45	525.21	647.76	876.87	1132.62	1002.53	770.64
Machine Labour	0	78.74	211.3	503.41	609.79	996.7	2534.13	2534.13*	3118.35*
Insecticides	0	0.96	9.66	78.88	131.29	232.61	730.65	730.65*	76009.38*
Irrigation Charges	4.13	5.72	22.5	1.14	0.77	79.51	0	-4.13	-100.00
Interest on working capital	13.36	29.07	63.13	105.09	129.07	186.56	313.88	300.52	2249.40
Fixed costs	440.21	941.87	1446.91	2709.99	2971.25	4359.94	8423.86	7983.65	1813.6
Rental value of owned land	261.5	647.97	1054.98	2202.09	2177.6	3391.67	7249.24	6987.74	2672.18
Rent paid for leased in	0	0	0	0	0	0	0	0	0.00
Land revenue	15.99	5.35	6.56	4.75	5.41	4.19	3.88	-12.11	-75.73
Depre-ciation on implements	38.58	89.94	181.67	178.47	210.37	248.89	366.48	327.9	849.92
Interest on fixed capital	124.14	118.61	335.52	324.69	577.87	715.19	804.26	680.12	547.87
Cost A_1	495.79	1054.50	2239.41	3651.21	4475.10	6409.45	10728.46	10232.67	2063.91
Cost A_2	495.79	1054.50	2239.41	3651.21	4475.10	6409.45	10728.46	10232.67	2063.91
Cost B_1	NA	1253.12	2475.37	3975.90	5052.97	7124.64	11532.72	12079.60*	820.32*
Cost B_2	881.43	1901.09	3530.35	6177.99	7230.57	10516.32	18781.96	17900.53	2030.85
Cost C_1	NA	1460.26	2647.04	4639.77	6261.72	8613.75	14236.49	12776.23*	874.93*
Cost C_2	963.90	2108.23	3702.02	6841.85	8439.32	12005.42	21485.73	20521.83	2129.04

*AC = Absolute change RC = Relative change (%) * As compared to 1984-85*

Table 3. Profitability indicators of soybean crop in Madhya Pradesh

Years	Value of main product (Rs/hs)	Value of by product (Rs/hs)	Gross Returns (Rs/ha)	Net returns over costs (Rs/ha)		Per rupee return over costs	
				A_2	C_2	A_2	C_2
1980 – 81	1042.90	67.05	1109.95	614.16	146.05	2.24	1.15
1984 – 85	2399.14	214.14	2613.28	1558.78	505.05	2.48	1.24
1989 – 90	3974.59	277.94	4252.53	2013.12	550.51	1.90	1.15
1994 – 95	8351.86	456.48	8808.34	5157.13	1966.49	2.41	1.29
1999 – 00	8143.89	566.52	8710.41	4235.31	271.09	1.95	1.03
2004 – 05	12883.41	683.29	13566.7	7157.25	1561.28	2.12	1.13
2009 – 10	27494.83	1502.14	28997	18268.51	7511.24	2.70	1.35
AC	26451.93	1435.09	27887	17654.35	7365.19	0.46	0.20
RC	2536.38	2140.33	2512.46	2874.55	5042.92	20.73	17.24

AC = Absolute change RC = Relative change (%)

maturity durations of not more than 100 days. Compared to these soybean growing countries, which have yields of almost 3 tonnes per hectare, India's soybean yield is very low. Despite this, the area of cultivation of soybean in Madhya Pradesh continues to increase at a fast rate even with a perceived increase in the cost of soybean cultivation. An increase in the cost of cultivation per ha could have significant impacts on the livelihoods of farmers in Madhya Pradesh. Small-scale and marginal farmers make up more than half of the farmers of Madhya Pradesh, and depend on soybean. Soybean continues to be the preferred *kharif* crop for farmers in Madhya Pradesh due to its high net returns. However, soybean production in Madhya Pradesh is far from optimum. Better knowledge on improved agriculture practices, as well as increased availability and affordability of farm inputs is required to achieve higher productivity level. In addition, there was some evidence from the field that long-term soybean production is reducing soil health and increasing problems of pests. This effect could become more pronounced in the future if inefficient soybean cultivation techniques continue in farmers' field. Hence, farmers must be educated about low cost low input technologies (plant geometry, seed treatment, cultural treatment, *etc.*) for enhancing the productivity and thereby increase in level of income as well as standard of living of the farmers growing soybean, in general, and small and marginal farmers in particular.

REFERENCES

Darling M L. 1925. *The Punjab Peasant in Prosperity and Debt*, Oxford University Press, Delhi

NSSO. 2005. *Situation Assessment Survey of Farmers: Some Aspects of Farming*, Report No. 496, 59th Round (January-December, 2003), National Sample Survey Organisation, Ministry of Statistics and Programme Implementation, Government of India, New Delhi, July.

NSSO. 2005b. *Situation Assessment Survey of Farmers: Indebtedness of Farmer Households*, Report No.498, 59th Round (January-December, 2003), National Sample Survey Organisation, Ministry of Statistics and Programme Implementation, Government of India, New Delhi, May.

Narayanamoorthy A and Kalamkar S S. 2005. Indebtedness of farmer households across states: Recent trends, status and determinants. *Indian Journal of Agricultural Economics* **60**(3): 290-301.

Government of India. 2007. *Report of the Expert Group on Agricultural Indebtedness*, Ministry of Finance, Government of India, New Delhi, July.

Reddy D N and Mishra S (Ed.). 2009. *Agrarian Crisis in India*, Oxford University Press, New Delhi.

Deshpande R S and Arora S (Ed.). 2010, *Agrarian Crisis and Farmer Suicides*, Sage Publications, New Delhi.

Rao V M. 2001. The making of agricultural price policy: A review of CACP reports. *Journal of Indian School of Political Economy* **13**(1): 1-28.

Sen Abhijit and Bhatia M S. 2004. *Cost of Cultivation and Farm Income in India*, Academic Foundation, New Delhi.

Soybean Research (Special Issue Number 2): 277-282: 2014

Dynamics of Profitability from Soybean in Central India

RAVI SINGH CHOUHAN[1], DEEPAK RATHI[2] and HARI OM SHARMA[3],
Agro-Economic Research Centre, Jawaharlal Nehru Krishi Vishwa Vidyalaya,Jabalpur 482 004, Madhya Pradesh, India
E mail: rsc.aerc@gmail.com

ABSTRACT

The cost and profitability of soybean vis-à-vis *risk in its production over competing crop (hybrid maize) have been analyzed in Chhindawara, Nirsinghpur and Khandwa districts of Madhya Pradesh considering 240 soybean growers from marginal (60), small (60), medium (60) and large (60) sized farms. Soybean was found to be more profitable over hybrid maize as an average farmer received 45.03 and 43.80 per cent more gross and net returns over hybrid maize. Although the cost of cultivation of soybean (Rs 15,238/ha) was found to be more than the hybrid maize (Rs 10,710/ha), an average soybean grower received more net income from soybean (Rs 19,202/ha) as compared to maize (Rs 13,239/ha). The cost of production per quintal was also found higher in case of soybean (Rs 13,297) as compared to hybrid maize (Rs 5,434), as the levels of yield was found more in hybrid maize (1,971 kg/ha) as compared to soybean (1,146 kg/ha). In both the cases operational cost as well as profitability was found to increase with size of farm. It is also observed that price and income risk were found more in soybean (14.99 % and 15.66 %) as compared to hybrid maize (8.71 % and 13.92 %), while acreage risk was found more in maize (122.29 %) as compared to soybean (50.25 %). This was true for all the categories of farms with minor variations. Hence, it can be said that soybean still found more profitable than its competing crop hybrid maize across all the categories of farms. This suggest that steps are to be taken to reduce price and income risk through stabilizing prices and net income at higher level in cultivation of soybean in Madhya Pradesh and by uplifting the standard of living of the farmer community.*

Key words: Hybrid maize, Madhya Pradesh, profitability, risk, soybean

Soybean, paddy, maize and jowar are the major crops cultivated by the farmers of Madhya Pradesh during rainy season. Hybrid maize is a competing crop of soybean in Madhya Pradesh in the state (Jaiswal and Hugar, 2011). The area, production and yield of both the crops are showing an increasing trend. The area, production and yield of soybean has increased with a higher pace with a magnitude of 124.58 thousand ha, 174.79 thousand tonnes and 11.54 kg per ha, respectively as compared to the maize 2.79 thousand ha, 11.51 thousand tonnes and 538 kg per ha during the period of last 20 years, respectively (Table 1).

Maize covers only 860 thousand ha of area producing 1,324 thousand tonnes with productivity of 1,492 kg per ha, while soybean covers 5,670 thousand ha producing 6,280 thousand tones with productivity of 1,108 kg per ha in Madhya Pradesh (2011-12). The productivity of maize (1,492 kg/ha) is found 34.65 per cent higher than soybean (1,108 kg/ha). The present study examines the level of different inputs used, cost of production and associated factor in production of these two crops.

[1]Research Associate; [2]Deputy Director; [3]Director

Table 1. Area, production and yield of soybean and maize in last two decades

Year	Area (000'ha)		Production (000'tonnes)		Yield (kg/ha)	
	Maize	*Soybean*	*Maize*	*Soybean*	*Maize*	*Soybean*
1991-92	878	2645	864	2088	984	790
2000-01	840	4475	1218	3431	1459	767
2010-11	849	5560	1340	6670	1266	1200
2011-12	860	5670	1324	6280	1492	1108
Mean	836.86	4365.81	1191.81	4337.29	1409.43	979.29
Regression Coefficient (b)	2.79	124.58	11.51	174.79	5.38	11.54
Linear Growth (%)	0.33	2.85	0.97	4.03	0.38	1.18

Source: Madhya Pradesh Agricultural Statistics, Department of Farmers' Welfare and Agriculture Development 2012/ Commissioner Land Record Gwalior 2012

MATERIAL AND METHODS

A multistage, purposive sampling method was used to select the districts, blocks, villages and farm households. At first stage, all the districts were classified into two categories *i.e.*, high area districts and low area districts considering area more than the mean and area less than the mean respectively for a particular crop. One district in each category having high area high yield (Chhindwara), high area low yield (Khandwa) and low area high yield (Narsinghpur) have been selected for the study (Table 2).

Table 2. Number of respondents in selected crops

Particulars	**Districts**	**Talukas/ Blocks**	**Villages**	*Sample size (HHs)*
High area high yield	Chhindwara	Chaorai	Simariya, Lahagdua, Chandanwada	80
High area low yield	Khandwa	Pandhana	Pipalod Khurd, Rustampur, Gokul Goan	80
Low area high yield	Narsinghpur	Kareli	Jova, Midali, Rakai	80
Total sample size				**240**

In the second stage one block has been selected on the basis of maximum area in respective crops in each. In the third stage three villages were selected randomly in each selected block. In the last stage a list of all the farmers of the selected villages was prepared in ascending order to their size of holding and classified them into marginal (less than 1 ha), small (1-2 ha), medium (2-4ha) and large (above 4 ha), and 20 farmers in each category were be selected randomly for soybean and 10 farmers to each category were selected for maize. Thus, the study covers 240 soybean growers and 120 maize growers of different size of farms in selected districts of Madhya Pradesh. The study ensures the adequate coverage of major agro-climatic regions of the state. The primary data of the study collected from sample respondents of different locations of the study through pre-tested interview schedule in light of the Madhya Pradesh conditions. The required secondary data were collected on different aspects of the study from the Commissioner, Land Record, Gwalior (Anonymous, 2012) and Department of Farmers' Welfare and Agriculture Development (Anonymous, 2010) from their published records and internet websites. The primary data pertained to the year 2010 – 11, whereas secondary data were pertained to years from 1991-92 to 2011-12. The total operational cost of cultivation has been taken into considerations while analyse the cost and profitability on different size of farms. Raju and Rao (1990) and Sharma *et al.* (2005) also used these concepts to calculate the profitability of soybean.

RESULTS AND DISCUSSION

Profitability of soybean *vis –a-vis* maize

Soybean competes with maize in the study area. The operational cost of cultivation per hectare in case of soybean was documented as Rs. 12,785, Rs 14,500, Rs 16,469, Rs 17,169 and 15,238 while in case of maize it was Rs 9,157, Rs 10,657, Rs 11,313 and Rs 11,714 and Rs 10,710 respectively in case of marginal, small, medium, large size and overall categories of farmers (Table 3).

Net income of soybean in case of marginal, small, medium, large and overall categories of the farmers was recorded as Rs 18, 395, Rs 18,129, Rs 19,170, Rs 20,443 and Rs 19,009 per ha, while in case of maize this was Rs 8,564, Rs 14,704, Rs 16,305, Rs 13,369 and Rs 13,125 per hectare, respectively. Soybean was found more profitable than its competing crop maize. The benefit: cost ratios obtained under soybean cultivation were 2.44, 2.25, 2.16, 2.19 and 2.25, while in case of maize, the ratios recorded were 1.94, 2.38, 2.44, 2.14 and 2.23 among above mentioned categories, respectively. The yield of soybean obtained under marginal, small, medium, large and overall categories was 1,057, 1,102, 1,190, 1,235 and 1,146 kg per ha and the cost of production to obtain a quintal of soybean was recorded as Rs 12,096, Rs 13,158, Rs 13,839, Rs 13,924 and Rs 13,297, respectively. In case of maize, the yield obtained was 1,589, 2,055, 2,249, 1,990 and 1,971 kg per hectare and the cost of production recorded was Rs 5,763, Rs 5,186, Rs 5,030, Rs 5,886 and Rs 5,434 per quintal respectively among above mentioned categories (Table 4).

Gautam and Nahatkar (1993) also reported that soybean is a prospective crop in terms of income and ensure the highest profit among major *kharif* crops of Madhya Pradesh. Jaiswal and Hugar (2011) also reported that even though the cost of cultivation of soybean was higher than that of maize, its gross return as well as net return were also correspondingly higher than maize in Madhya Pradesh.

Profitability *vis-à-vis risk* in soybean production

In soybean, acreage variability, yield, price and net income risk at overall level was found to be 50.25, 16.33, 14.99 and 15.66 per cent, while in case of maize it was found to be 122.29, 19.66, 8.17 and 13.92 per cent, respectively (Table 5).

The maximum variability was found in case of area in both the crops and yield risk in case of maize. At overall more price and net income variability was found in soybean as

Table 3. Operational cost of cultivation of soybean *vis –a-vis* maize (Rs/ha)

Cost items	Marginal	Small	Medium	Large	All Farms
			Soybean		
Seed	2747	2870	3008	3173	2950
Fertilizer and manure	2560	3054	3421	3405	3110
Insecticides and pesticides	1919	2343	3261	3501	2756
Human labour	- -	- -	- -	- -	- -
Family	643	600	705	733	670
Hired	228	648	930	1257	766
Machine labour	2344	2497	2639	2746	2556
Bullock labour	- -	- -	- -	- -	- -
Irrigation	- -	- -	- -	- -	- -
Harvesting and threshing	2261	2392	2398	2273	2331
Interest on working capital	84	95	107	109	99
Total Operational Cost	12785	14500	16469	17196	15238
			Maize		
Seed	461	451	517	554	496
Fertiliser and manure	2792	2879	3008	3154	2958
Insecticides & pesticides	1195	1203	1326	1340	1266
Human labour	- -	- -	- -	- -	- -
Family	923	947	906	780	889
Hired	627	862	1007	1086	896
Machine labour	1176	2289	2503	2719	2172
Bullock labour	- -	- -	- -	- -	- -
Irrigation	- -	- -	- -	- -	- -
Harvesting and threshing	1970	2011	2031	2064	2019
Interest on working capital	13	14	16	17	15
Total Operational Cost	9157	10657	11313	11714	10710

compared to maize, while the acreage variability was found to be more in maize (122.29 %) as compared to soybean (50.25 %). This was found true for all the categories of farms with minor variation.

Among different size of holdings, the acreage variability, yield, price and net income risk of soybean were found maximum in medium (68.62 %), medium (18.48 %), small (22.11 %) and small (18.73 %) and minimum in large (35.44 %), large (13.81 %), medium (10.80 %) and large (13.51 %) categories. In case of maize the maximum acreage variability, yield, price and net income risk were found in marginal (170.47 %), marginal (23.90 %), large (10.95 %) and large (14.92 %) and minimum in medium (72.61 %), medium (15.15 %), small (5.87 %), medium (11.93 %) as compared to other categories.

Table 4. Profitability of soybean *vis –a-vis* maize (Rs/ha)

Particulars	Marginal	Small	Medium	Large	All Farms
			Soybean		
Yield (kg)	1057	1102	1190	1235	1146
Price (Rs/q)	2866	2877	2908	2959	2903
Value of main-product	30294	31705	34605	36544	33263
Value of by-product	886	924	1034	1095	985
Gross Income	31180	32629	35639	37639	34247
Net Income over operational cost	18395	18129	19170	20443	19009
Cost of production (Rs/t)	12096	13158	13839	13924	13297
Cost of cultivation	12785	14500	16469	17196	15238
Returns/ Rupee	2.44	2.25	2.16	2.19	2.25
			Maize		
Yield (kg)	1589	2055	2249	1990	1971
Price (Rs/q)	1049	1163	1163	1192	1142
Value of main-product	16669	23900	26156	23721	22501
Value of by-product	1052	1461	1462	1362	1334
Gross Income	17721	25361	27618	25083	23835
Net Income over operational cost	8564	14704	16305	13369	13125
Cost of production (Rs/t)	5763	5186	5030	5886	5434
Cost of cultivation	9157	10657	11313	11714	10710
Returns/ Rupee	1.94	2.38	2.44	2.14	2.23

1q = 100 kg

It is clear from the about discussion that soybean still found more profitable than its competitive crop hybrid maize as it provides Rs 34,247 and Rs 19009 more gross and net income to them as compared to hybrid maize although there was found more price and income risk in cultivation of soybean as compared to hybrid maize. Hence efforts should be made to reduce price and income risk associated with soybean production through stabilize prices of input as well as output in long run and by uplifting the standard of living of farmers. The study indicated that there have been incentives for farmers to grow soybean in *kharif* instead of its competitive crop. Similar observation made by Kajale (2002).

Table 5. Profitability vis-à-vis risks in soybean production

Indicators	Marginal	Small	Medium	Large	All Farms
Main crop			***Soybean***		
Acreage variability	30.65	66.27	68.62	35.44	50.25
Yield risk	17.67	15.36	18.48	13.81	16.33
Price risk	13.83	22.11	10.80	13.21	14.99
Net income risk	15.75	18.73	14.64	13.51	15.66
Main Competing Crop			***Maize***		
Acreage variability	170.47	165.61	72.61	80.45	122.29
Yield risk	23.90	20.69	15.15	18.89	19.66
Price risk	7.16	5.87	8.71	10.95	8.17
Net income risk	15.53	13.28	11.93	14.92	13.92

Coefficient of variation of area, yield, price and net income of main oilseeds and main competing crops

REFERENCES

Anonymous 2010, Madhya Pradesh Agricultural Statistics, Compendium 2009-10, Department of Farmers' Welfare and Agriculture Development pp 47-9. (www.mpkrishi.org)

Anonymous 2012, Commissioner Land Record Gwalior 2012, table 4a – 5b. (http://www.landrecords.mp.gov.in/agr_stat.htm)

Gautam D S and Nahatkar S B. 1993, Profit structure of soybean, cotton and sorghum cultivation in central Narmada valley of India. *Gujrat Agriculture University Research Journal* **19**: 98-102.

Jaiswal Ankit and Hugar L B. 2011. **An** economic analysis of soybean cultivation vis-a-vis its competing crops in Madhya Pradesh, *Karnataka Journal of Agricultural Sciences 24(4): 591-2.*

Kajale J G. 2002. Trade liberalization and the soybean sector in Maharashtra. *Indian Journal of Agricultural Economics* **57**(3): 340-5.

Raju V T and Rao D V S. 1990. *Economics of Farm Production and Management,* Oxford and IBH Publication Company and Private Limited, New Delhi, India.

Sharma H O, Yadav R and Nahatkar S B. 2005. Adoption pattern and constraints of soybean production technology in Malwa agro-climatic region of Madhya Pradesh. *Agriculture Situation in India* **61**(2): 3-17.

Soybean Research (Special Issue Number 2): 283-292: 2014

Soya Samriddhi: Increasing Income of Small and Marginal Farmers and Involvement of Women in Decision Making through Soy Value Chain - A Unique Example of Public Private Partnership

PADAM KUMAR JAIN[1],
SRIJAN, Bundi 323 001, Rajasthan
E mail: padamjain@srijanindia.org

ABSTRACT

Having seen the economic benefits of soybean farming in the neighbouring state of Madhya Pradesh in Central India, farmers in Rajasthan also started cultivation of this wonder crop. However, average soybean productivity in Bundi district of Rajasthan (Central India) was low (less than 1,000 kg/ha). Factors identified for such low yield were high pH, uncertain rainfall, use of low quality inputs, weaker economic condition of farmers and lack of know-how of appropriate technology. Soybean processing plants in the region suffered from low capacity utilization. Further, in spite of the fact that women are extensively involved in all the activities of the production process, they lack information and knowledge about best practices and market, resulting in negligible decision making. With the objective of mitigating constraints in harnessing the yield potential and augmenting profitability of soybean farming to small and marginal farmers in particular, 'SRIJAN', a Civil Society Organization launched the "Soya-Samriddhi" programme with the support of Bunge (Agribusiness and Food M and NC) in the Bundi region of Rajasthan since 2008. The project also ensured continuous supply of good quality soybean for Bunge's processing plant. In 2013, SRIJAN's professional team working with 15,300 farmers in Bundi to transfer appropriate package of practices for soybean cultivation under the technical guidance of renowned scientist Dr P S Bhatnagar and Directorate of Soybean Research (DSR), Indore as well as Local Agricultural Research Station. SRIJAN designed innovative extension strategy to ensure better adoption of suggested package of practices. In addition to crop advisory services, SRIJAN facilitates access to credit and market information, input arrangement and marketing of produce through Women SHG federation and Women Farm Producer Company, respectively. In 2012, 12,000 participating farmers experienced average increase in crop yields and net profit by 31 and 44 per cent, respectively as compared to other farmers in the district. The Federation arranged credit of Rs 25 million for purchasing good quality input and 30,000 quintal soybean were procured through 3 collection centres by Bunge and farmers got best price of their produce. To strengthen the program and enhance water availability, we guided 21 producers to Rastriya Krishi Viksas Yojana (RKVY) for construction of farm ponds.

Key words: Public private partnership, **s**oy value chain, soya samriddhi

Soybean [*Glycine max* (L.) Merrill] is world's most important legume oil seed crop, which contributes 28 per cent to the global vegetable oil production, about two thirds (68%) of the world's protein for livestock feeding and feeds for poultry and fish (Soy Statistics, 2013, USDA). Due to its unique chemical composition (20 % oil and 40 %

[1]*Program Leader, Soybean*

protein), the crop has potential to mitigate protein malnutrition in India.

In India, soybean has established itself as a major crop in the rainfed agro-ecosystem. Introduction of soybean in India has led to a shift in the cropping system and has resulted in an enhancement in the cropping intensity and resultant increase in the profitability per unit land area. The area under the soybean has increased from 0.03 m ha in 1970 to 12.03 million ha in 2013. Mean national productivity increased from 426 kg per ha in 1970 to 1,017 kg per ha in 2013. The major soybean growing states are Madhya Pradesh (6.26 m ha), Maharashtra (3.87 m ha), Rajasthan (1.06 m ha) Karnataka (0.25 m ha), Andhra Pradesh (0.28 m ha) and Chhattisgarh (0.16 m ha) (SOPA, 2013). The crop earns valuable foreign exchange (Rs. 105911 millions in 2012-13) (SOPA, 2013) by exporting soya meal. At present soybean contributes 45 per cent and 25 per cent to the total oilseeds and edible oil production of the country.

In India, soybean farming covers around 10 per cent of total world land under the crop and contributes only 4 per cent of world production at present. The national average soybean productivity (1, 017 kg/ha) is still below the half of the world average (2, 400 kg/ha).

Similar to the national productivity, the average productivity of Bundi district of Rajasthan has been historically quite low. Factors like unsuitable soil quality (high soil pH, low organic carbon), uncertain and non-uniform rainfall pattern, low quality agricultural inputs and lack of know-how of modern agriculture practices are the causes of observed low productivity in the region.

As a result of which, Bunge which operates a soybean crushing plant in the same region, suffered from low capacity utilization at their plant. Given that soybean is a relatively new crop for the Bundi region, farmers were unaware of simple and effective practices for its farming. Also, although women are extensively involved, typically as manual labour, throughout the soybean farming cycle, they lacked information and knowledge about best practices, resulting in negligible decision making power resting with them.

To address the above issues, SRIJAN-Bunge partnership runs the "Soya-Samriddhi" programme in the Bundi region since 2008 to assist small and marginal farmers in increasing their soybean productivity and thereby improving their livelihoods and assuring a continuous supply of good quality soya for the Bunge crushing plant. Major objectives of ongoing program are to promote (i) sustainable agricultural practices for increasing productivity and profitability of soybean, (ii) community-owned institutions for carrying the programme forward, market and credit linkages and encourage women's role in farming.

MATERIAL AND METHODS

Programme structure and activities

"Soya Samriddhi" program was designed from the perspective of small and marginal farmers encompassing 4 elements, namely agricultural inputs, technical know-how and training, credit and market. These elements were implemented to achieve the said objectives.

Agricultural inputs: Timely availability of quality agricultural inputs like seeds, fertilizers, pesticides, *etc* constituted the integral ingredient for raising productivity. In this project, Samridhhi Mahila Crop Producer's Company Ltd., a women-led producers company promoted by SRIJAN utilized its greater bargaining power by procuring these items in bulk and delivering to farmers at a reasonable price in order to reduce the cost of cultivation. Earlier farmers use to individually procure their individual requirements from dealers and hence, could not leverage the benefits of better prices from bulk procurement following group approach.

Technical know-how: There has been a definite lack of knowledge of appropriate soybean farming practices as reflected in the low productivity in the region. The program targeted this element by designing a set of package of practices for the local farmers with technical assistance from Directorate of Soybean Research, Indore, Madhya Pradesh followed by disseminating it through multiple avenues.

To change the adoption behaviour of the community, series of promotion activities, like street plays, wall painting, village meetings, soya chetna yatra, movie shows, farmer's fair, text and voice messages, pamphlet distribution, mobile van, *etc* were conducted amongst villagers (Fig. 1). In our model, we provided same message to farmers through various means so that his/her belief and perception towards particular activities will increase.

Fig. 1. Innovative program promotion strategy to change behaviour of farmers

SRIJAN carried out activities for expanding its programme, undertaken promotion drives, recruited s cadre of service providers (local youth) to facilitate daily interaction with the farmers and undertakes extensive capacity building exercises targeted at its own team as well as the beneficiaries. To allow for maximum adoption of recommended practices, it also build women-led community owned institutions like self-help groups which are further networked into clusters and a federation (Fig. 2).

Credit: Like most agricultural settings where formal credit is very burdensome in terms of procedure and the need for collateral, farmers in Bundi were also tied closely to the traditional credit system. Farmers take loans

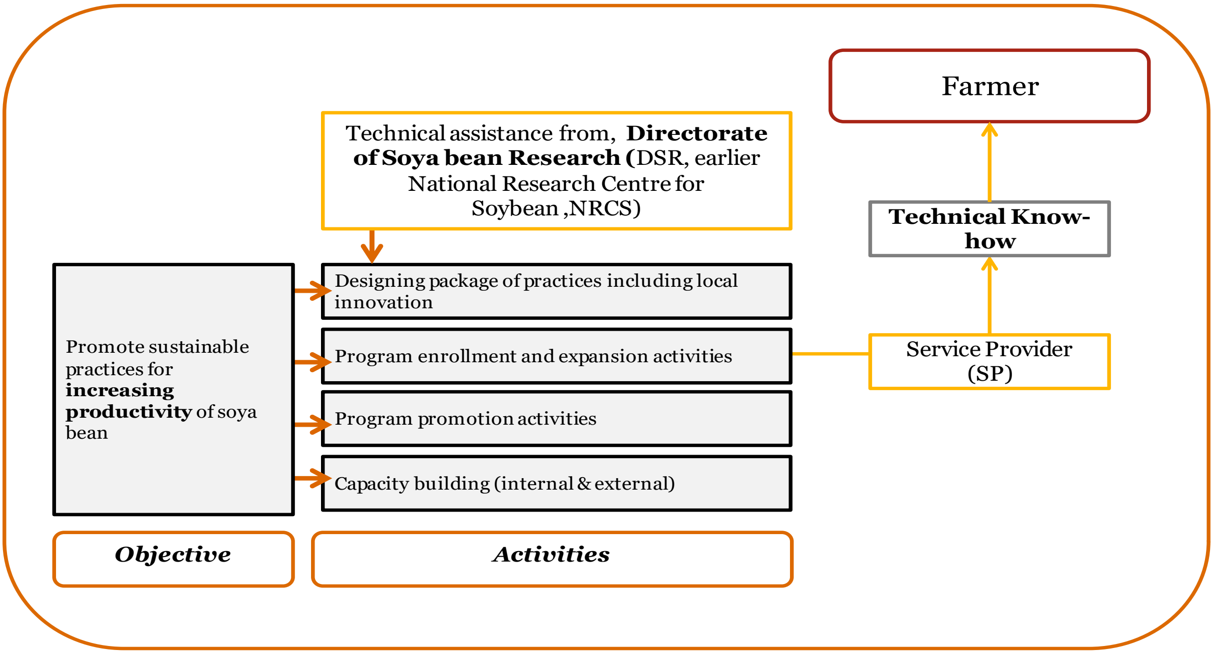


Fig. 2 Transfer of technical know-how

not only for productive-agricultural usage but also for non-productive uses like organizing a marriage from the local trader (Aaratiya). The farmer is hence bound to sell his produce through this Aaratiya who recovers the principal and interest from the sale price of the produce. Since interest rates can be exorbitant (24 - 36 % annually depending on the credit worthiness of the farmer), the farmer eventually is left with a small fraction of the value of his produce, which is usually not sufficient for making investments for the next cropping cycle. This creates a debt-trap for the farmers as they have to go back to the *aaratiya* every cropping cycle.

The Programme promoted women self-help groups (SHGs), which are women-led community institutions, which constituted an additional source of formal credit for agricultural purposes and for needs related to health and education. The women farmers utilized the internal saving scheme run by the SHGs or take loan from the federation. Commercial banks also lend directly to the SHGs.

There are two types of procurement methods for agricultural produce prevailing in Rajasthan. The mandi or the local agricultural marketplace, where companies buy produce *via* agents (Aaratiya) and the local traders (Vyapaarees) is one. The markets are run under the Rajasthan Agricultural Produce Market Committee (APMC) Act with Mandi officials monitoring the activities and ensuring timely same-day payments to the farmers. The other mode is procurement through collection centres licensed under the Rajasthan APMC Act where companies can buy directly from the farmers.

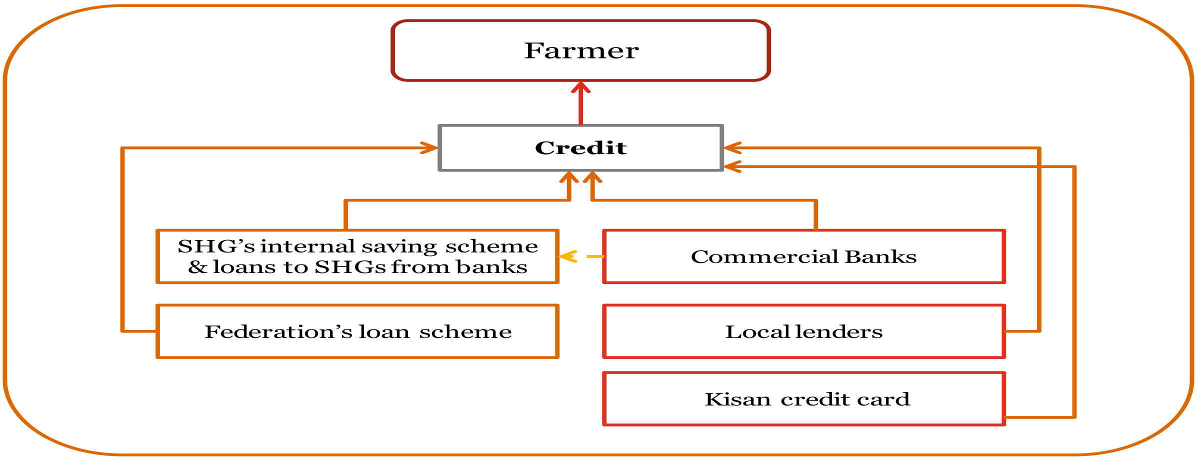


Fig. 3. Sources of credit available to the farmer Market

Till 2011, programme also focused on strengthening the soybean value chain for its farmers and so it was decided to open up collection centres near the farms for providing a ready market for farmers. With support from Bunge, 3 collection centres were started. A licensed agent runs the centre for Bunge and is compensated directly by Bunge. Bunge also commits to buy the entire produce which meets the required quality standards at the centre. For these centres, Bunge provides daily rate of soybean to SRIJAN and this message transferred to local community through network of service providers. These service providers test the soybean quality at the door steps of farmers and quoted rate of soybean according to quality. Interested farmers sell their soybean through these centres and get cash on the same day. The objectives of setting up these centres are as follows.

- Providing fair prices based on objective and scientifically determined quality tests as different from the traditional practice wherein the aaritiya uses his judgement to determine quality and the farmer cannot question this.
- Procure good quality and quantity of soybean for Bunge.
- Reducing transportation costs, time and leakages associated with transferring the produce first to the mandi and then to Bunge's plant. The collection centres located near the farms directly send the produce to Bunge's plant.

In the Bundi district, the demand for soybean is high. The local markets (mandis) are not dominated by one buyer but by several large ones (ITC, Bunge, Ruchi Soya, ADM, Adani), who procure mostly through the mandi or through local agents.

The programme structure has been summarized in fig 4.

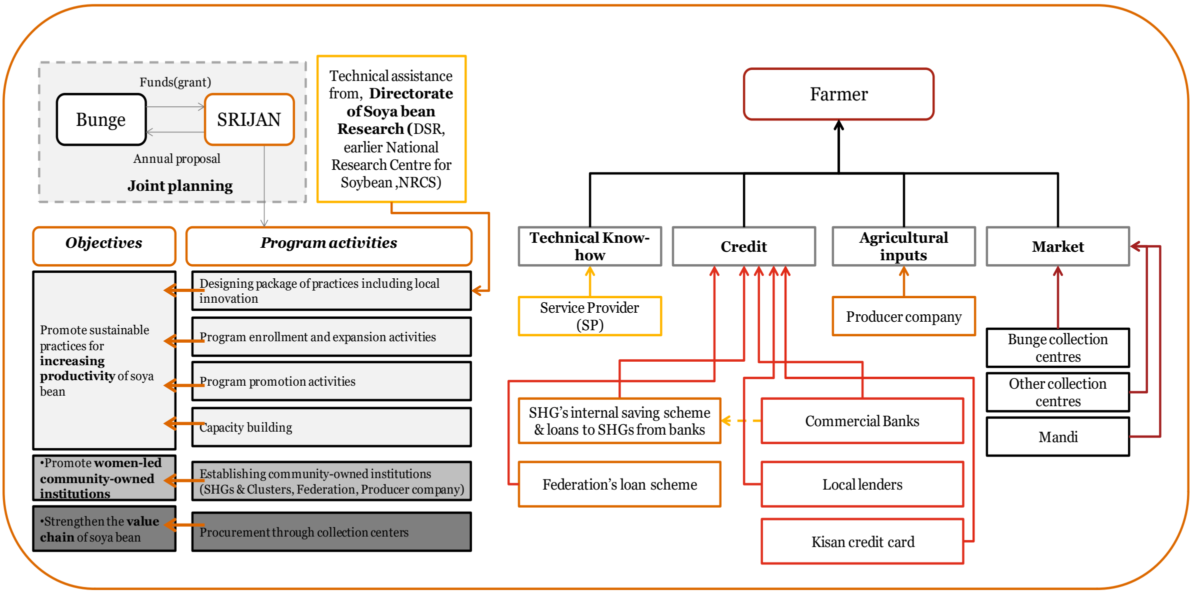


Fig. 4. Programme structure

Other programmes

Besides the "Soya Samriddhi" programme, to have a round the year interaction with the farmers, SRIJAN has started getting involved with mustard and wheat farmers and is also experimenting with low cost chemical free natural farming for wheat. This ensures continuity in terms of SRIJAN's relationship with the farmers.

Bundi district can be divided into two types of land: irrigated or command area (irrigated by the canal) and non-irrigated or non-command area. Farmers mainly produce one crop in a year either soybean or mustard on the non-irrigated land. To address the issue of irrigation, SRIJAN assisting farmers in applying for the government funded subsidy scheme for construction of farm ponds.

RESULTS AND DISCUSSION

Adoption of package of practices and yield comparison

.

Starting from merely 50 farmers in 2008, more than fifteen thousand farmers were covered under the "Soya Samriddhi" program by 2013. By following activities recommended in the package of practices, project beneficiaries reaped average yield of 1,230 kg per ha , which is 28 per cent more than the district average. These farmers realized net average profit of Rs 25,280/ha, which is 53 per cent more than the district average. The lower productivity in 2013 was on account of excessive rains.

SRIJAN team conducted a small study regarding understanding effectiveness of our program promotion strategy and farmer behaviour regarding adoption of different packages with randomly selected 188 project farmers. Result of this study is provided lots of insights to improve the program. Main highlights of this study area as follow

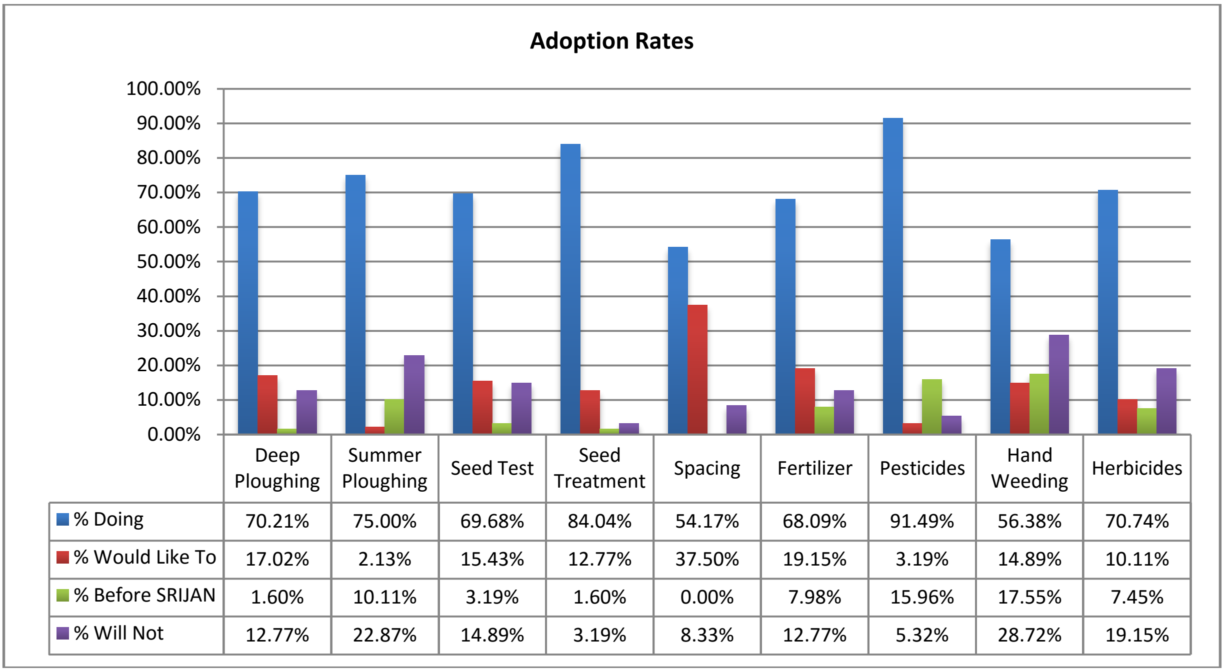
Table 1. Impect of adoption of practices and yield comparisons (2008-2013)

	Year 2008	Year 2009	Year 2010	Year 2011	Year 2012	Year 2013
Farmers (No)	50	678	3000	7000	12188	15300
Geographical spreads (Villages/Blocks/Districts)	5/1/1	40/1/1	87/3/1	140/3/1	240/3/1	252/5/2
Productivity (kg /ha)	1304	1289	1830	1874	1623	1230
District Productivity (kg/ha)	705	873	1107	1394	124 0	9560
Adoption Rate of selected practices						
Spacing (%)	6	30	45	65	66	62
Fertilizer (%)	80	35	44	49	33	68
Seed treatment (%)	100	80	77	86	78	84
Women soy/women in SHGs	0	250	750	1336	2430	3,100

Adoption rates: There is a strong indication that after SRIJAN's intervention, adoption of major practise is on increase and farmers would like to adopt the suggested package, but still there are lots of impediments that stop them from adopting, for example in case of spacing , if tractor owner do not agree to adjust seed drill , a farmer is unable to maintain recommended spacing (Fig. 5).

After our intervention yield of soybean increased, but at the same time application of pesticides also increased many folds. This is also a big concern for us. To minimize the chemical pesticide we promoted lots of integrated pest management activities with our project farmers successfully (Fig. 6).

Effectiveness of extension method: SRIJAN used variety of extension method and strategy to ensure adoption of package of practices. In this section we describe that which extension method was community preferred. Community need direct interaction with extension worker (SRIJAN Professional and its service providers). Wall painting and pamphlet distribution was seen ineffective as most of the farmers are illiterate. Apart from the SRIJAN team, farmer preferred Kisan Mela (Farmer fare) and mobile van program because in both the cases we engage professionals or service providers to guide the farmers (Fig. 7).



	Deep Ploughing	Summer Ploughing	Seed Test	Seed Treatment	Spacing	Fertilizer	Pesticides	Hand Weeding	Herbicides
% Doing	70.21%	75.00%	69.68%	84.04%	54.17%	68.09%	91.49%	56.38%	70.74%
% Would Like To	17.02%	2.13%	15.43%	12.77%	37.50%	19.15%	3.19%	14.89%	10.11%
% Before SRIJAN	1.60%	10.11%	3.19%	1.60%	0.00%	7.98%	15.96%	17.55%	7.45%
% Will Not	12.77%	22.87%	14.89%	3.19%	8.33%	12.77%	5.32%	28.72%	19.15%

Fig. 5. Adoption rates of improved practices

Credit linkage: Under the program, 426 SHGs (covering 4,222 women) have been promoted so far. These SHGs are grouped in 28 clusters which are further federated in a women's federation Samridhhi Mahila Mandal Trust (SMMT). These institutions are responsible for arranging credit, agri-inputs and farm implements for their members.

Apart from internal lending of Rs 31.1 million, in this year SHG members took loan of Rs 17.5 million from Banks, which was used by 2,022 women to purchase agri-inputs.

Input arrangement and marketing of soybean: In 2011, SRIJAN registered Samriddhi Mahila Crop Producer Company Ltd. Producer Company is purchasing quality inputs and providing it to its members on timely basis at a fair price. Producer company also arranged collective marketing of produce, *i.e.* soybean with Bunge. In this arrangement farmers got advance rates, premium for good quality, cash payment, fair weighing and increased prices by Rs 20-30 per 100 kg as compared to local rates. As collection centre is near to villages so farmer also save transportation cost and time. Producer Company's services are affecting local black-marketing of agri inputs and profit margin of local traders. These women mobilized farmers to sell their produce collectively at the three soy collection centres jointly operated by Bunge and Producer Company in project area. Till date, 4,000 tonnes of soybean seed was sold to Bunge through these centres. In 2013, producer company provided quality inputs worth Rs 7 million to producers at reasonable price.

To reduce the distress sell, this year company did a pilot of direct funding on farmer's stock with 78 farmers under warehousing receipt financing model. We did

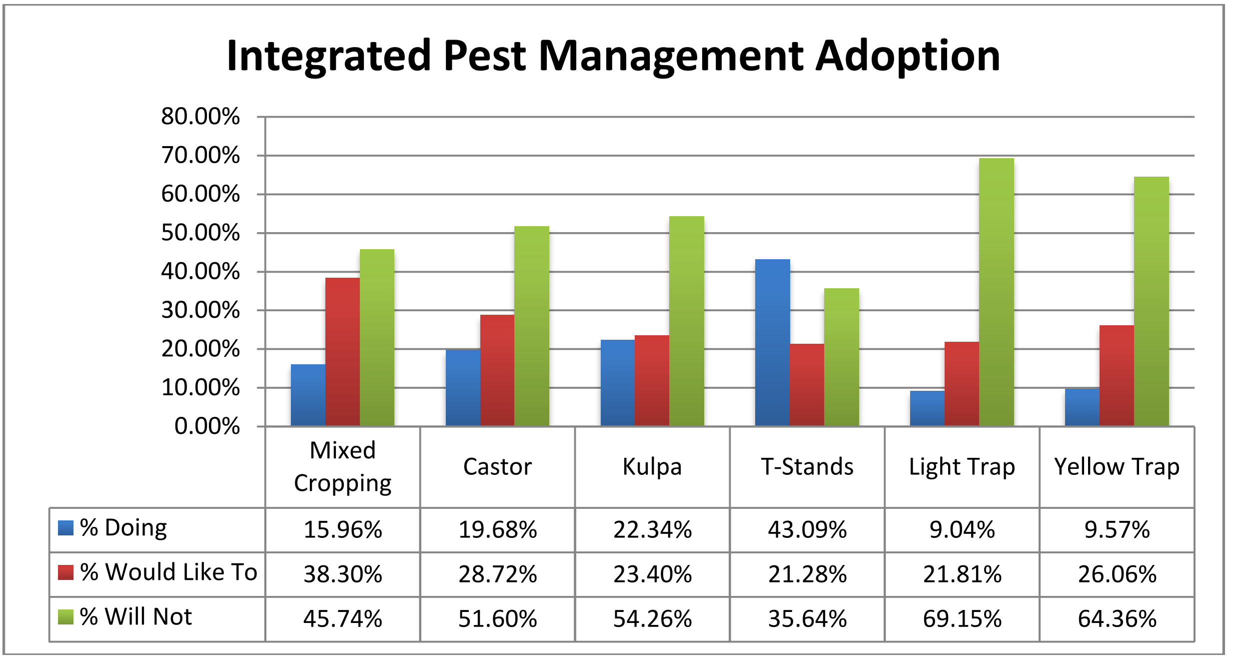


Fig. 6. Adoption rates of integrated pest management

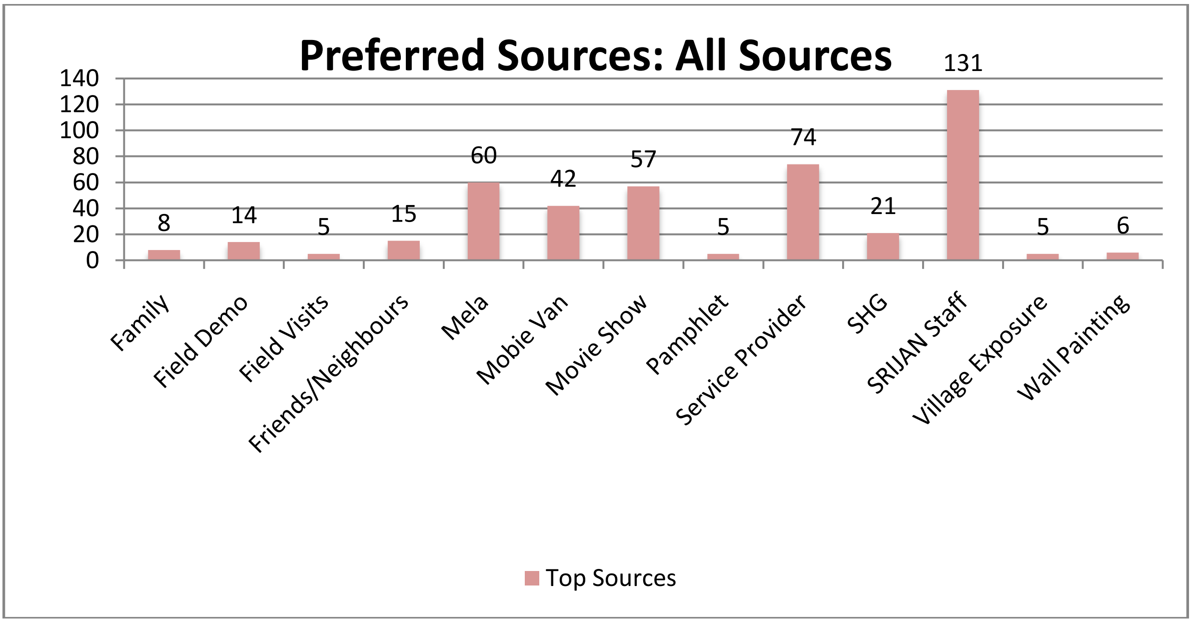


Fig. 7. Effectiveness of extension methods

partnership with ICICI Bank, Arya Collaterals and Bunge for this pilot. These farmers stocked 496 bags (90 kg each) at warehouse and ICICI bank provided credit of 60 per cent value of produce. We gave daily prices to farmers with option to sale at anytime to Bunge at competitive price. Apart from this producer company also stocked 700 bags in warehouse and got credit from ICICI bank against stock.

Developing community resource persons: Apart from this, we developed a social capital in the community in a form of cadre of 88 rural youth (service providers) and 50 master farmers as awareness creation only was not enough there were also requirement of follow-up for implementation of package of practices. One service provider offered serves to 200-250 farmers and he/she got payments on task basis. Master farmers motivate other farmers voluntarily regarding adoption of these technologies/practices on their fields. We are also constantly working on their capacity building and updating them with information and new technologies.

Ripple Effect: Roots of the "Soya Samriddhi" program are spreading fast. Farmers have realized importance of following scientific ways of farming. Farmers are spreading importance of our initiatives to their relatives in other villages. After seeing results of following the package of practices recommended for Soya by SRIJAN, farmers were eager to get similar help in wheat as well as other field crops. In most of villages they reduced seed rate and started maintaining spacing in other crops, like coriander, *Methi* (fenugreek), urdgram , wheat and mustard.

Since Bunge-SRIJAN partnership is geared towards development objectives along with business needs. So program gives value proposition to Bunge to get continuous supply of quality soybean to their factory gate at reduce transportation cost as well as maintaining good relationship with community. Same time program also helped woman farmers to empower them through knowledge on sustainable farming, increase decision making at house hold level and increase income through better farm productivity and proper market linkage. SRIJAN and Bunge have a vision to replicate this program with one 1,00,000 small and marginal farmers by 2020. SRIJAN investing in capacity building of local community regarding improved package of practices, credit and market linkages so that in long run SRIJAN promoted community institutions (SHG federation and Producer Company) will carry forward the program activities after SRIJAN exit from project area.

REFERENCE

SOPA. 2013. Second estimate of crop survey: Kharif 2013 (www.sopa.org).Soy Stats. 2013. (http://soystats.com/wp-content/uploads/ASA_SoyStats_fnl.pdf).

Soybean Research (Special Issue Number 2): 293-297: 2014

Evaluation of Soybean Varieties at High Plant Density in West Madhya Pradesh

S R RAMGIRY[1*], D K RAIDAS[2*], R KHAHANDWE[3*], K TSUJI[4**] and S KOBAYASHI[5],***

[*]RAK College of Agriculture, Rajmata Vijayaraje Scindia Agriculture University (RVSKVV), Sehore 460 601, M P, India, [**]Japan International Cooperation Agency (JICA), College of Agriculture Indore, 452 001, M P, India, [***]National Agriculture and Food Research Organization (NARO), Tsukuba 3058517, Ibaraki, Japan

E mail: sr.ramgiry57@gmail.com

Key words: High plant density, stability, soybean varieties, yield components

Higher yield of soybean over different growing environments is more important than high yield in small specific growing condition for obtaining sustainable productivity as a rainfed crop. Soybean cultivation in Madhya Pradesh with excess seed rate results in an extremely higher plant density than those recommended by local authorities and scientists (Rajpoot and Shrivastav, 1999; Thakur and Vyas, 2005). The high plant density causes yield losses through sterility, pod drop, and poor pod filling. Hence, an option is to select soybean cultivars or genotypes that maintain certain yield level at high plant density by avoiding the yield losses.

A field experiment was carried out in the research farm of RAK College of Agriculture Sehore, Madhya Pradesh with financial and technical assistance by Japan International Cooperation Agency. Twenty five genotypes/varieties were grown under two environments namely, normal and high plant density during *kharif* 2012. All the treatments were replicated thrice in a randomized complete block design. Each genotype was sown in four rows 45 cm apart with 2 m-row length. Different plant growth, maturity and physiological observations were recorded on five randomly selected plants from each treatment. Chlorophyll content was determined by using Minoltas SPAD 502 Chlorophyll meter. The sap of roots system was measured by cutting of plant at blooming stage above six inches of ground level, then wrapped with cotton and tighten with rubber band followed by removal of cotton and recording weight after 24 h and finally recorded ascent in mg. The photosynthesis rate was measured in micro mole CO_2 per m^2 per sec basis. The mean data were statistically analyzed as per procedure outlined by Panse and Sukhatme (1957). Similarly stability parameters like regression coefficient (b) and deviation from regression (s^2d) were estimated as per method given by Eberhart and Russell, (1966).

The interaction between variety and high plant density exerted significant impact on for different traits namely plant height,

[1]*Principal Scientist;* [2]*Scientist;* [3]*Senior Scientist;* [4]*Expert (JICA);* [5]*Chief co-ordinator (JICA)*

chlorophyll content, sap of root, nodules dry weight, branches per plant, seeds per pod, 100 seed weight, biological yield and yield (kg/ha). While nodules dry weight, nodules number and ascent of sap per plant exhibited non-significant effect (Table 1).

Different characters under present investigation revealed that plant height showed an increasing trend under high plant density as compared to normal plant density. The variety JS 93-05, JS 20-59 and RVS 2007-4 gave maximum chlorophyll content under both the environments. The average root weight recorded was higher at normal plant density (3.08 g) as compared to high density (1.56 g). The variety JS 20-86 followed by JS 20-53 and JS 20-59 recorded more sap of roots at normal plant density while RVS 2007-4 and RVS 2007-6 showed higher sap of roots at high plant density. Regarding nodulation activities, nodule number and dry weight showed non-significant differences between the two environments, though the variety RVS 2007-2, RVS 2007-5 and JS 97-52 exhibited high dry nodule weight under both the environments. Other yield traits *viz*., branches per plant and pods per plant showed significant differences between the two densities, and the variety JS 20-86, JS 20-71, JS 97 52 and RVS 2007-6 gave high magnitude at both normal and high plant density.

Similarly number of seeds per pod were maximum in RVS 2007-4 (3.22) and JS 93-05(3.00), seed index was found high in JS 95-60 (12.83 g) followed by RVS 2007-5 (12.67 g). The root efficiency in the form of ascent of sap was found non-significant. However, it was higher in normal than high plant density and variety JS 20-50, NRC 37 were found better. Likewise varieties JS 335, JS 20-69 and JS 97-52 were found superior in terms of biological yield and harvest index attributes. The mean yield kg per hectare showed (1,317) in normal density and (1,102) under high plant density. The variety namely JS 20-50, JS 97-52, RVS 2001-4 and RVS 2007-3 gave consistently higher yield in both densities. These results are in close harmony with Jaffery *et al.* (2005), Taware *et al.* (1999) and Parmar and Ramgiry (2012).

Stability parameters *viz*, mean seed yield, regression coefficient and deviation from regression over environments revealed that varieties RVS 2001-4, JS 335, Bragg, JS 97-52, JS 95-60 and genotype namely, JS 20-50 and RVS 2007-3 were found to posses tolerant capacity considering many yield contributing traits together (Table 2). Similar results were reported by Hassen *et al*. (2001) and Jaffery *et al*. (2005). Seed yield coupled with its contributing traits considering as the primary traits of economic value used as selection criteria in breeding programme for crop improvement. The classification of variety and genotype used in the present investigation based on the minimum deviation over both the environments were estimated as per procedure given by Eberhart and Rusell, (1966). In the present investigation considering major yield traits, it was revealed that variety namely JS 95-60, JS 97-52, JS 335 and RVS 2001-4 gave consistent performance. Similarly genotypes namely, RVS 2007-3, JS 20-50 and JS 20-71 were identified as stable ones from present finding. Since these varieties and genotypes exhibited high mean seed yield and unit regression coefficient near to one and deviation from regression as small possible. Therefore, high quality seed of these above varieties and genotypes needs to be properly produced and distributed to the farmer's community to overcome the yield losses due to over seed rate.

Table 1. Growth flowering and yield traits over environments in soybean

Variety	Environments	Plant height (cm)	Chlorophyll content (%)	Sap of Roots (g)	Nodules (No/ plant)	Dry weight of nodules (mg/plant)	Branches (No/ plant)	Pods (No/ Plant)	Seeds (No/ Pod)	100 seed weight (g)	Ascent of sap (%)	Biological yield (kg/plot)	Harvest index (%)	Seed yield (kg/ha)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RVS 2007-1	Control	48	37.64	2.03	39.89	20	4.33	36.33	2.67	9.50	37.51	1.08	50.27	1360
	HPP	63	40.89	1.15	37.22	21	4.67	35.67	2.78	10.00	31.4	1.01	45.26	1099
RVS 2007-2	Control	63	35.00	2.42	57.67	56	4.11	28.11	2.78	11.33	35.7	1.28	41.97	1190
	HPP	63	36.87	1.20	44.00	48	2.78	23.67	2.56	11.67	27.13	1.15	34.37	1049
RVS 2007-3	Control	62	43.28	2.59	49.89	23	4.00	26.33	2.67	12.33	34.83	1.20	52.44	1820
	HPP	69	41.29	1.35	45.33	38	3.78	22.78	2.67	12.33	30.84	1.38	29	1111
RVS 2007-4	Control	62	43.97	2.51	54.89	44	4.67	36.44	3.22	8.83	20.05	1.29	30.77	1170
	HPP	65	42.42	1.99	48.44	37	3.78	27.56	2.67	9.33	20.03	0.98	39.13	978.0
RVS 2007-5	Control	57	35.48	2.28	67.11	63	3.00	20.11	2.67	12.67	25.77	0.97	38.95	1010
	HPP	58	35.51	1.25	56.78	61	2.67	16.78	2.44	12.50	25.53	1.07	33.57	976.0
RVS 2007-6	Control	56	37.51	3.42	56.22	45	3.11	43.56	2.44	9.00	22.74	1.63	28.12	1410
	HPP	67	38.00	2.10	50.78	53	3.78	22.78	2.67	9.83	20.46	1.77	23.75	1160
RVS 2007-7	Control	60	40.62	3.35	69.89	20	3.67	32.33	2.56	11.33	31.14	1.00	38.69	1410
	HPP	58	35.08	1.14	57.33	27	3.78	31.33	2.56	10.83	29.68	1.17	33.71	931.0
JS95-60	Control	64	43.20	2.85	56.56	24	3.33	27.11	2.89	12.83	25.80	0.95	47.03	1420
	HPP	58	40.67	1.39	55.89	28	3.00	25.22	2.78	12.83	20.00	1.17	35.98	1180
JS93-05	Control	64	43.77	1.89	48.89	26	3.67	22.22	3.00	10.50	31.33	1.01	56.63	1380
	HPP	61	41.31	1.48	45.22	30	4.44	21.22	2.67	11.00	23.32	1.12	39.11	1179
JS335	Control	55	40.07	2.42	43.33	44	4.22	31.33	2.67	10.50	28.35	0.84	69.35	1420
	HPP	61	43.18	1.21	42.67	36	4.78	29.33	2.78	11.67	26.28	1.00	45.52	1377
JS97-52	Control	52	39.14	3.67	62.67	54	4.67	37.11	2.22	7.00	30.4	1.40	37.72	1560
	HPP	68	42.83	1.42	57.89	33	5.67	32.00	2.56	7.50	27.67	1.71	30.37	1119
BREGG	Control	59	37.12	3.44	63.89	44	4.56	40.00	2.67	8.50	26.33	1.44	32.39	1380
	HPP	68	35.16	1.65	45.33	32	4.78	32.67	2.67	9.17	21.62	1.19	35.51	1114
NRC37	Control	63	36.78	4.71	44.44	46	5.33	38.11	2.56	8.50	46.26	1.01	46.79	1290
	HPP	66	38.43	1.77	42.11	40	4.56	30.00	2.56	9.33	32.32	1.33	34.26	1231

Table 1 contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RVS 2001-4	Control	58	40.87	3.21	61.89	48	4.33	38.78	2.56	10.33	29.94	1.37	45.87	1520
	HPP	60	36.44	1.28	52.33	41	3.11	28.89	2.67	10.50	26.37	1.23	43.75	1510
JS20-50	Control	57	38.21	3.49	51.22	48	4.78	32.33	2.44	9.67	45.99	1.17	53.25	1640
	HPP	67	38.96	1.36	49.44	34	3.89	22.22	2.67	9.00	32.53	1.60	30.35	1338
JS20-53	Control	55	37.48	5.39	48.00	46	4.00	34.67	2.67	10.17	27.08	1.17	36.30	1090
	HPP	66	41.9	1.25	46.22	30	3.20	30.78	2.67	10.67	18.74	1.25	31.03	998.0
JS20-59	Control	52	44.46	5.26	65.33	52	4.56	31.56	2.56	8.33	23.92	1.09	34.72	1270
	HPP	62	38.36	1.69	51.33	24	3.67	24.78	2.78	8.83	17.88	1.19	38.50	1183
JS20-69	Control	51	38.91	2.31	67.33	38	4.67	33.33	2.33	9.00	25.56	0.85	65.70	1280
	HPP	68	35.58	1.38	66.00	37	3.11	28.33	2.56	9.67	25.67	1.23	30.92	1104
JS20-71	Control	57	38.5	0.96	66.78	41	6.33	43.44	2.44	8.00	27.74	1.60	30.75	1410
	HPP	62	42.49	1.38	37.67	36	2.67	29.56	2.67	8.00	25.63	1.35	36.36	1350
JS20-73	Control	50	39.64	2.28	66.22	46	4.22	29.89	2.78	9.67	41.95	0.87	46.19	1130
	HPP	69	41.61	1.25	62.67	39	3.44	21.33	2.56	9.50	34.75	1.37	27.31	917.0
JS20-79	Control	50	40.96	2.35	63.44	43	5.33	47.44	2.56	7.33	34.14	1.09	53.49	1410
	HPP	68	39.49	1.84	56.67	27	4.00	27.00	2.44	8.67	19.08	1.27	44.38	1096
JS20-80	Control	56	41.47	2.39	50.44	26	3.56	32.89	2.67	9.33	24.85	0.82	45.39	1060
	HPP	65	40.14	1.94	47.89	39	3.44	28.22	2.67	11.17	20.58	0.85	40.84	964.0
JS20-86	Control	52	42.17	5.46	40.56	29	6.67	39.22	2.67	8.67	28.75	0.84	48.16	1230
	HPP	73	43.16	1.64	37.89	35	4.22	36.11	2.67	9.00	28.71	1.28	32.13	1057
JS20-87	Control	49	40.62	1.78	45.00	21	5.12	32.00	2.44	7.67	37.71	1.30	42.65	1360
	HPP	64	42.07	1.62	34.89	56	4.89	29.22	2.56	7.50	28.69	1.58	22.27	974.0
Control	Mean	56	39.47	3.08	56.05	39	4.41	33.74	2.61	9.69	31.49	1.12	44.34	1317
HPP		64	40.2	1.56	48.63	37	3.88	27.18	2.65	10.11	25.7	1.25	34.38	1102
Control	**C D (P = 0. 05)**	**10**	**3.17**	**0.47**	**NS**	**77**	**1.44**	**11.27**	**0.38**	**1.31**	**NS**	**0.31**	**14.22**	**1553**
HPP		**NS**	**3.62**	**0.25**	**NS**	**07**	**1.19**	**NS**	**NS**	**1.23**	**NS**	**0.36**	**12**	**1337**
Control	C V %	11	4.78	9.26	21.4	11.75	19.46	19.91	8.83	9.09	10.3	16.97	18.9	1930
HPP		9.02	5.36	9.88	21.51	11.82	18.03	19.98	6.91	7.25	14.3	17.5	20.3	1630

HPP- High plant population

Table 2. Frequency distribution for major yield traits and stability parameters

Genotypes	Stability parameters			Genotypes	Stability parameters		
	Mean seed yield over environments (kg/ha)	Regression coefficient (b)	Deviation from regression (S^2d)		Mean seed yield over environments (kg/ha)	Regression coefficient (b)	Deviation from regression (S^2d)
RVS 2007-1	1295.5	0.87	-0.13	NRC 7	636.5	1.43	-0.12
RVS 2007-2	1119.5	2.02	-0.16	RVS 2001-4	1515.0	1.05	0.08
RVS 2007-3	1465.5	1.11	0.07	JS 20-50	1514.0	1.01	-0.02
RVS 2007-4	1074.0	1.42	-0.02	JS 20-53	1044.0	2.20	-0.05
RVS 2007-5	993.0	1.01	-0.11	JS 20-59	1226.5	1.22	-0.12
RVS 2007-6	1285.0	1.21	-0.08	JS 20-69	1192.0	1.33	0.09
RVS 2007-7	1170.5	1.25	0.22	JS 20-71	1380.0	1.15	0.05
JS 95-60	1300.0	1.02	0.03	JS 20-73	1023.5	1.11	0.06
JS 93-05	1279.5	0.69	-0.09	JS 20-79	1253.0	1.60	-0.08
JS 335	1398.5	0.74	0.08	JS 20-80	1012.0	2.00	-0.31
JS 97-52	1339.5	0.94	0. 09	JS 20-86	1143.5	1.30	-0.12
BRAGG	1447.0	1.11	0.03	JS 20-87	1167.0	0.88	-0.01
NRC 37	1260.5	2.00	0.17				

REFERENCES

Eberhart S A and Russell W A. 1966. Stability parameters for comparing varieties. *Crop Science* **6**: 36-40.

Hassen M Z, Al-assity K A and Sharaf A E. 2001. Evaluation of some soybean cultivars at various plant population densities on new redaimed land of East and Qwait Arab University. *Journal of Agricultural Sciences* **9**: 615-22.

Jaffery Edward T, Larry C Purcell and Douglas E Karcher. 2005. Soybean yield and biomass response to increasing plant population among diverse maturity groups. *Crop Science* **45**: 1778-85.

Rajput R L and Shrivastav U K. 1999. Influence of variety sowing dates and seed rate on physiological parameter and yield of soybean. *Legume Research* **22**: 117-20.

Thakur B S and Vyas M D. 2005. Relative performance of soybean varieties under varying plant population and new spacing. *M Sc(Ag) Thesis*, JNKVV, Jabalpur, Madhya Pradesh.

Taware S P, Halvankar G B and Rant V M. 1999. Stability analysis of soybean varieties under different plant density growing condition. *Soybean Abstract* **22**: 22.

Panse V G and Sukhatme P V. 1978. *Statistical Methods for Agricultural Workers*, Indian council of Agricultural Research, New Delhi, Pp 186.

Parmar D and Ramgiry S R. 2012. Stability analysis for growth and yield traits in soybean (*Glycine max* L. Merrill) *Soybean Research* **10**: 18-22.

Soybean Research (Special Issue Number 2): 298-300: 2014

Integrated Nutrient Management in Soybean

S U PAWAR[1], V B AWASARMAL[2], R A KOLGANE[3], G D GADADE[4] and D N GOKHALE[5]
Department of Agronomy, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani 431 403, Maharashtra, India
E mail: pawarsu7@rediffmail.com

Key words: Integrated nutrient management, soybean

Soybean is finding its place in policy agenda of industrial, medicinal and food sector of India due to wide spectrum of its chemical composition. The dry seed of soybean is rich source of phosphorus, potassium, sulphur, iron and vitamin A, B, D and oil in unsaturated fatty acid with the anti-cholesterol principle. Its sprouts contain appreciable amount of vitamin C, which is generally obtained from fresh fruits and vegetables. Therefore, soybean is frequently referred as poor man's meat to vegetarians due to its high protein content (Singh *et al.* 2005).

The legumes are known to increase the soil fertility particularly the soil nitrogen and consequently enhance the soil productivity of succeeding cereal crop (Nelson, 1989). Adequate fertilization is a must to increase the soybean productivity.

Integrated fertility manage-ment using chemical fertilizer and bio-fertilizers along with manures will facilitate restoration, enhancement and maintenance of soil productivity at high level which in turn will ensure profitable and intensive agriculture (Kumaraswamy, 2003). Application of organic manures alone sustain the fertility of soil but are unable to fulfill the increasing food demands of growing population, whereas, application of chemical fertilizers alone helps to get higher yields but they cannot sustain the fertility of soil on a long-term basis. Fertilizer use efficiency is also low in all chemical fertilizers and organic manures when used separately or alone. In light of above, this trial was conducted with an objective to work out the effect of integrated nutrient management on growth and yield of soybean crop and to study the economics of integrated nutrient management in soybean.

The field experiment was conducted during *kharif* 2011 at the Experimental Farm, Department of Agronomy, College of Agriculture, Parbhani. The average annual precipitation is 900 mm with 70 rainy days. The present experiment was laid out in randomized block design with seven treatments replicated three times. The treatments were recommended dose of fertilizers (RDF), 50 per cent RDF + Rhizobium + phosphorus solubilising bacteria (PSB) + sulphur @ 25 kg per ha + FYM @ 5 t per ha, 75 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + FYM @ 5 t per ha, 100 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + FYM @ 5 t per ha, 50 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + vermicompost @ 3 t per ha, 75

[1,2and4]Assistant Professor; [3]PG Student; [5]Head, Department of Agronomy

per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + vermicompost @ 3 t per ha, 100 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + vermicompost @ 3 t per ha. The soybean variety MAUS 71 was sown on 10th July, 2011 at crop geometry of 45 cm x 05 cm. The gross and net plot size was 5.4 m x 4.5 m and 4.5 m x 3.6 m, respectively. The recommended plant protection measures were followed.

Application of 100 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + vermicompost @ 3 t per ha to soybean crop produced significantly highest seed yield (2,806 kg/ha) which was found at par with the application of 100 per cent RDF + Rhizobium + PSB + sulphur @ 25kg per ha + FYM @ 5 t per ha and significantly superior over rest of the treatments (Table 1). Higher yield with combined application of 100 per cent RDF and vermicompost or FYM along with biofertilizer might have attributed due to sustained nutrients supply and better utilization through improved micro-environmental conditions. Similar finding reported by Kumar *et al.* (2006) and Shinde *et al.* (2009)

Application of 100 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + vermicompost @ 3 t per ha recorded maximum straw yield (3,874 kg/ha), which was significantly superior over rest of the treatments but was found at par with the treatment 100 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + FYM @ 5 t per ha. This might be due to enhanced growth attributes. The results were in confirmation with Shinde *et al.* (2009).

Table 1. Seed, straw and biological yields and Harvest index of soybean as influenced by different treatments

Treatment	Yield (kg/ha)			Harvest Index
	Seed	Straw	Biolo-gical	
RDF	2260	3210	5470	41.01
50 % RDF + Rhizobium + PSB + sulphur @ 25 kg/ha + FYM @ 5t/ha	1945	2702	4647	41.81
75% RDF + Rhizobium+ PSB + sulphur @ 25 kg/ha + FYM @ 5 t/ha	2238	3184	5422	40.66
100 % RDF + Rhizobium + PSB + sulphur @ 25 kg/ha + FYM @ 5 t/ha	2786	3855	6641	43.00
50 % RDF + Rhizobium + PSB + sulphur @ 25 kg/ha + vermicompost @ 3 t/ha	2164	2888	5052	42.84
75 % RDF + Rhizobium + PSB + sulphur @ 25 kg/ha + vermicompost @ 3 t/ha	2450	3383	5833	41.53
100 % RDF + Rhizobium + PSB + sulphur @ 25kg/ha + vermicompost @ 3 t/ha	2806	3874	6680	42.00
SEm (±)	71.12	66.28	131.61	-
C D (P = 0.05)	**219.18**	**204.27**	**405.59**	**-**

The data on biological yield revealed that application of 100 per cent RDF + Rhizobium + PSB + sulphur @ 25kg per ha + vermicompost @ 3t per ha recorded significantly higher biological yield (6,680 kg/ha) over rest of the treatments except treatment application of 100 % RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + FYM @ 5 t per ha.

Data indicated that highest harvest index was observed with application of 100 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg ha + FYM @ 5 t per ha whereas lowest was recorded with application of 75 per cent RDF + Rhizobium + PSB + sulphur @ 25 kg per ha + FYM @ 5 t per ha.

REFERENCES

Kumar Y K D, Ananda M R, Rehman H M A, Vishwanath A P and Vitthal N. 2006. Nutrient uptake, availability and yield of soybean as influenced by integrated nutrient manage-ment Environment *and Ecology* **24**(4): 1056-8.

Kumarswamy K. 2003. Eco-friendly soil productivity management for sustainable farming system. *Kisan World* **30**(7): 50-2.

Nelson W L. 1989. Determination of soybean fertility needs. *Soybean World Research Confederation* **4**: 615-20.

Shinde P S, Sankpal V Y, Jawale S M, Shaikh A A, Dalvi N D and Jadhav M B. 2009. Effect of integrated nutrient manage-ment on yield attributes and quality of soybean. *Journal of Maharashtra Agricultural Universities* **34**(1): 107-8.

Singh S R, Najar G R and Singh U. 2005. Productivity and nutrient uptake of soybean *(Glycine max)* as influenced by bio inoculants and farmyard manure under rainfed conditions. *Indian Journal of Agronomy* **52**(4): 325-9.

Soybean Research (Special Issue Number 2): 301-305: 2014

Effect of Organics on Physico-Chemical Properties of Salt Affected Soil of Purna Valley of Vidarbha Region of Maharashtra under Soybean Cultivation

***S M SHENDURSE*[1], *S N INGLE*[2], *S P NANDAPURE*[3] *and S R IMADE*[4],**

Department of Soil Science and Agricultural Chemistry, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444 104, Maharashtra, India

E mail: satishimade130884@rediffmail.com

Key words: Organics, salt affected soil, soil properties, soybean

In India, an area of about 10.1 million ha is affected due to salinity and sodicity (Sehgal and Abrol, 1994). The salinization/ sodification is a chemical deterioration mainly observed in arid and semi-arid region due to use of poor quality water for irrigation, inadequate drainage, seepage from irrigation channels and increase in level of ground water. It may also be due to geological reasoning (native salinity/sodicity) especially observed in Purna valley of Vidarbha region (Sagare *et al*., 2000). Salt affected soils in Vidarbha occur mainly in Purna valley affecting 894 villages in 16 tehsils of the region. The Purna valley, part of the Payanghat plain is an oval shaped basin comprising the districts of Amravati, Akola and Buldana of Maharashtra, India. Soybean [*Glycine max* (L.) Merrill] is a short duration legume, energy rich oil seed crop next to groundnut and mustard. Initially the origin of soybean crop is in China and it was introduced in India during 1968 from USA (Katyayan, 2005). Area of soybean in India, in general and Maharashtra, in particular is continuously increasing due to its dual utility as pulse as well as oilseed crop, besides it fetches better market price. Incorporation of organics significantly increased the productivity of soybean and proved to be better for reducing soil salinity and improving physical properties and organic matter content of salt affected Vertisols (Bharambe *et al*., 2001). Thus, organics like FYM, vermicompost, crop residues play a key role in modern agriculture for management of soil fertility and productivity of crops in sustainable manner. Keeping this view in mind the present investigation was undertaken.

A field experiment was conducted during *kharif* 2007 at Karanja Ramzanpur (Taluka Balapur, District Akola. The soil of experimental site belonged to Vertisols and was clayey in texture, strongly alkaline, low in available nitrogen (180.61 kg N/ha), medium in available phosphorus (21.2 kg P_2O_5/ha) and high in available potassium (349.57 kg K_2O/ha) content. The experiment comprised of eight treatments replicated thrice in a randomized block design with soybean (variety TAMS 38). The treatments comprised of recommended dose of fertilizers (RDF) (30:75:00:: $N:P_2O_5:K_2O$/ha), FYM @ 6 t per ha, wheat straw @ 6 t per ha, sunflower straw @ 3 t per ha, cotton stalk @ 6 t per ha, sugarcane

[1]M Sc Student; [2]Professor; [3]Ph D Student; [4]Ph D Student, Department of Agronomy, NAU, Navsari

trash @ 10 t per ha, soybean straw @ 4 t per ha and a control. The experimental plot size was 7.2 m x 5.5 m. The soybean was sown by drilling at 45 cm x 5 cm crop geometry at a depth of 5-6 cm using recommended seed rate of 75 kg per ha.

Soil samples (depth 0-30 cm) from the experimental field were collected before sowing and after harvest of soybean. The bulk density was determined by clod coating method, cation exchange capacity of soil with a flame emission spectrophotometer (Black, 1965). Saturated hydraulic conductivity by constant head method and percentage water stable aggregate of different size ranges were determined by Yoders wet sieving method (Singh, 1980). Organic carbon by Walkley and Black digestion method, available P by Olsen's method, available K by neutral N ammonium acetate method, pHs of saturated paste of soil by electrode method with Backman pH metre and electrical conductivity of saturated extract of soil (Jackson, 1967). Available N from soil was determined by alkaline permanganate method (Subbiah and Asija, 1965). The level of statistical significance to the experimental data was carried as per procedure by Gomez and Gomez (1984).

Effect on physical properties of soil

FYM and crop residues significantly decreased the bulk density, increased hydraulic conductivity and per cent water stable aggregates (> 0.25 mm) of soil over control. FYM @ 6 t per ha recorded lowest values of bulk density and higher value of saturated hydraulic conductivity followed by soybean straw @ 4 t per ha over other treatments. The per cent of water stable aggregates was found to be significantly higher in FYM @ 6 t per ha (50.82), which was found statistically non-significant with treatment comprising of soybean straw @ 4 t per ha, sugarcane trash 10 t per ha and sunflower straw @ 3 t per ha (Table 1). These results are in confirmation with Biswas (1982), Bharambe *et al*. (2001) and Bonde *et al*. (2005).

Effect on chemical properties of soil

None of the treatments could significantly influenced pH, electrical conductivity and cation exchange capacity of the soil (Table 2). Numerically lowest values of these three parameters were

Table 1. Effect of different treatments on physical properties of soil at harvest of soybean

Treatment	Bulk density (Mg/m^3)	Hydraulic conductivity (cm/h)	Water stable aggregates > 0.25 mm (%)
RDF @ 30:75:00 $NP_2O_5K_2O$ kg/ha	1.49	0.22	47.88
FYM @ 6 t/ha	1.44	0.27	50.82
Wheat straw @ 6 t/ha	1.47	0.24	48.50
Sunflower straw @ 3 t/ha	1.46	0.25	49.11
Cotton stalk @ 6 t/ha	1.48	0.23	48.25
Sugarcane trash @ 10 t/ha	1.48	0.24	49.67
Soybean straw @ 4 t/ha	1.45	0.26	50.14
Control	1.50	0.21	47.05
SEm (±)	0.015	0.014	0.62
C D (P = 0.05)	**NS**	**NS**	**1.90**
Initial value	1.52	0.14	46.17

recorded with application of FYM @ 6 t per ha followed by soybean straw @ 4 t per ha. However, the values for exchangeable sodium percentage of soil revealed maximum reduction with application of FYM @ 6 t per ha (10.19 dS/m) followed by the treatment soybean straw @ 4 t per ha (11.36 dS/m), wheat straw @ 6 t per ha (11.55 dS/m) and sunflower straw @ 3 t per ha (11.71 dS/m), which did not significantly vary with each other, but significantly superior over control. These results achieved are in conformity with the reports of Sagare *et al*. (2000), Bharambe *et al*. (2001) and Sarkar *et al*. (1988).

Table 2. Effect of different treatments on chemical properties of soil after harvest of soybean crops

Treatment	pH	Electronic conducti-vity (dS/m)	Exchange-able sodium percentage	Cation exchange capacity (Cmolp$^+$/kg)
RDF @ 30:75:00 $NP_2O_5K_2O$ kg/ha	8.44	1.74	12.92	55.3
FYM @ 6 t/ha	8.40	1.70	10.19	55.1
Wheat straw @ 6 t/ha	8.43	1.73	11.55	54.7
Sunflower straw @ 3 t/ha	8.43	1.72	11.71	54.9
Cotton stalk @ 6 t/ha	8.42	1.74	12.60	54.6
Sugarcane trash @ 10 t/ ha	8.43	1.73	12.18	54.6
Soybean straw @ 4 t/ha	8.41	1.71	11.36	55.0
Control	8.46	1.75	13.02	54.4
SEm (±)	0.013	0.012	0.27	0.31
C D (P = 0.05)	**NS**	**NS**	**0.83**	**NS**
Initial values	8.51	1.80	15.12	54.2

Effect on fertility status

Application of FYM @ 6 t per ha (5.1 g/kg) significantly enhanced the organic carbon content over other crop residue treatments (4.5 to 4.8 g/kg), RDF (4.3 g/kg) and control (4.1 g/kg) (Table 3). Other crop residue treatments did not vary significantly with each other. Similar results were also noticed by Rasal *et al* (1989) and Gaur *et al* (1979).

Recommended dose of fertilizers recorded significantly highest content of available nitrogen (227.51 kg/ha), FYM @ 6 t per ha (218.32 kg/ha) and soybean straw @ 4 t per ha (210.57 kg/ha). Remaining treatments (198.62 – 204.86 kg/ha) were on par with each other, but significantly superior over control (184.82 kg/ha).

Maximum available phosphorus was recorded with recommended dose of fertilizers (24.5 kg/ha) followed by soybean straw @ 4 t per ha (23.1 kg/ha) and FYM @ 6 t per ha (23.0 kg/ha). Control treatment showed lowest value (21.5 kg/ha) for available phosphorus. The lowest available phosphorus was noticed in control treatment (21.5 kg/ ha) without any fertilizer and crop residue. RDF treatment was significantly superior over other treatments. It may be due to incorporation of fertilizers phosphorus in

Table 3. Effect of different treatments on fertility status of soil at harvest of soybean

Treatment	Organic carbon (g/kg)	Available nutrient (kg/ha)		
		N	P_2O_5	K_2O
RDF @ 30:75:00 NPK kg/ha	4.3	227.51	24.5	366.21
FYM @ 6 t/ha	5.1	218.32	23.0	364.84
Wheat straw @ 6 t/ha	4.6	202.40	22.9	362.56
Sunflower straw @ 3 t/ha	4.7	204.86	22.6	360.17
Cotton stalk @ 6 t/ha	4.6	201.48	22.3	358.21
Sugarcane trash @ 10 t/ha	4.5	198.62	22.5	358.72
Soybean straw @ 4 t/ha	4.8	210.57	23.1	364.13
Control	4.1	184.82	21.5	353.21
SEm (±)	0.079	2.05	0.40	1.11
C D (P = 0.05)	**0.24**	**6.23**	**1.22**	**3.37**
Initial values	3.90	180.61	21.2	349.57

RDF and decomposition of organic matter accompanied by the release of appreciable quantities of carbon dioxide.

Similar to available nitrogen and phosphorus, available potassium content was higher with application of recommended dose of fertilizers (366.21 kg/ha), FYM @ 6 t per ha (364.84 kg/ha) and soybean straw @ 4 t per ha (364.13 kg/ha), which were at par, but significantly superior over other organic residue treatments (358.21 – 360.17 kg/ha) and control (353.21 kg/ha). Similar findings were reported by Bairathi *et al*. (1974) and Jadhao (2005).

REFERENCES

Bairathi R C, Gupta I M and Seth S P. 1974. Effect of different legume crop residue on soil properties, yield and nutrients uptake by succeeding wheat crop. *Journal of Indian Society of Soil Science* **22**: 304-7.

Bharambe P R, Shelke D K, Jadhav G S, Vaishnava V G and Oza S R. 2001. Management of salt affected Vertisols with sub surface drainage and crop residue incorporation under soybean-wheat cropping system. *Journal of Indian Society of Soil Science* **49**: 24-9.

Biswas T D. 1982. Management of soil physical condition for soil productivity. *Journal of Indian Society of Soil Science* **30**: 42-77.

Black C A. 1965. *Methods of Soil Analysis Part I and II, American Society of Agronomy*, Madison Wisconsin, USA.

Bonde A N, Karle B G, Deshmukh M S, Tekale K V and Patil N P. 2005. Effect of different organic residue on physico-chemical properties of soil in cotton-soybean intercropping in Vertisol. *Journal of Soil and Crops* **14**(1): 112-5.

Gaur A C and Mukherjee D. 1979. Note on effect of straw on yield of groundnut and following wheat. *Indian Journal of Agricultural Sciences* **49**(12): 984-7.

Gomez, K A and. Gomez A A. 1984. *Randomized Block Design in Statistical Procedure for Agricultural Research,* published by A Wiley Inter Science, USA, pp 621-35.

Jackson M L. 1967. *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi.

Jadhao V O. 2005. Effect of crop residue management on soil productivity, yields and water use efficiency under soybean – chickpea cropping system. *Ph D (Agri.) Thesis* (unpublished, Dr PDKV, Akola, Maharashtra, India.

Katyayan Arun. 2005. *Crop Production. Fundamentals of Agriculture*, Kushal Publication, Varanasi, pp 81.

Rasal P H, Shingte V V and Patil P L. 1989. Effect of sugarcane trash on crop yield and soil properties. *Journal of Maharashtra Agricultural Universities* **1**: 79-82.

Sagare B N, Thakre S K and Babhulkar V P. 2000. Salt affected soil of Purna valley in Vidarbha, *Research Bulletin*, Dr PDKV, Akola, Maharashtra, India.

Sarkar S S, Rathore T R, Sachan R S and Ghilghal B P. 1988. Effect of wheat straw management on cation status of Tarai soils. *Journal of Indian Society of Soil Science* **37**: 402-4.

Sehgal J L and Abrol I P. 1994. *Soil Degradation in India*, Status and Impact, Oxford and IBH Publishing Co. New Delhi.

Singh R A. 1980. *Soil Physical Analysis*, Kalyani Publishers, New Delhi, pp.52-78.

Subbaih B V and G L Asija 1965. A rapid procedure for determination of available nitrogen in soils. *Current Science* **25**: 258-60.

Soybean Research (Special Issue Number 2): 306-308: 2014

Evaluation of Phosphorus Availability to Soybean [*Glycine max* (L.) Merrill] Plants on Vertisols of Madhya Pradesh

B S DWIVEDI[1*], A K UPADHYAY[2**], N CHOUHAN[3*], B SACHIDANAD[4*], N AE[5], K TSUJI[6***] and S KOBAYASHI[7***]***

[1]Jawaharlal Nehru Agricultural University (JNKVV), Jabalpur 482 004, M P, India, [2]College of Agriculture, Tikamgarh 472 001, M P, India, [3]Japan International Cooperation Agency (JICA), College of Agriculture Indore, Indore 452 001, M P, India

E mail: bsd_75@rediffamil.com

Key words: Available P extraction method, plant dry matter, rhizosphere pH, soybean

The uptake process of phosphorus (P) by plant roots is complicated by the fact that P is an immobile element in soil, and that the P transport to roots take place by diffusion whose rate is very low (0.13 mm/day) (Marschner, 1986). Thus, plants take up available P near roots by solubilizing P bonded onto soil particles or with other elements like calcium (Ca) in "rhizosphere" and "rhizosplane". In fact, past studies clarified that some plant species secrete organic acids and amino acids to the rhizosplane, and solubilize bonded P in the rhizosphere by decreasing the soil pH to acidic levels (Kirkby, 1968, Grinsted *et al.,* 1982).

In India, the Olsen's method using a 0.5 M $NaHCO_3$ extractant at pH 8.5 (Olsen *et al.*, 1954) is *in vogue* for estimation of soil P availability, because most national soils exhibit neutral to alkaline pH. This pH level (8.5) of Olsen's method does not correspond to acidic pH in rhizosphere or rhizosplane. Furthermore, Ae *et al.* (1991) reported that available P estimates by this Olsen's method are not exactly correlated to plant dry matter production and P absorption on the Vertisol and Alfisol of India. Thus, the objectives of this study were to re-evaluate the validity of Olsen's method and to search a better soil test method, especially for soybean [*Glycine max* (L.) Merrill] grown on the Vertisols of Madhya Pradesh in India. This study was carried out in two separate experiments using soybean to confirm pH decline in rhizosphere and rhizosplane, and to analyze the correlation of plant growth with available P estimates by different test methods.

Acidification of rhizosphere

Soybean and sorghum seeds were sown in pots filled with 1 kg of Vertisol without chemical fertilizers. At 12 days after the sowing, the roots holding rhizosphere soil were taken from the pots (Fig. 1). The rhizosphere soil was further separated from the roots by shaking and gentle brushing. And, the separated roots with rhizosplane-attached soil were put into water for pH measurement. Results showed that for soybean, the pH value 7.6 in bulk soil decreased to 7.4 and 6.0 in the rhizosphere and rhizosplane soils, respectively, and that for sorghum, it likewise decreased to 7.3 and

[1]Scientist; [2]Senior Scientist; [3]Senior Research Fellow; [4]Principal Scientist; [5 and 6]JICA expert; [7]Chief Advisor JICA

6.4, respectively. A greater pH decrease in rhizosplane soil was reported on a neutral pH soil (pH 7.0), while a lesser pH decrease was observed in an alkaline soil (pH 8.40) (Ae *at al.*, 1991; Refat *et al.*, 1989).

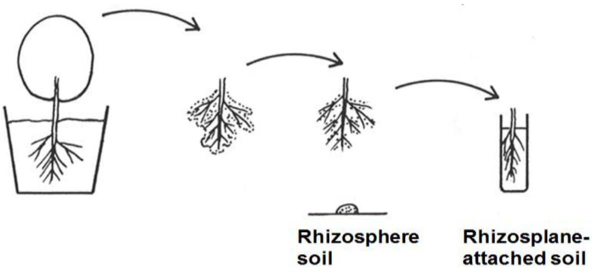


Fig. 1. Fractionation procedure of rhizosphere and rhizo-plane soils

To further confirm soil acidification by soybean roots, soybean seedlings were grown for 10 days in plastic cubes filled with sand and taken with gentle washing of roots by distilled water. And, the washed roots were placed on agar plates containing the following pH indicator: bromothymol blue (pH 7.6 blue - pH 6.0 yellow), bromocresol purple (pH 6.8 yellow - pH 5.2 purple), methyl red (pH 6.2 yellow - pH 4.4 red) and bromocresol green (pH 5.2 blue - pH 3.8 yellow). The initial pH level of agar plate was adjusted to 7.0. The soybean roots used changed the color of plates with bromothymol blue and bromocresol purple to yellow and purple, respectively, but did not exhibit visible color changes for methyl red and bromocresol green. The current results from pot and agar plate experiments implicated that soybean roots are capable to acidify the rhizoplane soil by the pH levels of 6.0 to 5.2.

Comparison of soil test methods

Another pot experiment was carried out in the 2012 rainy season in a JNKVV glass house to evaluate the validity of Olsen's method, as compared to Bray's 2 and Truog's methods using acidic extracting solutions. Pot soils were collected from 5 different locations in Jabalpur district, Madhya Pradesh on the basis of Olsen P values. The soil chemical properties and available P values are shown in table 1. The data indicated that Bray's 2 method gave the highest available-P estimates, followed by Troug's and Olsen's method. The collected 5 soils were further amended with 3 levels of P fertilizers (0, 50 and 100 mg/kg) to use for soybean planting in 3 replication and to analyze the relationships of plant dry matter yield and available P estimates. As shown in fig. 2, the greatest correlation was observed for Bray's 2 method (r^2 = 0.645, P < 0.01), followed by Truog's (r^2 = 0.524, P < 0.01) and Olsen's (r^2 = 0.335, P < 0.05).

Table 1. Chemical properties and available P of 5 soils for pot experiment

Location of soil collection	pH	EC (dS/m)	OC (g/kg)	Available P (mg/kg)		
				Olsen's	Troug's	Bray's 2
Kukrikheda	7.5	0.137	3.8	1.93	9.2	11.81
Rampura	7.2	0.173	6.1	2.45	19.4	17.65
Kendra kheda	7.2	0.443	9.2	38.45	95.2	234.14
Dumna	6.3	0.087	4.9	2.98	6.8	23.14
Suhagi	7.1	0.160	6.3	13.50	42.8	90.59
Min. - Max.	-	-	-	1.9-38.5	6.8-95.2	11.8-234.1

The current study demonstrated that soybean roots decrease the pH of rhizosphere soil to an acidic level of < pH 6.0 especially near root surface where P uptake occurs. The fresh root from the soybean grown for more than 15 days after sowing also showed acidity. Probably, the acidification is attributable to the secretion of acidic substances from roots, and is solubilizing soil- or Ca-bonding P near root surface. And, the Olsen's method using an alkaline extractant in adverse to the acidified soil probably underestimates solubilized P by roots, while, as shown in this study, the Bray's 2 using an acidic extractant has a potential to accurately estimate soil P availability. Further studies are desired to improve soil extractant for a better estimation of available P and to save P fertilizers by optimum input based on the improved method.

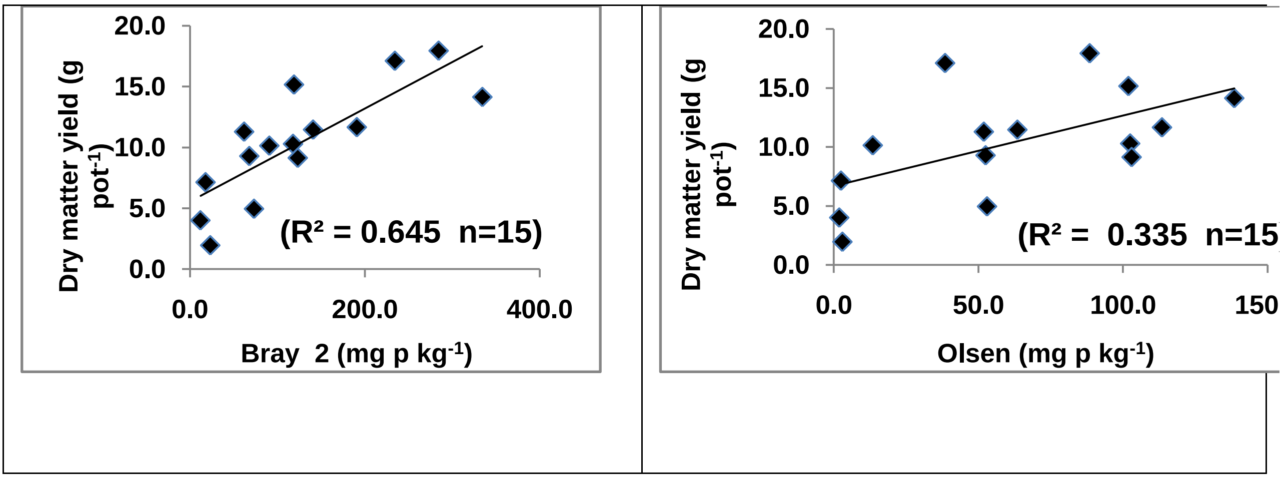


Fig. 2. Relationship between plant dry matter yield and available P estimates by (a) Bray's 2 and (b) Olsen,s methods

REFERENCES

Ae N, Arihara J and Okada K. 1991. Phosphorus response of chickpea and evaluation of phosphorus availability in Indian Alfisols and Vertisols. Pp 33-41 in ICRISAT conference paper no. CP 671. ICRISAT, *Phosphorus Nutrition of Grain Legumes in the Semi-arid* Tropics, Johansen C, Lee K K and Sahrawat, K. L. (Eds). Patancheru, A. P. 502 324, India: ICRISAT.

Grinsted M J, Hedley M J, White R E and Nye P H. 1982. Plant induced changes in the rhizosphere of rape (*Brassica napus* var. Emerals). 1. pH changes and increased in P concentration in the soil solution. *New Phytologist* **91**: 19-29

Kirkby E A. 1968. Influence of ammonium and nitrate nutrition on the cation and anion balance and nitrogen carbohydrate metabolism of wheat mustard plants grown in dilute nutrition solution. *Soil Science* **105**: 133-51.

Marschner H. 1986. *Mineral Nutrition of Higher Plant*, pp 447-77, Academic Press, London.

Olsen S R, Cole C V, Watanabe F S and Dean L A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *U. S. Department of Agriculture Circular 939*, Washington, DC, USA: U. S. Government Printing Office, Pp 19.

Refat A Youssef and Chino M. 1989. Root–induced changes in the rhizosphere of plants. *Soil Science and Plant Nutrition* **35**: 461-8.

Soybean Research (Special IssueNumber 2): 309-311: 2014

Impact of Communication Interventions on Adoption of Ridge and Furrow Sowing Method in Soybean [*Glycine max* (L.)Merrill]

SARVESH KUMAR[1] and R C SHARMA[2],
Krishi Vigyan Kendra (Jawaharlal Nehru Krishi Vishwa Vidyalaya), Harda 461 331, Madhya Pradesh, India
E mail: sarveshkvkharda@gmail.com

Key words: Communication interventions, ridge and furrow method, soybean

Soybean has come to be recognized as one of the premier agricultural crops today for various reasons. In brief, soybean is a major source of vegetable oil, protein and animal feed. Soybean, with over 40 per cent protein and 20 per cent oil, has now also been recognized world over as a potential supplementary source of edible oil and nutritious food. The protein of soybean is called a complete protein, because it supplies sufficient quantity of the essential amino acids required by the body for building and repair of tissues. Its food value in heart disease and diabetes is well known. It is significant that Chinese infants using soybean milk in place of cow's milk are practically free from rickets (Singh, 2003).

Soybean is a rich source of edible oil containing no cholesterol. Soybean oil surpasses all other oils because it is an ideal food for heart patients and those who wish to avoid heart disease. It also contains fair amount of fat-soluble vitamins beside a large amount of lecithin which is an important constituent of all organsof the human bodyespecially of the nervoustissue, the heartand liver. Soybeanis, therefore, a complete food (http: // en. wikipedia. org/wiki/ Soybean).

Being crop of rainy season, soybean requires a sound plant protectionmanagement strategy with better drainage system to optimise crop production. Keeping in mind to sort out this problem, a new method of sowing known as ridge and furrow was generalised in soybean growing areas so that there may be minimum loss in crops during heavy and continuous rains. A numbers of communication interventions were followed by Krishi Vigyan Kendra, Harda, Madhya Pradesh to boost the adoption and awareness about this method hence,it was thought important to studythe impact of communication interventions on adoption of ridge and furrow sowing method in soybean.

Present study was conducted at Krishi Vigyan Kendra, Harda, Madhya Pradesh during 2012-13. Out of three blocks (Harda, Khirkiya and Timarni), a total five villages as Lalmati, Ranhaikalan, Bafala, Alampur and Sautada were selected randomly to collect the information. A sample of 150 soybean farmers (30 from each village) through proportionate sampling method was taken. During this study, 30 farmers were made aware by literature, 30 by trainings, 30 trained by

[1]*Scientist (Agricultural Extension and Rural Sociology);* [2]*Programme Coordinator*

demonstration, 30 by training and demonstration both and last group was trained by combination of literature + training + demonstration. For the data collection, well - conceived interview schedule was developed based on important variables. Data was collected at two stages, fist before the commencement of training programmes and second immediately after completing the training programmes. The reported responses were compiled, tabulated and analyzed with statistical tools like frequency, percentage, rank and correlation coefficient.

Present study was targeted to assess the impact of adoption of ridge and furrow sowing method in soybean by the farmers using various modes of transfer of technology through Krishi Vigyan Kendra communication inter-ventions in the district.

The highest adoption of ridge and furrow sowing method in soybean was found through combination of literature + training + demonstration (Table 1) as more than three forth (77.33 %) of the farmers in this category adopted the practice soybean. The impact of combination of training and demonstration both was considerably noticeable (62.67 %), however, the impact of demonstration (48 %), trainings (45.33 %) and literature (16.67 %), when used alone were found to be comparatively less meaningful. The results of this study are in line with the findings of Sahu *et al.* (2010).

Table1. Adoption of ridge and furrow sowing method in soybean through Krishi Vigyan Kendra communication interventions in Harda, Madhya Pradesh

Communication interventions	**Respondents**	**Frequency**	**Percentage**	**Rank**
Literature	30	4	16.67	**V**
Training	30	12	45.33	**IV**
Demonstration	30	17	48	**III**
Training + demonstration	30	19	62.67	**II**
Literature + training + demonstration	30	24	77.33	**I**

As adoption is a mental process which is governed by various socio-economic, situational and personal considerations, number of other independent variables was found to have played an important role in determining adoption level of ridge and furrow sowing method in soybean. Correlation analysis at 1 per cent and 5 per cent level (Table 2) to assess the relationship between the independent variables and adoption level of soybean farmers reveals that innovativeness, education, mass media exposure, risk orientation, economic motivation, extension orientation, social interaction, decision making behaviour, self confidence and experience in soybean farming had a significant and positive relationship with adoption level at 1 per cent level, but area under soybean farming showed a significant and positive relationship with knowledge at 5 per cent level. Moreover highly educated farmers used to seek information from various agricultural information sources also like mass media (television, newsletters and extension literature, *etc.*) as well as through interaction with agricultural-experts and Krishi Vigyan Kendras. The similar results also reported by Sahu *et al.* (2007) and Jaganathan (2010).

Table 2. Relationship between the independent variables and adoption level of ridge and furrow sowing method in soybean

Profile characteristics	Correlation Co-efficient
Age	0.205*
Education	0.720**
Soybean farming experience	0.360**
Farm size	0.208*
Area under Soybean farming	0.118*
Social interaction	0.423**
Extension orientation	0.616**
Mass media exposure	0.673**
Innovativeness	0.725**
Economic motivation	0.631**
Risk orientation	0.633**
Decision making behaviour	0.420**
Self confidence	0.371**

***Significant at 1 per cent level;*Significant at 5 per cent level*

The present study reconfirmed that Krishi Vigyan Kendra's communication interventions are very effective and result oriented for transfer of technology up to ultimate users. The production levels of soybean farmers who adopted ridge and furrow method (1440 kg/ha) was observed to be more than plain sowing (1,075 kg/ha) in the study area. Out of different communication interventions for promotion of ridge and furrow method of sowing, combination of farm literature + training + demonstration, and training + demonstration, or demonstration and training alone were found to be the best methods of transfer of technology. These interventions increased the motivation level of the growers to adopt ridge and furrow sowing method in soybean, hence it is recommended that the officials or extension personnel engaged in dissemination of agricultural technologies can concentrate on these interventions to enhance the adoption of such proven technologies and innovations. Finally the study concludes that ridge and furrow sowing method of soybean is an effective method and gives better crop protection from heavy and continuous rains, with proper drainage along with intercultural operation thereby helps to achieve more production compared to normal method of sowing in soybean crop in Harda district of Madhya Pradesh.

REFERENCES

http://en.wikipedia.org/wiki/ Soybean

Jaganathan D. 2010. Knowledge level of farmers on organic farming in Tamil Nadu. *Indian Research Journal Extension Education,* **12**(3): 70-3.

Sahu R P, Prasad A, Ram D and Yadav F B. 2007.Impact of training of KVK on the productivity of wheat and knowledge of farmers. *Environment and Ecology* **25S**(4): 1449-51.

Sahu R P, Singh K.and Singh R J. 2010.Effectiveness of KVK programmes on the productivity and knowledge level of garden pea farmers. *Journal of Communication Studies,* **XXVII**: 72-5.

Singh B B. 2003.Success of soybean in India: The early challenges and pioneer promoters. http://asianagrihistory.org/vol-10/successofsoyabean.pdf, pp 1-7.

Soybean Research (Special Issue Number 2): 312-316: 2014

Effect of Maize (*Zea mays* L.) and Soybean (*Glycine max* (L.) Merrill) Intercropping on Weed Dynamics

LOWRENCE KITHAN[1] and L TONGPANG LONGKUMER[2]
Department of Agronomy, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus 797 106, Nagaland, India
E mail:tong_lkr@yahoo.co.in

Key words: Economics, intercropping, land equivalent ratio, maize, sole crops, soybean, weed dynamics

Maize (*Zea mays* L.) ranks second to wheat in world cereal production and it is the most widely grown among the major crop species. It is primarily grown throughout the temperate, tropical and sub-tropical zone and has a worldwide significance as human food; feed for livestock and for industrial and pharmaceutical sectors as well. In India, it is estimated that in the year 2009 the area, production and productivity for maize was 8.60 m ha, 22.26 mt and 2,566 kg per ha (Anonymous, 2012). In North East Hill Region the area and production and yield of maize for the year 2011-2012 under Nagaland was 5.14 thousand ha, 10.07 mt and 1951 kg per ha, respectively (Anonymous, 2012a).

Soybean (*Glycine max* (L.) Merrill) is an important and a major oilseed crop of the world. The crop covers an area of 10.84 m ha producing 14.67 m tonnes with a productivity of 1,353 kg per ha in India (Anonymous, 2012). In Nagaland, the estimated area under soybean cultivation is about 26,000 ha with a production of 36,000 metric tonnes (Anonymous, 2012a).

Crop-weed competition is one of the major constraints in the productivity of any crops and assuch it interferes in the successful crop production. In India, it was observed that weeds cause 45 per cent, insect 30 per cent, diseases 20 per cent and other pests 5 per cent loss of agricultural production (Gupta and Anmol, 1997). The critical period of crop-weed competition is the period from the time of sowing up to which the crop is to be maintained in a weed free environment to get higher yield. In maize, during the first 2-3 weeks of its emergence, weeds attain 15-18 per cent of their growth while maize attains only 2-3 per cent. (Subramanian *et al*., 1997)

Intercropping is a potential agronomic practice of growing more than one species in the same field where crop intensification is done both in time and space dimension thus increasing the total yield per ha. It is more advantageous when legume is one of the components of an intercropping system as it gives higher yield; greater land use efficiency per unit area and at the same time enhances soil fertility through fixation of atmospheric nitrogen and provides complementary benefit to the companion crop (Willey, 1979). Intercropping of legumes with cereals like maize economizes the use of nitrogen fertilizer and increases the production per unit area (Singh *et al*., 1986). For successful and profitable intercropping system, there must be proper row ratio of component crops

[1]Research Scholar; [2]Asssociate Professor

in order to avoid limitation of reduced plant population of base crop under traditional inter-cropping system (Pandey *et al*., 1999).

An experiment was conducted at the experimental farm of School of Agricultural Sciences and Rural Development Medziphema, Nagaland, during *kharif* of 2011 under rainfed condition to study the performance of maize + soybean intercropping on weed dynamics. The experimental site is located at 25^{0}45′43′′ North latitude and 93^{0}53′04′′ East longitude at an altitude of 310 metre above mean sea level. The prevailing climate represents sub-humid tropical climatic zone with high relative humidity, moderate temperature and medium to high rainfall. The mean temperature ranges from 21 ºC to 30 ºC during summer and rarely goes below 8 ºC in winter due to high atmospheric humidity. The average rainfall varies between 2,000 and 2,500 mm starting from April and ends with the month of September while the period from October to March remains completely dry. The soil of the experiment plot was categorized as sandy loam and well drained. The experiment was conducted in randomized block design with 4 replications. The seven treatments in the experiment were comprised of sole maize, sole soybean, and maize + soybean in the row ratios of 1:1, 1:2, 2:1, 2:2 and 2:3, respectively. The varieties used for maize and soybean were Dekalb All Rounder and JS 335 respectively. Fertilizer application @ 100:80:60 kg $N:P_2O_5:K_2O$ was made as per recommendation. Plant protection measures such as Malathion dust @25 kg per ha and Chlorpyriphos 20 per cent EC were applied.

Observations on weed dynamic parameters (weed flora, weed density, weed dry matter, weed index) were taken and economic evaluation of the treatments (cost of cultivation, B:C ratio, gross returns, net returns) was done in addition to working out of harvest index and land equivalent ratio). The significance of treatment differences was tested by ‘F’ test. Critical Difference (CD) means at 5 per cent probability level of significance (P = 0.05) was worked out for comparison of treatments.

Among the weed flora encountered in the field (Table 1), the major weeds identified were *Amaranthus viridis* (L.), *Leucas aspera*, *Cyperus rotundus* (L.), *Cyperus iria* (L.), *Cynodon dactylon* (L.), *Mimosa pudica* (L.), *Setaria glauca* (L.), *Borreria hispidia* (L.), *Imperata cylindrical* (L.) and *Digitaria sanguinalis* (L.). Similar weed species were also found in maize based intercropping as reported by Fanai (2000). All the treatments recorded marked variation in weed density per m^2 and highest weed number (5.82) was recorded in treatment maize + soybean (1:2) followed by 1:1 (5.52) and 2:1 (5.41) row ratios, which were at par (Table 2). While the remaining combinations showed weed density values at par. The lowest weed population was recorded in treatment maize + soybean (2:2). This may be due to available space in between the rows of crops for the weed species to grow as compared to the intercrop treatments. A similar finding was also reported by Mohandoos *et al* (2002) in maize + sunflower + black gram.

The lowest dry weight (1.13 g/m^2) of weeds was recorded with maize + soybean (2:2) and for other treatments it ranged from 1.57-4.19 g/m^2). This may be due tothe fact that the weeds were controlled effectively during the period of maximum crop weed competition *i.e.,* during the 2-6 weeks after sowing. This may be due to lesser weed population in that particular denser row arrangement of crops, limiting the growth of weeds. This is in conformity with findings of Mohandoos *et al* (2000). The highest weed index was obtained from sole soybean with

Table 1. Weed flora in the experimental field

Botanical Name	Common Name	Family
Broad Leaf Weeds		
Borreria hispidia (L.)	Pig weed	Rubiaceae
olled	Sensitive plant	Rubiaceae
Amaranthus viridis (L.)	Slender Amaranthus	Amaranthaceae
Ageratum conyzoides (L.)	Bill goat weed	Compositae
Leucas aspera	Guma	Labiatae
Oxalis corniculata (L.)	Creeping Sorrel	Oxilidaceae
Commelina bengalensis	Creeping Annual	Commelinaceae
Chromalena odorata	Siam Weed	Compositae
Sedges		
Cyprus rotundas (L.)	Nut Sedge	Cyperaceae
Cyprus iria (L.)	Rice Flat Sedge	Cyperaceae
Grasses		
Cynodon dactylon (L.)	Bermuda Grass	Poaceae
Setaria glauca (L.)	Fox Tail	Poaceae
Imperata cylindrica (L.)	Thatch Grass	Poaceae
Digetaria sanguinalis (L.)	Crab Grass	Poaceae
Eleusine indica (L.)	Goose Grass	Poaceae

49.91per cent, which indicated per cent yield advantage over sole crops (Table 2). The cost of cultivation for different treatments remained same as it did not involve application of any special input except the difference in their row ratios.

No significant differences in harvest index values were recorded in case of maize. However, maximum harvest index was recorded in soybean planted in maize in 2:1 ratio (Table 3). This is in accordance with Bhondave *et al.* (1995), who reported similar results in maize + soybean intercropping system.

Land equivalent ratio (LER), which gives reliable assessment of biological efficiency of intercropping over pure cropping, was greater than 1 for all the intercropping treatments (Table 3) indicating yield advantage. Related findings were also reported by Khan *et al*. (1999) in maize, sunflower and soybean intercropping. The highest LER value (1.8 %) was obtained from 2:2 ratio, which indicated yield advantage over sole crops and it was statistically significant.

The maximum grain yield was recorded in sole crop as there was no competition for space, moisture, nutrients *etc* as compared to intercropping treatments. Among the intercropping treatments, 2:2 ratio was found to be superior in respect of both maize and soybean yield. This might be due to appropriate combination of row ratio for utilization of natural resources and benefit associated with atmospheric fixation by the soybean crop. This observation gets support from the results reported by Buriro *et al*. (1991) on maize based intercropping of systems.

Table 2.Effect of maize and soybean intercropping on weed dynamics at harvest

Treatments	Weed density (No/m²)	Weed dry weight (g/m²)	Weed index (%)
Sole maize	3.73	1.57	37.82
Sole soybean	3.73	1.92	49.91
Maize + soybean (1:1)	5.52	4.01	7.71
Maize + soybean (1:2)	5.82	4.49	7.18
Maize + soybean (2:1)	5.41	3.54	9.90
Maize + soybean (2:2)	3.38	1.13	0
Maize + soybean (2:3)	4.46	3.43	11.6
SEm (±)	0.33	0.34	
C D (P = 0.05)	**0.97**	**1.00**	

Economic evaluation of treatments revealed that gross returns in all the intercropping systems were higher than sole crops (Table 4). Among theintercropping treatments, maize + soybean in paired ratios recorded highestgross returns (Rs 1,00,256). Thehighest net returns + were recorded in maize + soybean (Rs 75, 472). Higher combined yield of both the component crops without incurring any extra cost of cultivation was recorded in intercropping treatments leading to higher net returns. Behera *et al*. (1998) also reported similar results. Benefit: Cost ratio was maximum in 2:2 of maize + soybean (3.04) which might be due to highest net returns, though cost of cultivation was almost the same as other intercropping treatments.

The study suggested that the paired rows of maize + soybean (2:2) is the best combination for getting advantage in intercropping when compared with other row arrangements as judged by the weed dynamics and favourable economic indices like net returns and B:C ratio.

Table 3. Effect of maize and soybean intercroppingon yield and economics

Treatments	Harvest Index (HI)		Land Equivalent Ratio (LER)	Grain yield (kg/ha)	
	Maize	Soybean		Maize	Soybean
Sole Maize	40.58	-	1.00	2699	-
Sole Soybean	-	40.44	1.00	-	2175
Maize + Soybean (1:1)	41.61	43.50	1.65	2152	1854
Maize + Soybean (1:2)	39.93	43.37	1.67	2191	1839
Maize + Soybean (2:1)	40.83	46.53	1.60	2230	1682
Maize + Soybean (2:2)	39.12	44.44	1.80	2308	2034
Maize + Soybean (2:3)	38.28	44.30	1.60	1917	1917
SEm (±)	0.90	0.92	0.04	1.12	0.59
CD (P=0.05)	NS	2.76	0.11	3.38	1.78

Table 4. Effect of maize and soybean intercroppingon economics

Treatments	Cost of cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	Benefit cost (B:C) ratio
Sole Maize	24784	45900	21116	0.85
Sole Soybean	24784	65250	40466	1.63
Maize + Soybean (1:1)	24784	92234	67450	2.72
Maize + Soybean (1:2)	24784	92417	67633	2.73
Maize + Soybean (2:1)	24784	88370	63586	2.56
Maize + Soybean (2:2)	24784	100256	75472	3.04
Maize + Soybean (2:3)	24784	90099	65315	2.63

REFERENCES

Anonymous. 2012. *Agricultural Statics at a Glance 2012* (http://eands.dacnet.nic.in/Previous_AT_Glance_2004.htm)

Anonymous. 2012a. *Statistical Handbook of Nagaland*, Directorate of Economics and Statistics. Government of Nagaland, Kohima, pp 51.

Khan Aslam, Khan Sartaj, Asar Muhammad and Khan Munir. 1999. Efficiency of intercropping maize, soybean and sunflower on grain yield. *Pakistan Journal of Biological Sciences* **2**(4): 1611-3.

Bhondave T S, Patil D F, Bhoi P G and Kunjir N T. 1995. Performance of maize based intercropping system. *Indian Journal of Agronomy* **40**(4): 693-4.

Buriro U A, Ahmed K, Kumbar A K, Jamro G H and Sethar M A. 1991. Effect of intercropping on growth, yield and components of maize. *Field Crops Abstract* **44 (**8): 585-589.

Fanai M. 2000. Studies on maize (*Zea mays* L.) and turmeric (*Curcuma longa* L.) intercropping as affected by weed management practices under rainfed conditions, *M Sc (Ag) Thesis,* Nagaland University.

Gupta G S and Anmol L A. 1997. Yield and nutrient uptake in maize as influenced by presence of weeds. *Indian Journal of Agronomy* **17**(5): 225-30.

Mohandoos M, Pannerselvam P and Kuppuswamy G. 2002. Effect of intercropping on weed dynamics. *Agricultural Science Digest* **22**(2); 138-9.

Pandey A K, Prakash V, Singh R D and Mani V P. 1999. Effect of intercropping pattern of maize and soybean on yield and economic under mid hills of N-W Himalayas. *Annals of Agricultural Research* **20**(3): 354-9.

Singh P, Agnihotri R C, Mittal S P and Agnihotri Y. 1986. Studies on intercropping of legumes with maize in Shiwalik foot hill region. *Indian Journal of Soil Conservation* **14**(1): 40-5.

Subramanian S, Mohamed Ali A and Jaya Kumar R. 1997. All About Weed Control, Kalyani Publishers, New Delhi.

Willey R W. 1979. Intercropping its importance and research needs – 1. Competition of yield advantage; Part 2. Agronomy and research approaches. *Field CropAbstract* **32:** 1-10 and 73-85.

Soybean Research (Special Issue): 317-319: 2014

Optimization of Plant Spacing and Seed Rate in Soybean (*Glycine max* (L.) Merrill)

V B AWASARMAL[1], S U PAWAR [2], H A WAGH [3], G D GADADE[4], S S SOLUNKE[5] and B V ASEWAR[6],
Department of Agronomy, Vasantarao Naik Marathwada Krishi Vidyapeeth), Parbhani 431 402, Maharashtra, India
E mail: vbawasarmal@rediffmail.com

Key words: Row spacing, seed rate, soybean

Establishment of an optimum plant density per unit area is a non-monetary input factor for enhancing the production of soybean. There is a considerable scope for increasing soybean yield by optimizing the plant population and plant geometry. The seeding rate or plant population is one of the most important factors when it comes to profitability for the producer. Seed cost and technology fees are increasing rapidly. With these increases, producers must be more economically disciplined and aware of modern research and technology.

Seeding rate is an area of the production cycle where the producer can possibly reduce an input without limiting the yield; thus, realizing additional net returns. Farmers tend to plant 25 per cent more seed than needed. Some of that is to make up for poor equipment or lack of calibration. Some of it is just habit, but some producers feel that the high seeding rates are needed for better weed control. Most people can reduce seeding rate by 25 per cent without affecting either weed control or yield and therefore, increase profits. Seeding rate is dependent on the size of the seed, width of row and the germination rate of seed. The measurement of seeds per row feet is a good planting guide because of the large variation in seed size among different varieties from year to year. In view of above research work was carried on optimization of plant spacing and seed rate in soybean (*Glycine max* (L.) Merrill)

A field experiment was conducted to optimize plant spacing and seed rate in soybean during *kharif* 2012 at the Experimental Farm, College of Agriculture, Parbhani. The experiment was laid out in factorial randomized block design with three replications. There were nine treatment combinations with three row spacing (45, 60 and 75 cm) and three seed rates (55, 65 and 75 kg/ha). The size of plot was 5.4 m x 4.5 m. The experimental soil was clayey in texture, low in organic carbon, low in nitrogen and medium in available phosphorous and high in potash and slightly alkaline (pH: 7.8). The variety of soybean used for this trial was MAUS 71. Sowing was done by dibbling method on 09th July, 2012. The recommended plant protection measures were followed.

The row spacing of 45 cm recorded highest seed yield (2,138 kg/ha) and was significantly superior over 75 cm (1,809 kg/ha), but was on par with 60 cm (2,068 kg/ha) (Table 1). These might be due to higher seed yield per unit area in case of 45 cm spacing. Similar results were reported by Deshmukh *et al.* (1977) and Kacha *et al.* (1990) and Tourino *et al.*, (2002).

[1,2and4]Assistant Professor; [3]Post-graduate Student; [5]Associate Professor; [6]Professor

The straw yield showed a similar trend with respect to row spacings. Planting at 45 cm row spacing produced highest straw yield (2,615 kg/ha), which differed significantly from 75 cm (2,246 kg/ha), but was on par with 60 cm. Similar trend was observed in case of biological yield. This may be due to higher plant height, profuse branching, more number of leaves, and maximum dry matter. These results are in conformity with those reported by Kacha *et al.,* (1990) and Tourino *et al.*, (2002). The row to row spacing of 60 cm recorded maximum harvest index than other two row spacing.

Planting soybean at seed rate of 75 kg per ha produced maximum seed (2,167 kg/ha) and and straw (2,524 kg/ha) yields, which was comparable with 65 kg per ha (2,060 and 2,160 kg/ha, respectively) and significantly superior over 55 kg per ha (1,788 and 2,261 kg/ha, respectively). Biological yield as well followed same trend. This indicated that sowing at 75 kg seed per ha provided optimum opportunity to plant to use natural resources rather than at lower seed rate for variety MAUS 71. Similar result was reported by Kumar and Badiyala (2005) and Jasani *et al.* (1993). Highest value of harvest index was recorded with the seed rate of 75 kg per ha, whereas lowest value was associate with 55 kg per ha.

The interaction effect of row spacing and seed rate could not reach to the levels of significance in influencing the seed, straw and biological yield.

Table 1. Seed, straw and biological yield and harvest index of soybean as influenced by different row spacing and seed rates

Treatment	Yield (kg/ha)			Harvest index (%)
	Seed	Straw	Biological	
Row to row spacing (S)				
45 cm	2138	2615	4753	44.98
60 cm	2068	2398	4452	46.45
75 cm	1809	2246	4055	44.61
SEm (±)	68.07	76.98	107.32	-
C D (p = 0.05)	**203.78**	**230.40**	**321.25**	**-**
Seed rate (R)				
55 kg/ha	1788	2261	4049	44.15
65 kg/ha	2060	2460	4520	45.57
75 kg/ha	2167	2524	4691	46.19
S Em (±)	68.07	76.98	107.32	-
C D (P = 0.05)	203.78	230.40	321.25	-
Interaction (S x R)				
S Em (±)	117.9	133.3	185.8	-
C D (P = 0.05)	NS	NS	NS	-

REFERENCES

Deshmukh S C, Saxena M C and Pandey R K. 1977. Yield, yield comp-onents and grain quality of Clark-63 soybean as influenced by date of planting, row spacing and plant population. *Indian Journal of Agronomy* **22**(1): 27-34.

Jasani K P, Patel M P and Patel H S. 1993. Growth and yield of soybean (*Glycine max*) as influenced by sowing period and seed rate. *Indian Journal of Agronomy* **38**(4): 670-2

Kacha R P, Modhwadia and Patel J C. 1990. Growth and yield of soybean as influenced by row spacing and NP fertility. *Indian Journal of Agronomy* **38**(4): 670-2.

Kumar J and Badiyala D. 2005. Effect of seed rate, row spacing and sowing time on growth and yield attributes of soybean. *Legume Research* **28**(4): 288-90.

Tourino M C C, de Rezende P M and Salvador N. 2002. Row spacing, plant density and intra row plant spacing uniformity effect on soybean yield and agronomic characteristics. *Prequisa Agropecuria Brasileira* **37**(8): 1071-7.

Soybean Research (Special Issue Number 2): 320-324: 2014

Effect of New Molecules of Herbicides on Productivity and Profitability in Soybean [*Glycine Max* (L.) Merrill] Under Chhattisgarh Plain

ANKITA GUPTA[1], AMBIKA TANDON[2], ASHISH BANJARE[3] and RAJENDRA LAKPALE[4]
Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur 492012, Chhattisgarh, India
E mail: 16ankitagupta@gmail.com

Key words: Herbicides, soybean productivity, soybean profitability, weed control

Soybean area is being consistently increasing in the state of Chhattisgarh. In the year 2012, the crop covered an area of 1.06 thousand ha producing 1.28 thousand tonnes with productivity of 1,205 kg per ha (Anonymous, 2012). There appears to be a wide gap between realizable yield potential of improved varieties and yield realized under real farm conditions. One of the main factor limiting the productivity enhancement of soybean in state is the severe weed problem.Weed competition in soybean at early stage of crop growth is critical, as it causes yield losses up to 10 to 86 per cent depending upon weed infestation. The critical period of crop-weed competition in soybean is reported to be first 45 DAS (Panneerselvam and Lourduraj, 2000).

Most prominent weed species found in soybean are *Echinochloa crusgalli, Cynodon dactylon, Corchorus spp., Cyperus rotundus, Euphorbia spp., Commelina benghalensis, Parthenium hysterophorus, Setaria glauca, Eclipta alba, Phyllanthus niruri, Acalypha indica, Trianthema portulacastrum,* and *Alysicarpus rugosus* (Kolhe *et al.*, 1998). The traditional method of weed control *i.e.,* hand weeding is tedious and time consuming (Yadav *et al.*, 2009). Moreover, hand-weeding and mechanical weeding are difficult due to continuous rainfall and less availability of labours at the critical stage of crop-weed competition. Use of herbicides not only improves crop yield but also makes available labour for other productive activities (Kurchania *etal.*, 1989). Hand weeding is a traditional and effective method of weed control, but untimely and continuous rains as well as unavailability of labour at peak time are main limitations of manual weeding. The only alternative that needs to be explored is the use of post-emergence herbicides. Alleviating weed competition through weed management practices especially involving new herbicides have been found to be effective in enhancing crop yield of soybean. The use of selective herbicide in soybean seems to be effective and economical.

The present investigation was carried out during *kharif* 2012 at Instructional cum Research Farm of IGKV, Raipur situated at latitude of 21°4′ N, longitude of 81°35′ E and altitude of 290.20 m above mean sea level. The crop received 1,375.8 mm rainfall and monthly average minimum temperature ranged between 21.2°C to 26.3 °C. Relative humidity throughout the crop season varied between 78.0 to 95.0 per cent at morning and

[1and 3] M Sc Student; [2]Assistant Professor; [4] Principal Scientist

37.0 to 91.0 per cent in evening hours. The soil of experimental field was *clayey* in texture, low in nitrogen (219.78 kg N/ha), medium in phosphorus (13.87 kg P_2O_5/ha) and high in potassium contents (365.31 kg K_2O/ha) with neutral pH (7.12). The experiment was laid out in randomized block design, comprising four replications and eight treatments which includedSulfentrazone @ 300 g a.i. per ha as pre-emergence (PE), Sulfentrazone @ 360 g a.i. per ha as PE, Pendimethalin @ 1 kg a.i. per ha as PE, Metribuzin @ 750 g a.i. per ha as PE, Imazethapyr @ 100 g a.i. per ha as post emergence (PoE), Odyssy 70 WG (imazethapyr 35 % + imazamox 35 %) @ 100 g a.i. per ha as PoE, hand weeding twice at 20 and 40 DAS and untreated control.. Soybean variety 'JS 97-52' was grown as a test crop. Crop was sown with spacing of 45 cm x 5 cm during the last week of June using the seed rate of 75 kg per ha and fertilizer dose was 25, 60 and 40 kg per ha of N, P_2O_5 and K_2O, respectively, at the time of sowing. Weed management practices were adopted as per the treatments, manually.

Amongst weed manage-ment practices, hand weeding twice at 20 and 40 DAS proved to be best in enhancing number of pods per plant however; it was found comparable with Sulfentrazone @ 360 g a.i. per ha as PE and Imazethapyr @ 100 g a.i. per ha as PoE .The lowest number of pods per plant was recorded under untreated control.This result may be due to the less competition at critical periods of crop growth and better suppression of weeds, which allowed the crop to grow their potential by absorbing sufficient nutrients, light, moisture and space which facilitate more translocation of photosynthates towards the reproductive parts as well as presence of favourable agro-climatic conditions due to removal of weeds, led to more number of pods per plant. Similar results have been reported by Kumar *et al.* (2001) and Vyas and Jain (2003). Hand weeding twice at 20 and 40 DAS was significantly superior to rest of the treatments in enhancing number of seeds per plant, which was found at par with Odyssy 70 WG (imazethapyr 35 % + imazamox 35 %) @ 100 g a.i. per ha as PoE , Imazethapyr @ 100 g a.i. per ha as PoE, Metribuzin @ 750 g a.i. per ha as PE,Pendimethalin @ 1 kg a.i. per ha as pre-emergence, Sulfentrazone @ 360 g a.i. per ha as PE and Sulfentrazone @ 300 g a.i. per ha as PE. The minimum number of seeds per plant was observed under untreated control. Hand weeding twice at 20 and 40 DAS produced the maximum seed yield of 2,081 kg per ha, which was superior to rest of the treatments except Sulfentrazone @ 360 g a.i. per ha as PE, Sulfentrazone @ 300 g a.i. per ha as PE and Imazethapyr @ 100 g a.i. per ha as PoE. The lowest seed yield was observed under untreated control (Table 1). Similar findings were also reported by Dubey *et al.* (2000), Dhane *et al.* (2009) and Yadav *et al.* (2009). Higher seed yield under above treatments was due to the weed managed at critical period and early crop growth, higher dry matter production, high growth in terms of LAI, which resulted in higher production of photo-synthesis, which acts as a source and greater translocation of food materials to the reproductive parts resulted in superiority of yield attributing characters and ultimately high yield. Lower weed population and higher weed control efficiency also resulted in higher seed yield. Hand weeding twice at 20 and 40 DAS produced the maximum stover yield of 2,289 kg per ha, which was superior to rest of the treatments except Sulfentrazone @ 360 g a.i. per ha as PE and Imazethapyr @ 100 g a.i. per ha as PoE. The lowest stover yield was recorded under untreated control. The higher stover yield in above treatments might be due to lesser weeds during early crop growth period and get higher yield attributes

Table 1. Effect of new molecules of herbicides on productivity, profitability and weed control efficiency in soybean

Weed management practices	Pods (No/ plant)	Seeds (No/ plant)	Yield (kg/ha)		Monetary returns (Rs/ha)		Benefit : cost ratio	Weed control efficiency (%)
			Seed	Stover	Gross	Net		
Sulfentrazone 48 % F @ 300 g a.i./ha as pre-emergence	68.3	205.1	1865	2064	62676	47431	3.11	87.61
Sulfentrazone 48 % F @ 360 g a.i./ha as pre-emergence	74.5	205.3	1923	2247	64744	49374	3.21	95.46
Pendimethalin 30 EC@ 1 kg a.i./ha as pre-emergence	63.2	181.6	1548	1764	52074	36133	2.27	51.44
Metribuzin 70 WP @ 750 g a.i./ha as pre-emergence	61.9	177.7	1389	1597	46739	30514	1.88	80.97
Imazethapyr 10 SL @ 100 g a.i./ha as post-emergence	73.1	196.7	1906	2124	64069	48274	3.06	84.84
Odyssey (imazethapyr 35% + imazamox 35%) 70 WG @ 100 g a.i./ha as post- emergence	64.3	186.9	1635	1873	55010	37997	2.23	87.70
Hand weeding twice	79.2	207.1	2081	2289	69921	53901	3.36	97.85
Untreated control	58.7	169.5	1232	1472	41512	27091	1.87	-
SEm (±)	3.0	11.6	81	69	-	-	-	-
CD (P=0.05)	**8.8**	**34.2**	**239**	**203**	**-**	**-**	**-**	**-**

and pod yield which leads to higher stover yield. While, in weedy check reverse trend was observed and therefore, the lowest stover yield was noted under this treatment. Similar findings were reported by Dhane *et al.* (2009).

The highest gross and net returns were obtained under treatment hand weeding twice at 20 and 40 DAS. It was followed by Sulfentrazone @ 360 g a.i. per ha as PE, Imazethapyr @ 100 g a.i. per ha as PoE, Sulfentrazone @ 300 g a.i. per ha as PE, and Odyssy 70 WG (imazethapyr 35 % + imazamox 35 %) @ 100 g a.i. per ha as PoE. The lowest values were recorded under untreated control followed by Metribuzin @ 750 g a.i. per ha as PE and Pendimethalin @ 1 kg a.i. per ha as PE. The highest benefit cost ratio was recorded under hand weeding twice at 20 and 40 DAS and it was followed by Sulfentrazone @ 360 g a.i. per ha as PE, Sulfentrazone @ 300 g a.i. per ha as PE and Imazethapyr @ 100 g a.i. per ha as PoE. The lowest benefit cost ratio was recorded under untreated control (Table 1). Total dry matter production of a plant often reflects its potentiality for its biomass production. Whereas, mobilization forwards the seed development is an important factor for realization of economic yield and serves as the yardstick resulting in maximum gross return which was produced in hand weeding twice at 20 and 40 DAS and this treatment also gave maximum net return, additional return over weedy check and benefit cost ratio. This was due to lower cost of cultivation associated with higher seed yield than other herbicidal treatments. It was conformity with the findings of Idapuganti *et al.* (2005), Tiwari *et al.* (2006) and Yadav *et al.* (2009). Kewat *et al.* (2000) reported that the, net return and benefit cost ratio were minimum under weedy check.

Highest weed control efficiency was noted under treatment hand weeding twice at 20 and 40 DAS followed by Sulfentrazone @ 360 g a.i. per ha as PE, Odyssy 70 WG (imazethapyr 35% + imazamox 35%) @ 100 g a.i. per ha as PE, Sulfentrazone @ 300 g a.i. per ha as PE, Imazethapyr @ 100 g a.i. per ha as PoE, Metribuzin @ 750 g a.i. per ha as PE and Pendimethalin @ 1 kg a.i. per ha as PE (Table 1).

REFERENCES

Anonymous. 2012. Agricultural Statistics at a Glance, 2012, Department of agriculture and cooperation, Government of India (http://agricoop.nic.in/agristatistics.htm)

Dhane J B, Jawale S M, Shaikh A A, Dalavi N D and Dalavi P N. 2009. Effect of integrated weed management on yield and economics of soybean (*Glycine max* L. Merrill). *Journal of Maharashtra Agricultural Universities* **34**(2): 141-3.

Dubey M P, Singh R, Tiwari U K, Kurmavanshi S M, Goswami S R and Jain S K. 2000. Response of soybean (*Glycine max*) and associated weeds to pre-emergence application of Chlorimuron Ethyl and Metolachlor. *Indian Journal of Weed Science* **32**(3 & 4): 153-5.

Idapuganti R G, Rana D S and Sharma R. 2005. Influence of integrated weed management on weed control and productivity of soybean [*Glycinemax* (L.) Merrill]. *Indian Journal of Weed Science* **37**(1/2): 126-8.

Kewat M L, Pandey J, Yaduraju N T and Kulshreshtha G. 2000. Economic and eco-friendly weed management in soybean (*Glycine max* (L.) Merrill). *Indian Journal of Weed Science* **32**(3 & 4): 135-9.

Kolhe S S, Choubey N K and Tripathi R S. 1998. Evaluation of fenoxaprop-p-ethyl and lactofen in soybean. *Indian Journal of Weed Science* **36**(3-4): 216-7.

Kumar P, Baghel R S and Singh S P. 2001. Weed management in soybean (*Glycine max* (L.) Merrill).*Progressive Agriculture* **1**(1): 38-41.

Kurchania S P, Tiwari J P, Trivedi K K and Dubey M P. 1989. Herbicidal weed control in soybean. *Pesticides* **23**(5): 42-5.

Panneerselvam S and Lourduraj A C. 2000. Weed sapectrum and effect of crop weed competition in soybean [*Glycine max* (L.) Merrill]- A Review. *Agricultural Review* **21**(2): 121-4.

Tiwari T K, Pawar V S and Mahatale P V. 2006. Effect of soil solarization and herbicides on weed control in soybean. *Annals of Plant Physiol*ogy **20**(1): 56-8.

Vyas M D and Jain A K. 2003 Effect of pre- and post-emergence herbicides on weed control and productivity of soybean (*Glycine max*). *Indian Journal of Agronomy* **48**(4): 309-11.

Yadav V K, Sankpal V Y, Shaikh A A and Bachkar S R. 2009. Effect of integrated weed management on yield and economics of soybean (*Glycine max* L. Merrill). *Journal of Maharashtra Agricultural Universities* **34**(1): 25-7.

Soybean Research (Special Issue Number 2): 325-330: 2014

Weed Management in Soybean (*Glycine max* L.)

***S S PRACHAND*[1], *K J KUBDE*[2] *and A S DEOTALU*[3]**
Department of Agronomy, Dr Panjabrao Deshmukh Krishi Vidyapeeth,
Akola 444 104, Maharashtra, India
E mail: smitaprachand80@gmail.com

Key words: Economics, growth, microbial count, soybean, weed control efficiency, weed index, yield

Soybean (*Glycine max* L.) is one of the important oilseed as well as leguminous crop. It grows slowly during the initial period, which results into vigorous growth and proliferation of weeds. Weeds compete with crop for soil moisture, nutrients, light, space, *etc*. In *kharif*, the weed competition is one of the most important causes of low yield in oilseeds, which estimated to be of 31-84 per cent (Kachroo *et al*., 2003) Thus, intense weed competition is one of the main constraints for increasing soybean productivity. Reduction in the yield due to weeds varies from 35 to 50 per cent, depending upon the type of weeds, their intensity and time of crop weed competition (Chandel *et al.,* 1995). The traditional method of weed control *i.e.*, hand weeding is expensive, tedious, and time consuming. Weeding also becomes difficult due to unfavourable weather, wet soil and unavailability of labour. Under such circumstances, use of effective herbicides gives better and timely weed control. In view of above, a study on weed management in soybean with weedicides was taken up.

The present investigation was carried out at research farm, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* 2012. The experiment was laid out in randomized block design with eight treatments replicated thrice. The treatments comprised of weedy check, recommended practices (1 hand weeding + 1 hoeing), Pendimethalin as pre-emergence@ 1.0 kg a.i per ha, Quizalofopethyl as post-emergence (PoE) @ 0.075 kg a.i. per ha, Imazethapyr as PoE @ 0.100 kg a.i. per ha, Imazethapyr as PoE @ 0.100 kg a.i. per ha + Quizalofop ethyl @ 0.075 kg a.i per ha, premix formulation of Imazethapyr + Imazamox @ 0.070 and @ 0.080 kg a.i per ha as PoE. The PoE application of herbicides was made after 15 days of sowing (DAS). The gross and net plot size were 4.5 m x 4.0 m and 3.6 m x 2.8 m, respectively. The experimental site was fairly uniform in topography. The soil was clayey and slightly alkaline in reaction with pH of 7.8. It was low in available nitrogen (221.47 kg N/ha), medium (16.86 kg P_2O_5/ha) in available phosphorus and rich in potassium (387.25 kg K_2O/ha). The soybean variety JS 335 was sown by drilling at 45 cm x 5 cm spacing on 2nd July 2012 and harvested on 8th October 2012. Data on the growth parameters were collected on five randomly selected and labeled plants in each treatment starting from 20 DAS at 20 days interval up to 80 DAS and at harvest. Serial dilution plate technique was used for isolation and enumeration of soil fungi, actinomycetes and bacteria as described by

[1and3]*PGStudent; 2Associate Professor*

Pahwa *et al* (1996). Data collected was statistically analysed by adopting standard procedure of analysis of variance by Panse and Sukhatme (1971).

Predominant weed species observed in the experimental field were *Euphorbia geniculata, Parthenium hysterophorus*, *Euphorbia hirta, Lagascamollis, Digera arvensis*and *Celosia argentea* among the dicot weeds, and *Commelina benghalensis, Dinebra Arabica, Poaannua, Echinochloa crusgalli, Eragrostis major, Cynodon dactylon* and *Cyperus rotundus* among the monocots.

Post-emergence applications of premix formulation Imazethapyr @ 0.100 kg a.i. per ha + Quizalofop ethyl @ 0.075/0.080 kg a.i. per ha equally lowered the total weed population, which was at par with 1 hand weeding + 1 hoeing, whereas, lower weed dry biomass was observed with premix formulation Imazethapyr @ 0.100 kg a.i. per ha + Quizalofop ethyl @ 0.075 kg a.i. per ha as compared to all other treatments. This might be due to combination of both herbicides that have longer effect on controlling weed population and brought significant reduction in weed dry matter ascompared toweedy check. Similar results werereported by Halvankar *et al.* (2005) and Bhattacharya *et al.* (2004).Weedcontrol efficiency of all thetreatments was higher, whereas weed index was noted lower as compared to weedy check. Similar findings were also reported by Sangeetha *et al.* (2011) and Tiwari et al. (2006). The highest weed control efficiency and lowest weed index was recorded under PoE applications of Imazethapyr @ 0.100 kg a.i. per ha and Quizalofop ethyl @ 0.075 kg a.i. per ha.

Maximum seed and straw yields were obtained with PoE application of premix formulation Imazethapyr @ 0.100 kg a.i. per ha + Quizalofop ethyl @ 0.075 kg a.i. per ha as compared to other treatments. Seed yield increased in this treatment by 150.35 per cent over the treatment weedy check. This might be due to the better weed control and improvement in yield contributing characters in these treatments. Similar results were reported by Sharma (2000) and Raskar and Bhoi (2002).

Application of premix formulation Imazethapyr @ 0.100 kg a.i. per ha + Quizalofop ethyl @ 0.075 kg a.i. per ha also recorded significantly highest gross monetary returns (Rs 81,500/ha), net monetary returns (Rs 56,269/ha) and benefit cost ratio (3.23). The lowest gross monetary returns, net monetary returns and benefit cost ratio were observed with weedy check. Similar results were reported by Dhane *et al*. (2009).

The treatment 1 hand weeding + 1 hoeing recorded significantly higher bacterial, fungal and count, whereas, reduction in microbial population was more in pre-emergence application of Pendimethalin 1.0 kg a.i per ha. At harvest, the microbial population was not significantly affected by different treatments. Effect of herbicide after 15 days of treatment significantly influenced the population of bacteria, fungi, and actinomycetes in soil as compared to their population before herbicide application. However, subsequent increase in the microbial population indicated that the effect of herbicide on soil microbes was temporary which was in conformity with the results of Selvamani and Sankaran (1993) and Pal *et al.* (2009).

Table 1. Effect of different weed control treatments on weed population, weed dry biomass, weed control efficiency and weed index in soybean

Treatments	Weed count/m² at 40 DAS			Weed dry biomass at 40 DAS (g)	Weed control efficiency (%)	Weed index (%)
	Monocot	Dicot	Total			
Weedy check	26.33	26.67	53.00	14.36	-	60.05
1 Hand weeding + 1 hoeing	9.33	12.00	21.33	6.22	56.68	10.54
Pendimethalin as PE @1.0 kg a.i/ha as PE	12.67	12.33	25.00	6.83	51.43	6.99
Quizalofop ethyl @ 0.075 kg a.i./ha as PoE	12.00	13.00	26.00	7.41	48.39	18.15
Imazethapyr @ 0.100 kg a.i./ha as PoE	13.00	12.00	24.00	7.28	49.30	11.12
Imazethapyr @ 0.100 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i/ha as PoE	10.00	10.00	20.00	5.04	64.90	0
Premix Imazethapyr + Imazamox @ 0.070 kg a.i./haas PoE	12.67	13.33	25.33	6.25	56.47	13.08
Premix Imazethapyr + Imazamox@ 0.080 kg a.i/ha as PoE	12.00	12.33	25.00	6.59	51.10	9.52
SEm (±)	0.83	0.76	1.18	0.59	-	-
CD (P = 0.05)	2.54	2.33	3.64	1.81	**-**	**-**

PE-Pre-emergence, PoE- Post-emergence

Table 2. Growth characters, yield parameters, yield **and economics as influenced by different weed control treatments**

Treatment	**Growth characters**		**Yield parameters**				**Yield (kg/ha)**		**Monetary returns (Rs/ha)**		**B:C ratio**
	Plant height (cm)	**Dry matter (g/plant)**	**Pods (No/ plant)**	**Seeds (No/ pod)**	**Seed weight (g/plant)**	**100 seed weight (g)**	**Seed yield**	**Straw yield**	**Gross**	**Net**	
Weedy check	52.33	12.39	26.00	2.67	7.23	10.42	1089	1272	32524	9999	1.44
1 Hand weeding + 1 hoeing	63.63	17.30	38.33	3.67	16.09	11.44	2334	2906	72932	47007	2.81
Pendimethalin as PE @ 1.0 kg a.i/ha as PE	63.87	13.47	40.67	3.20	15.16	11.65	2505	3146	75938	51881	3.16
Quizalofop ethyl @ 0.075 kg a.i./ha as PoE	61.13	13.62	33.00	3.37	12.42	11.17	2079	2704	66756	43125	2.82
Imazethapyr @ 0.100 kg a.i./ha as PoE	59.47	16.40	35.33	3.33	14.05	11.94	2282	3072	72655	48530	3.01
Imazethapyr @ 0.100 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i/ha as PoE	64.33	18.11	45.33	3.77	20.51	12.00	2297	3233	81500	56269	3.23
Premix Imazethapyr + Imazamox @ 0.070 kg a.i./haas PoE	63.53	14.73	36.33	3.50	14.39	11.32	1882	2957	70991	48306	3.13
Premix Imazethapyr + Imazamox@ 0.080 kg a.i/haasPoE	61.47	17.34	34.00	3.10	11.57	10.98	2090	3079	73880	51175	3.03
SEm (±)	1.93	1.05	1.16	0.26	0.53	0.18	86	201	3292	3292	-
C D (P = 0.05)	**5.92**	**3.23**	**3.56**	**NS**	**1.64**	**0.56**	**266**	**616**	**10101**	**10101**	**-**

Table 3. Effect of different weed control treatments on soil microbial population

Treatments	Microbial population (cfu/g soil)								
	Bacteria (10^7)			Fungi (10^4)			Actinomycetes (10^6)		
	Before sowing	15 DAT	At harvest	Before sowing	15 DAT	At harvest	Before sowing	15 DAT	At harvest
Weedy check	11.50	17.00	35.60	10.33	19.00	33.67	8.57	12.33	28.33
1 Hand weeding + 1 Hoeing	11.70	17.33	35.80	12.00	19.33	34.00	8.67	12.67	29.00
Pendimethalin as PE @ 1.0 kg a.i/ha as PE	10.70	13.07	33.80	10.67	16.07	31.67	7.50	9.33	25.33
Quizalofop ethyl @ 0.075 kg a.i./ha as PoE	10.90	15.80	34.60	11.33	17.33	32.00	8.10	10.67	26.33
Imazethapyr @ 0.100 kg a.i./ha as PoE	11.07	15.93	34.80	10.67	18.67	32.33	8.07	11.00	27.33
Imazethapyr @ 0.100 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i/ha as PoE	11.60	16.97	35.40	11.00	18.33	33.33	8.00	12.00	27.33
Premix Imazethapyr + Imazamox @ 0.070 kg a.i./haas PoE	10.73	16.80	33.70	11.33	18.00	32.67	8.23	12.00	27.00
Premix Imazethapyr + Imazamox@ 0.080 kg a.i/haasPoE	11.33	15.97	33.70	11.67	17.67	32.33	8.20	11.33	25.67
SEm (±)	0.44	0.80	1.31	0.51	0.59	1.26	0.55	0.48	0.94
C D (P = 0.05)	NS	**2.47**	**NS**	NS	**1.83**	**NS**	NS	**1.47**	**NS**

DAT-Days after treatment; PE-Pre-emergence; PoE- Post-emergence; cfu – colony forming unit

REFERENCES

Bhattacharya S P, Monal L, Pal D and Saha M. 2004. Bioefficacy of Targa super (Quizalofop ethyl) 5% EC in controlling weeds of jute. *Pestology* **28**(4): 32-5.

Chandel A S, Saxena S C and Singh K. 1995. Integrated weed control and its economics in soybean (*Glycine max*) grown in Mollisols of Uttar Pradesh. *Indian Journal of Agronomy* **40**(2): 228-34.

Dhane J B, Jawale S M, Shaikh A A, Dalavi N D and Dalavi P N. 2009. Effect of integrated weed management on yield and economics of soybean (*Glycine max* L. Merrill). *Journal of Maharashtra Agricultural Univesities* **34**(2): 141-3.

Halvankar G B, Varghese P, Taware S P and Raut V M. 2005. Effect of herbicides on weed dynamics and yield of soybean. *Journal of Maharashtra Agricultural Univesities* **30**(1): 35-7.

Kachroo D, Dixit A K and Bali A S. 2003. Weed management in oilseed crops. *Journal of Research, Sher-e-Kashmir University of Agricultural Sciences and Technology* **2**(1): 1-12.

Pahwa S K and J Prakash. 1996. Studies on the effect of herbicide on the growth, nodulation and symbiotic nitrogen fixation in mungbean *Indian Journal of Weed Sciences* **28**(3 and 4): 160-3.

Pal D, Ghosh R K, Sounda G, Dolai A K, Pramanick and Mallick M. 2009. Bio-efficacy of some promising herbicides in transplanted *kharif* rice and their influence on soil microflora. *Indian Agriculturist* **53**(3/4): 193-8.

Panse V G and Sukhtame P V. 1971. *Statistical Methods for Agricultural Workers*, Indian Council of Agricultural Research, New Dehli.3rd Edition, Pp 341.

Raskar B S and Bhoi P G. 2002. Bio-efficacy and phytotoxicity of pursuit plus herbicides against weeds in soybean (*Glycine max* L.). *Indian Journal of Weed Science* **34**(1 and 2): 50-2.

Sangeetha C, Chinnusamy C and Prabhakaran N K. 2011. Performance of early post-emergence herbicides in irrigated soybean (*Glycine max* L. Merrill). *Madras Agricultural Journal* **98**(4/6): 144-6.

Selvamani S and Sankaran S. 1993. Soil microbial population as affected byherbicides. *Madras Agricultural Journal* **80**(7): 397-9.

Sharma P B. 2000. Quizalofop ethyl: An efficient herbicide, against grassy weeds of soybean. *Pestology* **24**(4): 60-2.

Tiwari D K, Dubey O P, Baghel S S and Agrawal S B. 2006. Bioefficasy of post emergence herbicides for control of grassy weed in soybean (*Glycine max* L. Merrill). *International Journal of Agricultural Science* **2**(1): 54-5.

Soybean Research (Special Issue Number 2): 331-334: 2014

Influence of Post-Emergence Herbicide on Growth and Yield of Soybean

VIMAL BHARTI[1], SHRIKANT K PHAJAGE[2], NIDHI VERMA[3], ANIL CHAVAN[4], SATISH IMADE[5] and GANESH GAIKWAD[6],
Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, Madhya Pradesh, India
E mail: skphajage@gmail.com

Key words: Imazethapyr, herbicide, post-emergence, soybean, weed, yield

Soybean [*Glycine max* (L.) Merrill], being a rainy season crop, is exposed to excessive weed infestation. Severe weed competition is one of the major constraints for low productivity of soybean. The stress created by weeds on soybean for nutrient, water, light and space are responsible for poor yield. Weeds, in general, cause competition stress on soybean growth, especially during the first 40 days after sowing (Tiwari *et al.* 1997). The weeds, if not controlled during critical period of weed-crop competition, there is reduction in the seed yield of soybean by 35 to 55 per cent depending upon type and weed intensity (Chandel and Saxena, 1998, Kewat *et al*., 2000, Singh, 2007). Weed management through manual weeding or hoeing although effective in reducing the weed competition, but it is not free from several limitations such as non-availability of sufficient manpower during peak periods, high labour cost, time consuming and non-feasibility in heavy soils under high rainfall conditions. To overcome these difficulties, weed control by chemical is resorted to, which is effective, easier, cheaper and many times faster than the conventional methods. Recently, some of the post-emergence herbicides have been developed which selectively control either grassy or broad leaved weeds in a single application. The objective of the present investigation was to study the effect of post-emergence herbicides on growth and yield of soybean.

A field experiment was conducted during *kharif* 2009 at Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur. The soil of the experimental field was sandy loam, which was low in organic carbon (0.68 %), available nitrogen (215.0 kg N/ha) and phosphorus (9.2 kg P_2O_5/ha), medium in available potassium (318.0 kg K_2O/ha) and neutral in reaction (pH 7.35) and having electronic conductivity of 0.48 dS per m. Nine treatments (Table 1) were laid out in randomized block design with three replications. All herbicide treatments were applied in 500 litres of water per hectare using flat fan nozzle at 10 days after sowing. Soybean variety `JS 97-52' was sown on 8 July, 2009 after adequate rains were received at a row spacing 30 cm. The crop was raised by following recommended package of practices. Observations on plant population (at harvest), plant height (at harvest) branches per plant (at 90 DAS), leaves per plant (at 60 DAS) and nodules per plant (at 60 DAS) were recorded on the five randomly tagged plants. Pinkish root nodules counted as active root nodules (pinkish fluid was oozed out when pressed with fingers). Other observations were recorded at harvest, The economic

[1]M Sc(Agri) Student, Jabalpur;[2,4and5]Ph D Scholar, Navsari;[3]Ph D Scholar, Jabalpur; [6]Ph D Scholar, Navsari

viability of treatment was computed with prevailing market rate at the time of harvesting of crop.

Effect on growth parameters

The plant population of soybean at harvest was not adversely affected by any of the treatments indicating no effect on the germination and further survival of crop plants. Hand weeding at 30 DAS gave maximum and significantly higher plant height (86.40 cm), branches per plant (3.67) and leaves per plant (22.63) compared to weedy check. Among herbicidal treatments,

Table 1. Effect of herbicide on growth of soybean

Treatments	Plant popula -tion (No/m)*	Plant height (cm)*	Branches (No/ plant)**	Leaves (No/ plant)***	Root nodules (No/plant)*** Total	Active
Imazethapyr (75g/ha)	10.23	80.52	2.27	17.20	4.33	2.67
Imazethapyr (100g/ha)	10.15	80.63	2.33	18.17	4.67	3.33
Imazethapyr + Emulan (@ 75 g a i + @ 1 L/ha)	10.32	80.80	2.93	18.60	5.00	3.67
Imazethapyr + Emulan (@ 100 g a i + @ 1 L/ha)	10.22	82.60	3.00	20.74	6.33	3.67
Imazethapyr + Emulan + A S (@ 100 g a.i. + @ 750 ml + @ 1 kg/ha)	10.26	84.93	3.60	21.07	7.00	4.33
Chlorimuron-ethyl (9.7g/ha)	10.37	77.80	2.07	16.73	4.00	2.33
Fenoxoprop ethyl (67.5 g/ha)	10.04	79.37	2.33	17.45	4.33	2.67
Hand weeding once at 30 DAS	10.21	86.40	3.67	22.63	7.33	4.33
Weedy check	9.74	72.80	1.87	15.67	3.33	1.67
SEm±	0.10	0.70	0.11	0.31	0.41	0.39
C D (P = 0.05)	**0.31**	**2.10**	**0.33**	**0.94**	**1.24**	**1.19**

**At harvest; **At 60 DAS; ***At 90 DAS; A S- ammonium sulphate* imazethapyr + Emulan (sticker) + ammonium sulphate (@ 100 g a i +@ 750 ml + @ 1 kg/ha) produced the maximum number of branches per plant, plant height, leaves per plant and leaf area index and it was followed by imazethapyr @ 100 g a i + Emulan (@ 100 g a i + @ 1 L/ha) (Table 1). Highest number of root nodules was recorded under hand weeding (7.33/plant), which was at par to imazethapyr + Emulan + ammonium sulphate (@ 100 g ai + @ 750 ml + @ 1 kg/ha) (7/plant) and imazethapyr + Emulan (@ 100 g a i + @ 1 L per ha) (6.33/plant) while, minimum in weedy check (3.33/plant). Number of active root nodules were maximum in hand weeding (4.33/plant), which was similar to imazethapyr + Emulan (sticker) + ammonium sulphate (@ 100 g a i +@ 750 ml + @ 1 kg/ha) (7/plant) and imazethapyr + Emulan (@ 100 g a i + @ 1 L per ha) (4.33) followed by imazethapyr + Emulan (@ 75 g a i + @ 1 L/ha), while minimum in weedy check (1.67/plant). Agarwal *et al.* (2007) also reported similar results.

Effect on yield attributes and yields of soybean

Among all the treatments, the minimum number of pods per plant (50.42) and seeds per pod (1.71) were recorded under weedy check, while maximum was in hand weeding (91.14 and 2.54, respectively). Among herbicidal treatments, imazethapyr + Emulan + ammonium sulphate (@ 100 g a i + @ 750 ml + @ 1 kg/ha) recorded higher number of pods per plant (87.77) and seeds per pod (2.42), which was on par with Imazethapyr + Emulan (@ 100 g a i + @ 1 L/ha (Table 2). The maximum seed index (11.84 g) and harvest index (32.97 %) was obtained under hand weeding, which was on par with imazethapyr + Emulan + ammonium sulphate (@ 100 g a i + @ 750 ml + @ 1 kg/ha) (11.75 g and 31.35 %, respectively). While, minimum harvest index was recorded under weedy check plots (22.76 %). The seed yield of soybean was highest under hand weeding (2,652 kg/ha), which was on par with imazethapyr + Emulan + ammonium sulphate (@ 100 g a i + @ 750 ml + @ 1 kg/ha) (2,555 kg/ha). Pandya *et al*. (2005) and Dhane *et al.*(2009) also reported similar results. The next best treatments were imazethapyr + Emulan (@ 100 g a i + @ 1 L/ha) (2,472 kg/ha) and imazethapyr + Emulan (@ 75 g a i/ha + @ 1 L/ha) (2,236 kg/ha). All the treated plots produced significantly higher straw yield (4,447 to 6,858 kg/ha), than weedy check (3,230 kg/ha).

Effect on economic returns

Hand weeding once at 30 DAS fetched maximum and significantly higher net returns (Rs 39,893 /ha) over weedy check (Rs 11,938). Among herbicidal treatments, application of imazethapyr + Emulan + ammonium sulphate (@ 100 g a i + @ 750 ml + @ 1 kg/ha) recorded maximum and significantly higher net returns (Rs 39,109 /ha) and B:C ratio (3.20). Weedy check treatment recorded the minimum B:C ratio (1.76).

REFERENCES

Agarwal H P, Verma V K, Shrivastava R, Sharma Geet, Bisen R K and Singh P R. 2007. Effect of weed management practices on root nodulation and growth parameters in soybean. *Advances in Plant Science* **20**(1): 155-8.

Chandel A S and Saxena S C. 1998. Technology for raising soybean productivity in Uttar Pradesh. *Indian Farming* **38**: 10-2.

Dhane J B, Jawale S M, Shaikh A A, Dalvi N D and Dalvi P N. 2009. Effect of integrated weed management on yield and economics of soybean (*Glycine max* (L.) Merrill). *Journal of Maharashtra Agricultural Universities* **34** (2): 141-3.

Table 2. Effect of herbicide on yield attributes, yield and economics of soybean

Treatments	Pods (No/ plant)	Seeds (No/ pod)	Seed Index (g/ 100 seeds)	Har-vest index (%)	Seed yield (kg/ha)	Straw yield (kg/ha)	Net returns (Rs/ha)	B:C Ratio
Imazethapyr (75g/ha)	69.88	2.19	10.23	28.03	1861	4779	24466	2.43
Imazethapyr (100g/ha)	76.64	2.23	11.02	29.33	2194	5287	31220	2.79
Imazethapyr + Emulan (@ 75 g a i + @ 1 L/ha)	79.46	2.32	11.27	29.10	2236	5637	32246	2.85
Imazethapyr + Emulan (@ 100 g a i + @ 1 L/ha)	83.72	2.34	11.49	30.12	2472	6449	37310	3.10
Imazethapyr + Emulan + A S (@ 100 g a.i. + @ 750 ml + @ 1 kg/ha)	87.77	2.42	11.75	31.35	2555	6649	39109	3.20
Chlorimuron-ethyl (9.7g/ha)	65.93	2.08	10.00	25.27	1638	4447	20632	2.27
Fenoxoprop ethyl (67.5 g/ha)	68.80	2.17	10.13	27.83	1791	4645	22891	2.33
Hand weeding once at 30 DAS	91.14	2.54	11.84	32.97	2652	6858	39893	3.14
Weedy check	50.42	1.71	9.77	22.76	1250	3230	11938	1.76
SEm±	1.20	0.07	0.14	-	47.89	76.02	-	-
C D (P = 0.05)	3.62	0.20	0.41	-	144.25	228.98	-	-

A S- ammonium sulphate

Kewat M L, Pandey J, Yaduraju N T and Kulshreshthra G. 2000. Economic and eco-friendly weed management in soybean. *Indian Journal of Weed Science* **32**(3 and 4): 135-9.

Pandya N, Chauhan G S and Nepalia V. 2005. Influence of integrated weed management on yield and economic viability of soybean (*Glycine max* (L.) Merrill) grown at different crop geometries. *Indian Journal of Agricultural Sciences* **75**(8): 510-2.

Singh Guriqbal. 2007. Integrated weed management in soybean (*Glycine max*). *Indian Journal of Agricultural Sciences* **77**(10): 675-6.

Tiwari J P, Kurchania S P, Paradkar N R and Bhalla C S. 1997. Varietal susceptibility and weed control efficiency of fluazifop-p-butyl in soybean (*Glycine max*). *Indian Journal of Agricultural Sciences* **67**(4): 147-9.

Soybean Research (Special Issue Number 2): 335-338: 2014

Status of Soybean Defoliators and Soybean Aphid in Manipur

NILIMA KARAM[1], T SUNANDA DEVI[2] and H NANITA DEVI[3]
All India Coordinated Research Programme on Soybean,
Directorate of Research, Central Agricultural University,
Imphal 795 001, Manipur, India
E mail: nilikaram@gmail.com

Key words: *Aphis* spp., *Helicoverpa armigera*, lepidopteran defoliators, *Spilarctia obliqua*

Soybean [*Glycine max* (L.) Mirrill] is a unique crop and one of the most important leguminous oil seed crops of great economic value, occupying an important position in the world trade. It is an excellent source of protein and oil. Manipur is a great biodiversity hot spot and the agro-climatic conditions are very conducive for the growth and multiplication of many species of insect-pests. (Azadthakur *et al*., 1987). These characteristics have made soybean to fit well in sustainable agriculture. In Manipur, soybean is mostly cultivated in the foothills and mid hills of Manipur. About 70 per cent soybean production in Manipur is mostly used for the production of a fermented food item known as *Hawaijar*. Soybean seed yield and quality are are being adversely affected by major insect-pests *viz*., girdle beetle, tobacco caterpillar, green semilooper, gram pod borer, jassids and white fly (Talekar and Chen, 1983). The defoliators [(*Spodoptera litura* (Fab.), *Diachrysia orichalcea* (Fab.), *Spilarctia obliqua* (Walk.) and *Helicoverpa armigera* (Hubner)] feeds on foliage, flower and pods causing significant yield loss (Rai *et al*., 1973; Singh and Singh, 1990). Soybean aphid has also been causing great economic loss to this crop (Wang *et al*., 1998). The objective this study was to find out the status co of defoliators and aphids of soybean in Manipur.

The study on pest incidence on soybean was conducted during *kharif* 2012 in Agricultural Research Farm, Central Agricultural University, Imphal, Manipur with soybean variety JS 335. Sowing of soybean was done on the second week of June 2012. A fixed survey on unprotected soybean field was conducted. Incidence of lepidopteran defoliators and aphid were recorded at weekly interval starting from one week after germination till the crop maturity. The number of defoliators and natural enemies were counted at three points in ten randomly selected one metre crop row leaving the border rows. Apid population was recorded on five leaves in ten randomly selected plants; three leaves from upper and two leaves from middle strata of the plant canopy. The defoliation was also rated on a visual scale of 1-5 where 1, 2, 3, 4 and 5 denotes 1-20, 20-40, 40-60, 60-80 and 80-100 per cent visual defoliation.

The studies on the seasonal incidence of insect-pests of soybean crop on variety JS 335 revealed that occurrence of insect-pest complex commenced from 20 days after germination. During the course of study, three insect species, *viz.,* gram pod borer [(*Helicoverpa armigera* (Hubner)], Bihar hairy caterpillar [(*Spilarctia obliqua* (Wlk.)] and soybean aphid (*Aphis* spp.) were observed as

[1]*Junior Entomologist;* [2]*Junior Agronomist;* [3]*Junior Plant Breeder*

the major pests causing damage at various growth stages of soybean crop in Manipur (Table 1). The two major lepidopteran defoliators *viz.*, gram pod borer, *H. armigera* and Bihar hairy caterpillar, *S. obliqua* were found defoliating in a large scale. *S. obliqua* larvae were gregarious in early instars and defoliating the plants extensively at later stages. Soybean aphid was observed attacking the crop by sucking cell sap during the entire crop season.

The activity of *S. obliqua* increased with the crop growth reaching peak activity in the last week of July recording 2.53 larvae per metre row length (mrl). Likewise, the incidence of *H. armigera* reached peak density

Table 1. Insect-pest observed on soybean variety JS 335 during *kharif* 2012 at Imphal, Manipur

Insect-pest	Range of incidence	Peak period of activity
Gram pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae)	0.13 - 3.47 larvae / mrl	Last week of July
Bihar hairy caterpillar, *Spilarctia obliqua* (Wlk.) (Lepidoptera: Arctiidae)	0.13 - 2.53 larvae / mrl	Last week of July
Soybean aphid, *Aphis* spp. (Hemiptera: Aphididae)	2.90 - 24.50 aphid / plant	Last week of July
Minor insect- pests : Tobacco caterpillar (*Spodoptera litura* (Fab.)), whitefly (*Bemisia tabaci* Genn.)		

Table 2. Seasonal incidence of lepidopteran defoliators and aphid on soybean variety JS 335 during *kharif* 2012

Standard Meteorological weeks	Population of insect-pests			Visual defoliation rating
	***Helicoverpa armigera* (larvae/mrl)**	***Spilarctia oblique* (larvae/ mrl)**	**Aphids (No/ plant)**	
26 week	0.00	0.00	0.00	0
27 week	0.20	0.07	0.00	0
28 week	0.27	2.27	3.60	0
29 week	0.40	1.07	10.70	1
30 week	**3.47**	**2.53**	**24.50**	1
31 week	1.00	1.47	10.60	1
32 week	0.47	1.07	11.30	1
33 week	0.40	0.27	15.80	1
34 week	0.20	0.40	14.50	1
35 week	0.13	0.00	7.80	1
36 week	0.13	0.00	2.90	1
	0.61	**0.83**	**9.25**	-

of 3.47 larvae per mrl during the last week of July (30 week). Both defoliators appeared after three and a half weeks of sowing and seasonal mean of lepidopteran defoliators was 1.44 larvae per mrl. During the whole period crop growth, defoliation by the two lepidopteran pests could be rated visually as 1 (1- 20 per cent defoliation). These results are in confirmation with the findings of Thippaiah (1997) that Bihar hairy caterpillar caused 40 per cent defoliation in soybean. Soybean aphid was recorded infesting the crop from second week of July onwards. The peak density of aphid (24.5 aphids/plant) was recorded during last week of July, and seasonal mean of 9.25 aphids per plant was observed during the season.

The activity of lepidopteran defoliators decreased gradually in the following weeks after peak period of incidence. The population of soybean aphid however remained high up to the pod development stage.

Among the biocontrol agents, spiders and ~~a~~ predatory coccinellids were observed (Table 3).

Table 3. Population of natural enemies recorded in the *kharif* 2012

Standard Meteorological weeks	No. of Spiders/ plant	No. of Coccinellids/ plant
26 week	0.00	0.00
27 week	0.00	0.00
28 week	0.10	0.00
29 week	0.10	0.00
30 week	0.20	0.30
31 week	0.20	0.30
32 week	0.00	0.60
33 week	0.40	0.00
34 week	0.10	0.10
35 week	0.30	0.20
36 week	0.00	0.10

Therefore it can be concluded that three insect species *viz.*, gram pod borer [*Helicoverpa armigera* (Hubner)], Bihar hairy caterpillar [*Spilarctia obliqua* (Wlk.)] and soybean aphid (*Aphis* spp.) were observed as the major pests on soybean variety JS 335 under Manipur condition causing damage at various stages of the crop. All these insects made their first appearance on the crop in the first week of July 2012. The three insect-pests reached their maximum population during the last week of July during which rainfall was intermittent with cloudy skies and very high relative humidity. C~~e~~occinellid and spider predators were also found in the soybean fields at Imphal, Manipur.

REFERENCES

Azadthakur N S, Firake D M, Behere G T, Firake P D and Saikia K. 1987. Biodiversity of agriculturally important insects in North eastern Himalaya: An overview. *Indian Journal of Hill Farming* **25**(2): 37-40.

Netam H K, Gupta R and Soni S. 2013. Seasonal incidence of insect pests and their biological agents on soybean. *Journal of Agriculture and Veterinary Science* **2**(2): 7-11.

Rai P S, Seshu Reddy K V and Govindan R. 1973. A list of insect pests of soybean in Karnataka state. *Current Research* **2:** 97-8.

Singh O P and Singh, K J. 1990, Insect pests of soybean and their management. *Indian Farming* **39**(100): 9-14.

Talekar N S and Chen B S. 1983. Seasonality of insect pests of soybean and mungbean in Taiwan. *Journal of Economic Entomology* **76**(1): 34-7.

Thippaiah M. 1997. Bioecology of semilooper, *Thysanoplusia orichalcea* (Fabricius) (Noctuidae :Lepidoptera) with observation on other pest complex of soybean and their management *M. Sc(Agri) Thesis,* University of Agricultural Sciences, Bangalore, Pp 142.

Wang C R, Chen J G, Guo Y R, Gong X Y, Xu Z F and Lin C. 1998. Development and control of soybean aphid *Aphis glycines* in Heilongjang province. *Soybean Bulletin* **6**: 15.

Soybean Research (Special Issue Number 2): 339-343: 2014

Status of Girdle Beetle Infestation in Marathwada Region

B B BHOSLE[1], B V BHEDE[2], A G BADGUJAR[3] and S T SHINDE[4],
College of Agricultural Biotechnology,
Vasantrao Naik Marathwada Krishi Vidhyapeeth,
Parbhani 431 402, Maharashtra, India
E mail: bbbhosle@gmail.com

Keywords : Girdle beetle, hot spots, soybean

Soybean is extensively cultivated oilseed crop in *kharif* season in India, particularly in Maharashtra. In last ten years, soybean gained popularity and the area under its cultivation expanded rapidly. Cultivation of soybean covered about 2.73 million hectares and produced about 4.32 million tonnes of seeds with a productivity of 1,581 kg per ha during 2010-11 in Maharashtra (http://www. mahaagri.gov.in/). The crop is reported to be attacked by 275 species of insects-pests, of which about two dozen are of economic importance (Rawat and Kapoor, 1968; Singh *et al.,* 1989). Whereas, in Maharashtra, particularly in Marathwada 19 species have been identified attacking soybean crop (Mundhe, 1980). The insect pests caused severe damage and consequent reduction in yield (Sharma, 1999). Soybean seed yield and quality are adversely affected by major insect-pests *viz.*, girdle beetle, tobacco caterpillar, green semilooper, gram pod borer, jassids and white fly and 15 - 20 per cent of the total soybean production is lost directly or indirectly by the attack of insect pests every year (Biswas, 2008). Girdle beetle, *Obereopsis brevis* (Coleoptera: Lamiidae) is one of the major insect-pests of soybean. Changing cropping pattern and climate leads to change in pest scenario. In different districts of Marathwada the girdle beetle infestation caused considerable yield losses. In evolving sound management strategies, detailed information on the spatial distribution of the pest is of great importance. Therefore, the present survey was conducted to know the status of girdle beetle in different districts of Marathwada region of Maharashtra, India.

To study the status of girdle beetle infestation, field surveys were conducted in Parbhani, Hingoli, Nanded, Latur, Osmanabad, Beed, Aurangabad and Jalna districts of Marathwada region of Maharashtra, India during 2010-2012. The fields of at least one acre were selected for recording observations. About 10 fields were observed from each taluka and five rows of one meter length were randomly selected for recording observations in each field. The survey was conducted two times *i.e.*, during second fortnight of August and September every year. The observations on number of infested plants in 1 m row were recorded and per cent infestation was worked out. The data was analyzed by using SAS 9.3 (SAS Institute Inc., 2011).

During the year 2010, the maximum girdle infestation was recorded in Parbhani taluka (10.8 %) and minimum in Pathri taluka (7.5 %). In 2011, the infestation was highest in

[1]*Associate Dean and Principal;* [2]*Assistant Professor (Entomology);* [3]*Research Associate*

Parbhani taluka, followed by Gangakhed, Pathri, Selu, Manvat and Jintur taluka of Parbhani district. The infestation was maximum in Gangakhed taluka (9.7 %) and minimum in Pathri taluka (4.2 %) during 2012 (Table 1).

In Hingoli district, the highest girdle beetle infestation was noticed in Sengaon taluka (21.50 %) during 2010 followed by Basmat (16.5 %), Kalamnuri (14.0 %) and Aundha nagnath (12.2 %). The lowest girdle beetle infestation was in Hingoli taluka (10.8 %). Similarly during 2011 the maximum girdle beetle infestation was in Sengaon (12.4 %) followed by Basmat, Aundha (8.5 %) and Kalamnuri (6.5 %) and minimum in Hingoli (5.1 %). In year 2012, the maximum girdle beetle infestation was recorded in Aundha (10.5 %) followed by Sengaon (9.5 %), Basmat (7.8 %) and Kalamnuri (7.0 %) and minimum in Hingoli (5.2 %). The girdle beetle infestation was maximum in Sengaon and minimum in Hingoli taluka (Table 1).

The data on girdle beetle infestation in Nanded district (Table 1) indicated that during 2010, maximum infestation of girdle beetle was recorded in Ardhapur taluka (14.2 %) followed by Hadgaon (14.0 %), Bhokar (13.5 %), Kinvat (12.7 %), Nanded(12.5 %), Kandhar (10.5 %), Degloor (10.0 %), Loha (8.6 % and) Mukhed (7.5 %).

During 2011, the per cent infestation of girdle beetle was maximum in Ardhapur (10.6 %) and minimum in Loha (5.0 %).During 2012, girdle beetle infestation was highest in Kandhar (12.2 %) followed by Ardhapur (11.5 %), Kinvat (10.5 %), Hadgaon, (10.0 %) Degloor (9.5 %) Bhokar (9.2 %), Nanded (8.5 %), Mukhed (7.6 %) andd Loha (6.5 %). Overall, maximum girdle beetle infestation was recorded during 2010 (11.50 %) and more in Ardhapur taluka (14.2 %).

In Latur district (Table 2) during 2010, maximum damage was recorded in Jalkot and Chakur taluka (7.5 %) followed by Latur (7.0 %) and minimum in Udgir (3.2 %) and during 2011 the highest girdle beetle damage was observed in Nilanga followed by Jalkot (7.2 %) and lowest damage in Ausa (2.5 %) taluka. Considering year 2012, the maximum girdle beetle damage was noticed in Jalkot (10.2 %) followed by Chakur Nilanga (8.5 %).

Consideration of girdle beetles damage in Osmanabad district revealed that during 2010 maximum damage was noticed in Osmanabad taluka (3.0 %) followed by Kalamab (2.7 %) where as during 2011, the highest girdle beetle infestation was noticed in Tulajapur (6.3 %), Osmababad (5.2 %), Bhoom (5.0 %), Omarga (4.0 %) and Kalamb (3.5 %). Regarding year 2012, the infestation was highest in Bhoom (9.2 per cent) and minimum in Osmanabad. (Table 2)

In Beed district (Table 3) during 2010 mean per cent infestation was 13.9 per cent. During 2010, lowest infestation was recorded in Majalgaon taluka (9.8 %) followed by Ambejogai (13.6 %), Parli vaijanath (14.0 %), Kej (14.5 %), Georai (15.0 %) and Beed (16.5 %). During 2011, girdle beetle infestation in Georai, Beed, Kej, Ambajogai, Parli Vaijanth, Majalgaon was 5.3, 5.2, 4.5, 3.0 per cent, respectively. The per cent infestation during 2012 was maximum in Parli Vaijanth (8.5 %), and minimum in Majalgaon (4.8 %). The maximum infestation of girdle beetle was recorded in year 2010 (13.5 %).

In Aurangabad district during 2010, the maximum infestation was recorded in Kannad taluka (7.0 %) followed by Khultabad (6.5 %), Aurangabad (6.0 %), Paithan (5.0 %) and Sillod (4.5 %). The overall mean infestation was 5.8 per cent in Aurangabad district during 2010. During 2011, the maximum infestation was recorded in Khulatabad (4.0 %) followed by Kannad (3.5 %), Aurangabad (2.5 %), Sillod (1.5 %) and

Table 1. Girdle beetle infestation (%) in soybean in Parbhani, Hingoli and Nanded districts during 2010-2012

Parbhani				Hingoli				Nanded			
Taluka	**2010**	**2011**	**2012**	**Taluka**	**2010**	**2011**	**2012**	**Taluka**	**2010**	**2011**	**2012**
Parbhani	10.8	10.2	8.6	Basmat	16.5	10.0	7.8	Hadgaon	14.0	8.5	10.0
Manvat	9.5	5.5	6.0	Aundha Nagnath	12.2	8.5	10.5	Bhokar	13.5	7.0	9.2
Selu	10.5	7.4	5.5	Hingoli	10.8	5.1	5.2	Nanded	12.5	6.2	8.5
Pathri	7.5	8.5	4.2	Kalamnuri	14.0	6.5	7.0	Kinvat	12.7	6.0	10.5
Jintur	7.7	4.4	5.0	Sengaon	21.50	12.4	9.5	Degloor	10.0	7.0	9.5
Gangakhed	9.8	9.0	9.7	-	-	-	-	Mukhed	7.5	5.2	7.6
-	-	-	-	-	-	-	-	Loha	8.6	5.0	6.5
--	-	-	-	-	-	-	-	Kandhar	10.5	7.5	12.2
--	-	-	-	-	-	-	-	Ardhapur	14.2	10.6	11.5
Mean	9.30	7.50	6.50	**Mean**	15.0	8.5	8.0	**Mean**	11.50	7.0	9.5
SD	1.39	2.19	2.16	SD	4.21	2.87	2.08	SD	2.44	1.74	1.81
SEm (+)	0.57	0.89	0.88	SEm (+)	1.88	1.28	0.93	SEm (+)	0.81	0.58	0.60
P value	**<0.0001**	**0.0004**	**0.0007**	**P value**	**0.0013**	**0.0027**	**0.001**	**P value**	**<0.0001**	**<0.0001**	**<0.0001**

Table 2. Girdle beetle infestation (%) in soybean in Latur, Osmanabd and Beed districts during 2010-2012

Latur				Osmanabd				Beed			
Taluka	**2010**	**2011**	**2012**	**Taluka**	**2010**	**2011**	**2012**	**Taluka**	**2010**	**2011**	**2012**
Udgir	3.2	5.3	6.5	Bhoom	2.0	5.0	9.2	Parli Vaijanath	14.0	4.0	8.5
Nilanga	6.5	8.0	8.5	Kalamb	2.7	3.5	6.5	Ambajogai	13.6	4.5	5.0
Ausa	6.2	2.5	5.5	Osmanabad	3.0	5.2	5.8	Kej	14.5	5.0	6.0
Latur	7.0	5.8	7.3	Omarga	2.5	4.0	8.5	Beed	16.5	5.2	7.5
Renapur	5.5	4.4	6.0	Tuljapur	2.4	6.3	8.0	Majalgaon	9.8	3.0	4.8
Chakur	7.5	6.0	8.5	-	-	-	-	Georai	15.0	5.3	7.2
Jalkot	7.5	7.2	10.2		-	-	-	-	-	-	-
Mean	6.2	5.6	7.5	**Mean**	2.5	4.8	7.6	**Mean**	13.9	4.5	6.5
SD	1.50	1.81	1.66	SD	0.37	1.09	1.41	SD	2.24	0.88	1.47
SEm (+)	0.56	0.68	0.62	SEm (+)	0.16	0.48	0.63	SEm (+)	0.91	0.35	0.60
P value	**<0.0001**	**0.0002**	**<0.0001**	**P value**	**0.0001**	**0.0006**	**0.0003**	**P value**	**<0.0001**	**<0.0001**	**0.0001**

Table 3. Girdle beetle infestation (%) in soybean in Aurangabad, Jalna and Marathwada region during 2010-2012

Aurangabad				Jalna				Marathwada			
Taluka	**2010**	**2011**	**2012**	**Taluka**	**2010**	**2011**	**2012**	**District**	**2010**	**2011**	**2012**
Sillod	4.5	1.5	6.8	Badnapur	5.5	3.5	8.0	Parbhani	9.3	7.5	6.5
Aurangabad	6.0	2.5	7.0	Jafrabad	7.8	4.5	5.0	Hingoli	15.0	8.5	8.0
Paithan	5.0	1.0	6.0	Jalna	3.2	4.8	7.5	Nanded	11.5	7.0	9.5
Kannad	7.0	3.5	8.5	Ambad	3.5	4.0	6.7	Latur	6.2	5.6	7.5
Khultabad	6.5	4.0	9.2	-	-	-	-	Osmanabad	2.5	4.8	7.6
-	-	-	-	-	-	-	-	Beed	13.9	4.5	6.5
-	-	-	-	-	-	-	-	Aurangabad	5.8	2.5	7.5
-	-	-	-	-	-	-	-	Jalna	5.0	4.2	6.8
Mean	5.8	2.5	7.5	**Mean**	5.0	4.2	6.8	**Mean**	8.65	5.57	7.48
SD	1.03	1.27	1.31	SD	2.12	0.57	1.31	SD	4.49	1.97	0.98
SE±	0.46	0.57	0.58	SEm (+)	1.06	0.28	0.65	SEm (+)	1.59	0.69	0.34
P value	**0.0002**	**0.011**	**0.0002**	**P value**	**0.0182**	**0.0007**	**0.0019**	**P value**	**0.001**	**<0.0001**	**<0.0001**

Paithan (1.6 %). During 2012, the maximum infestation was observed in Khultabad taluka (9.2 %) and minimum in Paithan (6.0 %). (Table 3)

The data on girdle beetle infestation in Jalna district (Table 3) revealed that the maximum damage was recorded in Jafarabad (7.8 %), Jalna (4.8 %) and Badnapur (8.0 %) during 2010, 2011 and 2012.

The data on average of girdle infestation in different districts of Marathwada revealed that the fields from Hingoli district recorded maximum infestation (15 %), followed by Beed, Nanded, Parbhani, Latur, Aurangabad, Jalna and lowest in Osmanabad district (2.5 %) during 2010. During the year 2011, the infestation was highest in Hingoli district (8.5 %) and lowest in Aurangabad district (2.5 %). During 2012, the girdle beetle infestation ranged between 6.5 to 9.5 per cent in different districts of Marathwada (Table 3).

Netam *et al.* (2013) observed peak activity of girdle beetle (3.2 damaged plants/m row) during last week of August. Uttam Kumar *et al.* (2012) recorded incidence of girdle beetle during vegetative, flowering and pod stage of soybean. Rai and Patel (1990) reported that the girdle beetle first appeared on 10th August and activity continued until 12th October. In the present investigation the girdle beetle infestation was recorded in all the district of Marathwada and became one of the major constraints in soybean production.

REFERENCES

Biswas G C. 2008. Insect pests and their management of soybean crop in Bangladesh, *Proceedings of the Workshop on Prospects and Performance of Soybean in Bangladesh* (M.A. Bakr Ed.) ORC, BARI, Gazipur, pp 67.

http://www.mahaagri.gov.in/

Mundhe D R. 1980. Insect-pest complex on soybean (*Glycine max* L. Merrills) in Marathwada region. *Journal of Maharashtra Agricultural Universities* **5**: 259-60.

Netam H K, Gupta R and Soni S. 2013. Seasonal incidence of insect pests and their biocontrol agents on soybean. *Journal of Agriculture and Veterinary Science* **2**: 7-11.

Rai R K and Patel R K. 1990. Girdle beetle, *Obereopsis brevis* Swed. Incidence in *kharif* soybean. *Orissa Journal of Agricultural Research* **3**: 163-5.

Rawat R R and Kapoor R H. 1968, Arthropod pest of soybean in M.P. *Conference on Soybean Production and Marketing*, September 20-23. Proceedings, NJKVV, Jabalpur, pp. 62-5.

SAS Institute Inc. 2011. SAS 9.3 Statements: Reference, Cary, NC: SAS Institute Inc.

Singh O P, Verma S N and Nema K K. 1989. *Insect-Pests of Soybean in India*, International Book Distributors, Book Sellers and Publishers, Deharadoon, India.

Sharma A N. 1999. *IPM System in Agriculture*. Aditya Books Pvt. Ltd. New Delhi 137-169.

Uttam Kumar, Sharma Pawan Kumar and Shrivastava Surabhi. 2012. Spectrum of insect pest complex of soybean (*Glycine max* (L.) Merrill) at Lambapeepal Village in Kota Region, India. *Journal of Biological Sciences* **1**: 80-2.

Soybean Research (Special Issue Number 2): 344-347: 2014

Evaluation of Yield Losses by Girdle Beetle, *Obereopsis brevis* in Soybean Crop in Parbhani District of Marathwada, Maharashtra

D G MORE[1], K S BAIG[2], D H SARANG[3] and D T PAWAR[4]
AICRP on Soybean, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani 431 402, Maharashtra, India
E mail: daya_more@ rediffmail.com

Key words: Girdle beetle, Maharashtra, soybean, yield loss

Soybean [*Glycine max* (L.) Merrill] has revolutionized the agriculture as well as generated economy of many countries. Among the major soybean growing countries, India ranks fourth in terms of area, but, it in terms of production it ranks fifth after China. In India soybean has become a leading oilseed crop with 25 per cent contribution towards total edible oil production besides earning foreign exchange of Rs 65850 million through export of DOC (Anonymous, 2012a). The area under soybean cultivation in India was 10.69 million ha in *kharif* 2012 with production of 12.68 million tonnes and productivity of 1,185 kg per ha. In Maharashtra, area under soybean was 3.21 million ha with production of 3.99 million tonnes and productivity of 1,243 kg per ha (Anonymous, 2012b). Since soybean is giving consistent yield and good monetary returns; the area under this crop in Maharashtra, particularly in Marathwada is increasing very fast replacing the cotton and other pulse crops. Insect-pests are one of the major constraints, which lead to low productivity. The crop is reported to be attacked by 273 species of insects. Mundhe (1982) identified 19 insect species attacking this crop in Marathwada. However, during last 3-4 years, the incidence of leaf miner (*Aproaerema modicella*) is found decreasing every year, whereas the incidence of girdle beetle (*Obereopsis brevis*), stem fly (*Melangromyza sojae*) and green semilooper (*Gesonia gema*) is showing an increasing trend (Anonymous, 2009, 2010 and 2011). The girdle beetle is a serious growing menace to the soybean in the region. Gangrade (1976) observed 75 per cent infestation of *O. brevis* in early stage of plant growth which reduced the pod and seed yield to the extent of 84.4 and 47.2 kg per ha, respectively. Since, practically no work has been carried out on the actual yield losses caused by girdle beetle at different levels of infestation and different period of time under Marathwada condition, the present investigation was undertaken.

A field experiment in a non-replicated design was conducted in *kharif* 2012 to evaluate the yield losses by girdle beetle, *Obereopsis brevis* in Parbhani district of Marathwada, Maharashtra. The variety JS 335 was planted on 6th July in 100 sq m area, out of which 5 sq m area was maintained fully protected from insect damage by using suitable insecticides (soil application of phorate 10 G @ 10 kg per ha followed by three sprays of insecticides *namely*, triazophos 40 EC @ 0.064 per cent, chlorantraniliprole 20 SC @ 0.04 per cent and quinalphos 25 EC @ 0.05 per cent.

[1] Junior Entomologist, [2] Soybean Breeder and O/I, [3and4]Senior Research Assistant

Ten healthy plants from protected area were selected and tagged. These plants were harvested separately and observations on number of pods per plant, number of seeds per plant and weight of seeds per plant were recorded. Average of these ten plants for these parameters were used for calculating reduction in number of pods and seeds per plant and the yield loss.

Girdle beetle infested plants were tagged with date at weekly interval starting from initiation of infestation to 60 DAG (on 35th, 42nd, 49th and 56th DAG). Observations on number of pods per plant, number of seeds per plant and weight of seeds per plant were recorded on individual plant basis and average per plant was worked out. Yield loss due to different levels of girdle beetle infestation at different period of time was calculated as follows.

Yield loss = A-B/A*100

Where, A- seed weight of 10 healthy plants (seed weight of 1 healthy plant x 10); B- seed weight of 9 healthy plants + seed weight of 1 girdle beetle infested plant.

This gave seed yield as obtained due to 10 per cent girdle beetle infestation on a particular week. Similarly, yield loss due to 20, 30, 40 and 50 per cent girdle beetle infestation for different weeks were calculated by changing seed ratio of healthy and infested plants.

Average number of pods per plant, number of seeds per plant and weight of seeds per plant of healthy plant were 31.9, 77.6 and 13.51 g, respectively (Table 1).

Observations on girdle beetle infested plants

The observations on girdle beetle infested plants were recorded at various crop stages. The plants infested by girdle beetle at 35 DAG (days after germination) recorded 21.56, 45.84 and 6.41 number of pods per plant, number of seeds per plant and weight of seeds per plant (g), respectively whereas it was 26.69, 57.24 and 7.80 g, respectively at 42 DAG. These parameters increased in plants infested by girdle beetle at 49 DAG and recorded 31.21, 66.21 and 8.89 numbers of pods per plant, number of seeds per plant and weight of seeds per plant (g), respectively. Whereas, these parameters were 31.47, 69.24 and 9.26 g, respectively in plants infested by girdle beetle at 56 DAG (Table 1).

Table 1. Yield parameters of healthy and girdle beetle infested plants

Crop stage	Parameter		
	Pods (No/ plant)	Seeds (No/ plant)	Seed weight (g/plant)
Healthy plants	31.9	77.6	13.51
Girdle beetle infested lants			
35 DAG	21.56	45.84	6.41
42 DAG	26.69	57.24	7.80
49 DAG	31.21	66.21	8.89
56 DAG	31.47	69.24	9.26

DAG - days after germination

Losses due to girdle beetle in number of pods per plant

The losses in number of pods per plant decreased with increasing crop age. Data clearly indicated that at the early stage of infestation (35 DAG), the reduction in respect of number of pods per plant was comparatively high (3.24 to 16.20 with 10 to 50 % infestation). As the crop age advanced, it was in the range of 1.63 to 8.15, 0.21 to 1.05 and 0.13 to 0.65 at 42, 49 and 56 DAG, respectively (Table 2).

Losses due to girdle beetle in number of seeds per plant

At the early stage of infestation (35 DAG), the reduction in respect of number of seeds per plant was comparatively high (4.09 to 20.46 with 10 to 50 % infestation). As the crop age advanced, it was in the range of 2.62 to 13.14, 1.46 to 7.35 and 1.07 to 5.39 at 42, 49 and 56 DAG, respectively (Table 2).

Losses due to girdle beetle in seed weight per plant

The losses in seed weight caused by girdle beetle decreased with increasing crop age. Results indicated that at the early stage of infestation (35 DAG), the comparative losses in respect of seeds weight per plant were high (5.26 to 26.32 with 10 to 50 % infestation). As the crop age advanced, it was in the range of 4.26 to 21.17, 3.45 to 17.13 and 3.17 to 15.76 at 42, 49 and 56 DAG, respectively (Table 2).

Table 2. Reduction in number of pods per plant, seeds per plant and seed weight per plant due to girdle beetle infestation

Girdle beetle infestation (%)	35 DAG	42 DAG	49 DAG	56 DAG
	Per cent reduction in number of pods/plant at different crop stage			
10	3.24	1.63	0.21	0.13
20	6.48	3.26	0.42	0.26
30	9.72	4.89	0.63	0.39
40	12.96	6.52	0.84	0.52
50	16.20	8.15	1.05	0.65
	Per cent reduction in number of seeds/plant at different crop stage			
10	4.09	2.62	1.46	1.07
20	8.18	5.27	2.95	2.16
30	12.27	7.89	4.41	3.24
40	16.36	10.52	5.88	4.32
50	20.46	13.14	7.35	5.39
	Per cent yield loss in seed weight/plant at different crop stage			
10	5.26	4.26	3.45	3.17
20	10.56	8.49	6.87	6.32
30	15.81	12.72	10.29	9.46
40	21.07	16.94	13.71	12.61
50	26.32	21.17	17.13	15.76

Bardner and Fletcher (1974) reported that late infestation of plants by the beetle did not cause any mortality but the weights of pods and seeds of healthy plants were 2.9 and 3.0 times more than those of attacked plants. They further reported that the loss of pods and seeds amounted to 84.4 kg and 47.2 kg per ha at an average plant infestation of 8.7 per cent. More or less similar results were obtained in the present study as the weight of seeds of healthy and girdle beetle infested plants at 10 per cent level of infestation were 13.67 and 5.62 g, respectively indicating more than twice losses in seed weight. Kapoor *et al*. (1971) observed that the weight of pods per plant and yield of seed per plant in girdle beetle infested plants was 6.8 g and 4.76 g whereas these figures in un-infested plots were 27.02 and 9.35 per plant, supporting the findings of present investigation. Chechani *et al.* (1999) observed 40.27 per cent avoidable losses whereas, Bhargava and Joshi (1987) reported that insect-pest complex significantly affects per plant number of pods, weight of grains and weight per grain with 63.17 per cent avoidable net loss in soybean which partially supports the findings of present investigation.

ACKNOWLEDGEMENTS

The authors are thankful to the Directorate of Soybean Research, Indore, Madhya Pradesh, for providing the technical support during the course of investigation.

REFERENCES

Anonymous. 2009, 2010 and 2011. *Annual Report of All India Coordinated Research Project on Soybean*, VNMKV, Parbhani.

Anonymous. 2012a. *Director's Report and Summary Tables of Experiments 2012-13*, All India Coordinated Research Project on Soybean, Directorate of Soybean Research, Indore, Madhya Pradesh.

Anonymous. 2012b. www.sopa.org/ crop.po.doc

Bardner R and Fletcher K E. 1974. Insect infestation and their effects on the rowth and yield of field crops: a review. *Bulletin of Entomological Research.* **64**: 141-60

Bhargava G K and Joshi F L. 1987. Assessment of losses due to insect pests of soybean. *Indian Journal of Applied Entomology* **1**: 93-6.

Chechani V K, Joshi F L, Meena V R and Sharma U S. 1999. Assessment of losses caused by insect pests of soybean, *Glycine max* (L.) Merrill. *Indian Journal of Applied Entomology* **13**: 65-9.

Gangrade G A. 1976. Assessment of effect on yield and quality of soybean caused by major arthropod pests. Terminal Technical Report on the Project, JNKVV, Jabalpur, Madhya Pradesh, pp 143.

Kapoor K N, Gangrade G A and Gujarati J P. 1971. Note on the effect of infestation by *O. brevis* Swed on pods and yield of soybean. *Indian Journal of Agricultural Sciences* **41**(3): 272-3.

Mundhe D R. 1982. Insect-pest complex on soybean (*Glycine max*) in Marathwada region. *Journal of Maharashtra Agricultural Universities* **5**(3): 259-61.

Soybean Research (Special Issue Number 2): 348-352: 2014

MAUS 158: High Yielding Stem-fly tolerant Variety of Soybean Released for Marathwada region of Maharashtra

K S BAIG[1], D G MORE[2], D H SARANG[3] and D T PAWAR[4]
All India Coordinated Research Project on Soybean,
Vasantrao Naik Marathwada Krishi Vidyapeeth,
Parbhani 431 402, Maharashtra, India
E mail: khizerbaig1@rediffmail.com

Key words: Early maturing, soybean, variety, stem fly tolerant

In India, the area under soybean has increased up to 10.7 million hectare during 2012 (Anonymous, 2012). Under All India Coordinated Research Project on Soybean, 102 varieties has been released for different agro-climatic zones as well as developed improved production technology which helped to increase in the area, production and productivity of soybean in India. However, with the increase in area, the problems of pests and diseases are also increasing every year. Hence, there is urgent need to develop suitable high yielding early varieties of soybean coupled with pests and disease tolerance. Stem fly, girdle beetle are the major pests causing extensive damage to crop (Satyavathi *et al.*, 2005). The infestation of girdle beetle and stem fly are increasing in Marathwada region of Maharashtra since last couple of years, Therefore, there is need to develop stem-fly tolerant varieties coupled with earliness to minimize the losses. Previously, few stem-fly tolerant varieties *viz.*, JS 335, JS 93 05, JS 95 60, MAUS 47, NRC 7 *etc.*, were released for general cultivation in Central zone (Agarwal *et al.*, 2010).

The variety MAUS 158 was developed by adopting pedigree method of breeding from cross of Punjab 1 x DS 87-14 under All India Coordinated Research Project on Soybean, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The parent Punjab 1 was developed by Punjab Agricultural University, Ludhiana, whereas DS 87 14 was germplasm line maintained under All India Coordinated Research project on Soybean at Parbhani. After F_8 generation, the variety MAUS 158 was tested during *kharif* in preliminary station trials for four years (1999-2002) at Parbhani, initial evaluation trial, advance varietal trials for three years (2004-2006) and 33 state multi-location varietal trials for four years (2004-2007). Overall, MAUS 158 was tested in 55 breeding trials conducted for 10 years (1999-2008) in replicated trials under standard design and showed its superiority over local checks (MAUS 71 and MAUS 81) and national check JS 335.

Evaluation in station, state multi-location and national trials

In four station trials conducted during *kharif* season under rainfed conditions at Parbhani during 1999-2002, the variety MAUS 158 had recorded 16.93 percent increase over national check, JS 335 (Table 1). On an average of 33 state multi-location varietal trials conducted on nine locations in Maharashtra (Parbhani, Aurangabad, Latur, Tuljapur, Kasbe Digraj, Amrawati, Buldhana,

[1]Soybean Breeder; [2]Junior Entomologist; [3and4]Senior Research Assistant

Jalgaon and Pune) during 2004 to 2007, the variety MAUS 158 recorded 6.25, 14.20 and 13. 18 per cent increase over national check, JS 335 and local checks namely, MAUS 71 and MAUS 81, respectively. In All India Coordinated Project trials conducted over four locations in Maharashtra (Amrawati, Jalna, Nagpur and Parbhani) during 2004 to 2006, on an average of 12 trials the variety MAUS 158 recorded 16.31, 12.58 and 21.82 per cent increased yield over national checks *viz.*, Bragg, JS 335 and JS 93 05, respectively (Anonymous, 2004, 2005, 2006).

Thus, on an average of 55 breeding trials conducted over 10 years, the variety MAUS 158 recorded 17.46, 10.08 and 13.34 per cent increase over national check, JS 335 and local checks MAUS 71 and MAUS 81, respectively (Table 1).

Table 1. Summary data of MAUS 158 in different varietal trials conducted during 1999-2000 to 2008-2009

Particulars	Year of testing	No. of trials	Seed yield (kg/ha)				Per cent increase over		
			MAUS 158	JS 335	MAUS 71	MAUS 81	JS 335	MAUS 71	MAUS 81
Preliminary station trials	1999-2002	4	2120	1813	--	--	16.93	--	--
Initial state multi-location varietal trials	2003-2004	4	2279	1865	2010	1756	22.20	13.38	29.78
State multi-location varietal trials	2004-2007	33	2190	2061	1918	1935	6.25	14.20	13.18
AICRP on Soybean trials	2004-2006	12	1825	1621	--	--	12.58	--	--
Advanced station trials	2007-2008	2	2884	2260	2233	2292	27.61	29.15	25.83
	1999-2008	**55**	**2260**	**1924**	**2053**	**1994**			
Per cent increase over				**17.46**	**10.08**	**13.34**			

Performance of MAUS 158 for disease and pest reaction

The variety MAUS 158 was tested against various diseases for three years under natural conditions on four locations (Indore, Kota, Sehore, Jabalpur) in central zone during 2004 to 2006 under All India Coordinated Research Project on Soybean and was found tolerant to several diseases *viz.*, bacterial pustules, Rhizoctonia root rot, Rhizoctonia aerial blight, Phyllostica leaf spot, collor rot, charcol rot, target leaf spot, and Cercospora leaf spot (Table 2).

Table 2. Mean reaction of MAUS 158 to major diseases in All India Coordinated Research Project on Soybean trials (2004- 2006) under natural conditions in central zone (Indore, Jabalpur, Kota and Sehore)

Disease	MAUS 158	Bragg	JS 335	JS 93 05	JS 97 52
Bacterial pustules	0.7 HR	2.6 R	1.5 R	1.5 R	0.4 HR
Myrotheceum leaf spot	4.5 MR	5.5 MS	5.2 MS	4.0 MR	4.1 MR
Rhizoctonia root rot	1.3 R	3.0 MR	2.3 R	1.6 R	1.0 HR
Rhizoctonia aerial blight	2.5 R	5.0 MS	4.5 MR	4.0 MR	3.5 MR
Phyllostica leaf spot	1.0 HR	NT	NT	NT	1.0 HR
Collor rot	2.8 R	1.5 R	1.2 R	1.0 HR	1.9 R
Yellow mosaic virus	3.0 MR	5.0 MS	5.0 MS	3.0 MR	1.7 HR
Cotyledonary spot (%)	6.2 MS	4.2 MR	4.6 MR	NT	8.6 S
Alterneria leaf spot	5.8 MS	3.0 MR	3.0 MR	NT	4.0 MR
Charcol rot	1.0 HR	3.4 R	0.6 HR	1.3 R	0.0 AR
Target leaf spot	1.0 HR	4.0 MR	4.0 MR	2.0 R	1.0 HR
Cercospora leaf spot	1.0 HR	6.0 MS	4.0 R	1.0 HR	2.0 R

The variety MAUS 158 was also tested for insect-pest reaction in coordinated trials in central zone during 2004 to 2006 under natural field conditions and was found highly resistant against pod borer damage, resistant against stem fly (% tunneling) and leaf miner (leaflet damage) and moderately resistant against girdle beetle (% infestation), defoliators, G. *Gemma*, C. *acuta* and S. *litura* (Table 3).

The variety MAUS 158 had been categorized as resistant genotype by Maximin-Minimax method for stem fly and pest complex on the basis of consistent performance for pest resistance in screening trials conducted during 2004 and 2005 at various locations in the country.

Table 3. Pooled mean reaction of MAUS 158 in All India Coordinated Research Project on Soybean trials to insect-pests under natural condition in central zone (2004-2006)

Insect-pest	Loca-tions	MAUS 158	Bragg	JS 335	JS 93- 05	JS 97- 52
Stem fly (% tunneling)	10	17.31 R	24.91 MR	15.17 R	17.93 R	19.48 R
Leaf miner (Leaflet damage)	3	3.36 R	7.82 S	2.40 MR	3.46 R	4.80 R
Girdle beetle % (infestation)	4	16.00 MR	10.75 R	20.0 MR	10.73 R	18.10 MR
Defoliators	5	2.62 MR	4.03 LR	5.04 LR	5.73 S	3.00 LR
Pod borer damage	3	45.06 HR	48.66 HR	43.4 HR	24.32 HR	37.82 HR
G. gemma	1	1.3 MR	0.1 HR	1.9 LR	1.5 MR	2.9 HS
C. acuta	2	5.5 MR	4.25 MR	4.2 MR	4.4 MR	1.95 R
S. litura	3	1.96 MR	2.8 MR	3.16 MR	2.68 MR	1.63 MR

These short duration varieties help to overcome moisture stress problems and fit well in multiple cropping systems and maintain yield levels under variable planting time under rainfed conditions. The variety MAUS 158 matures early in 93-98 days. At present soybean cultivators are facing lot of difficulties at the time of harvesting and threshing, therefore, development and promotion of non-shattering varieties is the need of the day (Samra and Ramachandra, 2009). The variety MAUS 158 is tolerant for seed shattering for 15 days after physiological maturity. It contains about 42.4 per cent protein and 19.7 per cent oil with average test weight of 10 to 12 g. Good field emergence and longer seed viability have always been problems in soybean, the variety MAUS 158 recorded 96.0 per cent field emergence and 87.0 per cent germination after 12 months storage under ambient conditions. MAUS 158 is having semi-determinate growth habit, glabrous dark green leaves with purple flower colour. It had received National identity number IC 584050 from NBPGR and notified vide Government of India notification No. S. O. 2136 (E) August, 31, 2010. The variety MAUS 158 was released for general cultivation in Marathwada region of Maharashtra during 2009 and gaining popularity in the state and will help to replace area under JS 335 in coming years.

REFERENCES

Agarwal D K, Hussain S M, Ramteke R, Bhatia V S and Srivastava S K. 2010. *Soybean Varieties of India*, Directorate of Soybean Research, Indore, Madhya Pradesh, India, Pp 47.

Anonymous. 2004. *Directors Report and Summary Tables of Experiments 2002-2003*, All India coordinated Research Project on Soybean. Directorate of Soybean Research, Indore, Madhya Pradesh, Pp 31.

Anonymous. 2005. *Directors Report and Summary Tables of Experiments 2003-2004*, All India coordinated Research Project on Soybean, Directorate of Soybean Research, Indore Madhya Pradesh, Pp 36.

Anonymous. 2006. *Directors Report and Summary Tables of Experiments 2004-2005*. All India coordinated Research Project on Soybean, Directorate of Soybean Research, Indore Madhya Pradesh, Pp 41.

Anonymous. 2012. Annual Report 2012-13, Directorate of Soybean Research, Indore, Madhya Pradesh.

Samra J S and Ramachandra K S. 2009. *Soybean Based Farming Systems for Improving Livelihood of Rainfed Areas,* Policy paper-I, National Rainfed Area Authority, Ministry of Agriculture, Government of India, New Delhi, Pp. 27

Satyavathi Tara C, Hussain S M, Chauhan G S, Karmakar P G and Bharadwaj C. 2005. *Improved Soybean Varieties of India*. National Research Centre for Soybean, Indore, Madhya Pradesh, India, Pp 9.

Soybean Research (Special Issue Number 2): 353-356: 2014

MAUS 162: New High Yielding Soybean Variety Suitable for Mechanical Harvesting

K S BAIG[1], D G MORE[2], D H SARANG[3] and D T PAWAR[4]
All India Coordinated Research Project on Soybean,
Vasantrao Naik Marathwada Krishi Vidyapeeth,
Parbhani 431 402, Maharashtra, India
E mail: khizerbaig1@rediffmail.com

Key words: Mechanical harvesting, soybean, variety

Most of the soybean varieties developed in the country has shown narrow adoptability with unstable yield. The only exception is JS 335, which is cultivated on more than 40 per cent area in the country. However, the monoculture expansion of this variety may lead to rapid out-break of pest/diseases more frequently in one or other parts of the country. In addition, yield losses up to 10 to 15 per cent are frequently reported due to shattering in prevailing varieties if not harvested within 10-15 days after physiological maturity due to non-availability of labours at the time of harvesting. Thus, there is urgent need to have an additional non-shattering variety having suitability for mechanical harvesting for Marathwada region of Maharashtra. The variety NRC 37 (Ahilya 4) released by Directorate of Soybean Research, Indore is presently in seed chain having suitability for mechanical harvesting for central zone (Agarwal *et al*., 2010).

The variety MAUS 162 was developed by pedigree method from cross of JS 335 x Kalitur 3 at All India Coordinated Research Project on Soybean, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra), India. The parent JS 335 was developed by Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, whereas Kalitur 3 was selection from local indigenous native variety of Madhya Pradesh. After F_7 generation, the variety MAUS 162 was tested during *kharif* season in preliminary station trials for three years from 2000 to 2002 at Parbhani, initial varietal trials (IVT) over nine locations in central zone during 2002 (Parbhani, Amrawati, Nagpur, Jalna, Amlaha, Indore, Jabalpur, Kota and Sehore) and advance varietal trial I (AVT I) and II (AVT II) during 2003 and 2004, respectively at Parbhani. Simultaneously, the variety MAUS 162 was also tested in 29 state multilocation varietal trials conducted on 10, 8 and 11 locations during 2004, 2005 and 2006, respectively. Overall, the variety MAUS 162 was tested in 48 breeding trials conducted during 2000 to 2011. Popular local checks MAUS 47, MAUS 71 and MAUS 81 were used, whereas, JS 335 was used as national check. The experiment was conducted in randomized block design at all the locations. The analyses of variance were performed as per method suggested by Panse and Sukhatme (1985). The recommended package of practices was followed in each year at each location to raise the good crop.

[1]*Soybean Breeder;* [2]*Junior Entomologist;* [3an4]*Senior Research Assistant*

Evaluation in station, national and state multilocation trials

The variety MAUS 162 was tested in three station trials during *kharif* season under rainfed conditions at Parbhani (2000 to 2002) (Table 1). MAUS 162 recorded 36.98 and 32.91 per cent increase over local check (MAUS 47) and national check (JS 335), respectively. On an average of eleven trials conducted during 2002 to 2004 under All India Coordinated Research Project, the variety MAUS 162 recorded 25.2, 49.74 and 9.32 per cent increase over local check, MAUS 47 and national checks, Bragg and JS 335, respectively (Anonymous, 2002,2003 and 2004). Similarly, on an average of 29 trials, the variety MAUS 162 recorded 16.17, 20.25 and 11.60 per cent increased yield over local checks, MAUS 71, MAUS 81 and National check, JS 335 respectively, in state multilocation varietal trials conducted over eleven locations in Marathwada, Vidharbha and Western Maharashtra during 2004 to 2006. Thus, on an average of 48 trials conducted during 2000-2001 to 2011-2012, the variety MAUS 162 recorded 49.75, 9.94, 14.51 and 13.90 per cent increased yield over checks *viz*., MAUS 47, MAUS 71, MAUS 81, and JS 335, respectively (Table 1).

Performance of MAUS 162 for mechanical harvesting traits and pest reaction

The most important criterion for mechanical harvesting suitability is plant height and bottom most pod height. The plant height (74.42 cm) and bottommost pod height (11.32 cm) of MAUS 162 is more than MAUS 71, where as the per cent pods remaining on the plant after harvesting with combined harvester were found less in case of MAUS 162 (2.51 %) compared to MAUS 71 (5.52 %)(Table 2). It contains about 42.0 per cent protein and 21.0 per cent oil and retained more than 74 per cent germination in accelerated ageing test after 96.0 h. MAUS 162 is quite distinct from all other existing varieties in the state in terms of semi indeterminate erect plant type with pod bearing habit upto the growing tip of plant. Maturity duration is around 100-103 days with average plant height of 74.42 cm. The variety MAUS 162 has been found highly resistant against for stem tunneling, where as it was found moderately resistant against girdle beetle infestation and least resistant against stem fly infestation (Table 3).

Soybean cultivators are now facing problems of labour shortage particularly at the time of harvesting resulting into yield losses up to 10 to 15 per cent due to shattering and non-availability of suitable genotypes for machine harvesting. The bottom most pod height of proposed variety MAUS 162 is more compared to local check, MAUS 71 apart from its erect plant type. Hence, this variety is found more suitable for machine harvesting apart from high yielding and non-shattering trait. State variety release committee recommended MAUS 162 for general cultivation in Marathwada region of Maharashtra during April, 2013. The variety MAUS 162 has been awarded national identity number IC 593957 by NBPGR, New Delhi.

Table 1. Summary data of MAUS 162 in 48 different varietal trials conducted during 2000 to 2011

Particulars	Year of testing	No of trials	Seed yield (kg/ha)						% Increase over				
			MAUS 162	MAUS 47	MAUS 71	MAUS 81	Bragg	JS 335	MAUS 47	MAUS 71	MAUS 81	Bragg	JS 335
Initial station trials	2000-2002	03	2100	1533	--	--	--	1580	36.98	--	--	--	32.91
AICRPS trials	2002-2004	11	1746	1394	--	--	1166	1597	25.20	--	--	49.74	9.32
Advance station trials	2008-2011	4	3166	--	2704	2508	--	2532	--	17.09	26.24	--	25.04
State multi-location varietal trials	2004-2006	29	2155	--	1855	1792	--	1931	--	16.17	20.25	--	11.60
Off season trial	2002	01	1180	--	1022	1013	--	1000	--	15.46	16.49	--	18.00
	Mean	**48**	**2122**	**1417**	**1930**	**1853**	**1166**	**1863**					
Per cent Increase over				**49.75**	**9.94**	**14.51**	**81.98**	**13.90**					

Table 2. Mean performance of MAUS 162 for bottommost pod height and other traits in mechanical harvesting experiment during *kharif* season of 2010 at Parbhani

Variety	Plant height (cm)	Bottom most pod height (cm)	Length of stem after harvesting (cm)	% pod remaining on plant	% of broken seeds	% of whole seeds	Branches (No / plant)	Pods (No / plant)	Protein content (%)	Oil content (%)
MAUS 162	74.42	11.32	6.0	2.51	0.49	99.51	1.94	30.68	41.95	21.37
MAUS 71	41.97	8.60	6.0	5.52	0.53	99.47	2.92	17.87	42.76	21.56

Table 3. Categorization of MAUS 162 against major pests by following Maximini-minimax method (Data pooled of 2007 and 2008)

Genotype	Stem fly infestation (%)	Girdle beetle infestation (%)	Stem tunneling (%)
MAUS 162	18.95 (25.66)* LR	16.11 (23.63) MR	23.91 (29.22) HR
Bragg	13.26 (21.24) HR	9.44 (17.82) HR	34.40 (35.88) LR
JS 93 05	12.82 (20.91) HR	15.22 (22.90) MR	30.83 (33.67) R
JS 97 52	23.28 (28.69) HS	23.19 (28.66) HS	31.34 (33.91) MR
MAUS 71	25.00 (29.92) HS	11.91 (20.18) HR	24.66 (29.66) HR
MAUS 158	16.64 (24.05) MR	18.90 (25.49) LR	39.60 (38.96) HS
JS 335	9.84 (18.25) HR	9.79 (18.23) HR	37.82 (37.93) HS
SEm (±)	1.93	1.64	1.69
C D (p = 0.05)	**5.34**	**4.54**	**4.67**

**Figures in parenthesis indicates angular transformed values; LR (Least resistant); MR (Moderately resistant); R (Resistant); HR (Highly resistant); HS (Highly susceptible)*

REFERENCES

Agarwal D K, Hussain S M, Ramteke R, Bhatia V S and Srivastava S K. 2010. *Soybean varieties of India*, Directorate of Soybean Research, Indore, Madhya Pradesh, India, Pp 47.

Anonymous. 2002. *Directors Report and Summary Tables of Experiments 2002-2003*, All India coordinated Research Project on Soybean. Directorate of Soybean Research, Indore, Pp 30.

Anonymous. 2003. *Directors Report and Summary Tables of Experiments 2003-2004*, All India coordinated Research Project on Soybean, Directorate of Soybean Research, Indore, Pp 41.

Anonymous. 2004. *Directors Report and Summary Tables of Experiments 2004-2005*. All India coordinated Research Project on Soybean, Directorate of Soybean Research, Indore, Pp 41.

Panse V G and Sukhatme P V. 1985. *Statistical Methods for Agricultural Workers*, 2^{nd} Edn., ICAR, New Delhi.

Soybean Research (Special Issue Number 2): 00-00: 2014

Yield Improvement in Soybean through Group Approach with PPP Mode in Dahitne Cluster of Barshi Tahsil

P A GONJARI[1], A B SHASTRI[2] and L R TAMBADE[3],
Kirishi Vigyan Kendra (Mahatma Phule Krishi Vidyapeeth),
Solapur 413 255 Maharashtra, India
E mail: kvksolapurtech@rediffmail.com

Key words: Group approach, improved varieties, integrated nutrient management, public private partnership mode

In Solapur district of Maharashtra, soybean is cultivated on the area of 15,515 ha with district productivity of 1,660 kg per ha. The Krishi Vigyan Kendra, Solapur under took frontline demonstrations and trainings on the basis of participatory rural appraisal in its adopted village Dahitne (Barshi tehsil) in *kharif* 2012. The area under soybean in Dahitne has 246 ha area with a productivity of 1,065 kg per ha, which is far lower than the district average. Participatory rural appraisal brought out that these farmers were hesitant in adoption of new technology and non-availability of quality seed of improved varieties, lack of knowledge on *in situ* moisture conservation and use of integrated approach for nutrient and pest management and also lack group approach, were the reasons of low productivity. For tackling the problem of soybean growers Krishi Vigyan Kendra, Solapur made systematic efforts and conducted the study for assessing the impact of institutional backstopping on yield improvement with the objectives (i) to study the increase in yield of soybean due to use of improved variety along with integrated nutrient management and (ii) to assess the impact of group approach with private partnership mode in procurement of improved inputs and disseminating the technical knowhow.

The Dahitne cluster of Barshi tahsil of Solapur district was selected purposely for the study based on more area under soybean and higher responsive-ness among farmers. The outcome participatory rural appraisal conducted by Krishi Vigyan Kendra, Sholapur in the study area brought forth that the cause of low productivity of soybean was use of local cultivars and negligence in proper fertilizer management. To address this, thirteen frontline demonstrations on 5.2 ha area involving use of improved variety JS 93-05 and integrated nutrient management (15 t FYM/ha + recommended dose of fertilizers @ 50:75:00:: $NP_2O_5K_2O$ kg/ha) were organized. Seeds were inoculated with rhizobium and phosphate solublizing bacteria @ 25 g per kg seeds before sowing. For *in situ* soil moisture conservation, sowing was done across the slope and after preparation of square bunds at 6 m x 6 m (medium soil) and 10 m x 10 m (deep soil). Data from these frontline demonstrations were collected from the farmers in prescribed format, which was pretested and finalized on the basis of suggestions given by the experts. Observations on pod number per plant on

[1]*Subject Matter Specialist (Agricultural Extension);* [2]*Subject Matter Specialist (Agronomy);* [3]*Programme Coordinator*

randomly selected ten plants from each demonstration and the seed yield was worked out on the basis of crop cut operation. Data was compared with the bench mark survey to analyze the results.

To work in public private participatory mode, the Krishi Vigyan Kendra, Solapur coordinated with Maharashtra State Seed Corporation Ltd., State Agriculture Department, Zilla Parishad, Sholapur, Mahatma Phule Krishi Vidyapeeth, Rahuri, NABARD, Solapur, Agriculture Technology Management Agency and Vasantrao Naik Marathwada Agriculture University, Parbhani for procurement of improved variety seeds and other critical inputs. Group approach, which is said to be the restructured extension mechanism (Ayyappan *et al*., 2007), was utilized successfully in the present study.

The Krishi Vigyan Kendra, Solapur conducted different extension activities like group discussion, exposure visit, filed day, kisan goshti. Farmers were supported with the strong agro-advisory through tele-helpline, Kissan Mobile Advisory Services and Scientist visit to farmers' field.

The impact of group approach was assessed in terms of savings made in common procurement of improved seed and other critical inputs.

Front line Demonstration

The seed yield achieved in the front line demonstrations was remarkably higher by 79.74 per cent as compared to local practice (Table 1). The higher productivity achieved through front line demonstration could be explained on the basis of optimum plant density resulting in better dry matter production and higher number of pods per plant. Integrating fertilizers with biofertilizers like rhizobium and phosphorus solublizing bacteria could provide appropriate nutrients in these demonstrations. Such an advantage in growth and seed yield of *Sesbania aculeta* due to appropriate plant density and nutrition was reported by Yaragoppa *et al*. (2003). These results also corroborated the findings of Reddy *et al*. (1999) in case of soybean-wheat cropping system. An average of interventions made by Krishi Vigyan Kendra, Solapur led to seed yield improvement by 57.32 per cent. Higher B:C ratio of 4.80 was recorded in front line demonstrations beneficiaries of Krishi Vigyan Kendra. As viewed in the frontline demonstrations, the highest economic returns of Rs 68,979 per ha were achieved due to the use of improved variety (JS 93-05) and integrated nutrient management, which was followed by improved variety (JS 93-05) and soil moisture conservation (Rs 59, 736/ha) and improved varieties with recommended fertilizers (Rs 54,992/ha). The old variety (JS 335) was replaced by 73.35 per cent area in Dahitne cluster.

Impact of group approach with public private partnership mode in procurement of improved inputs

The adopted group approach could convince 455 farmers of Dahitne village to procure seed of improved varieties (JS 93-05 and MAUS 158) in unison resulting in purchase of 15, 155 kg and thereby saving Rs 1,86,120. Another critical input (rhizobium and phosphorus solubilizing bacteria, 150 kg each) were also purchased for the seed treatment to cover an area of 80 ha by the farmers (Table 2). Due to these interventions made by KVK, Solapur, a total of 455 farmers from Dahitne cluster were able to increase the productivity of soybean by 581 kg per ha. The efforts made in public private partnership mode were most effective.

The study suggested that a model involving public private partnership and

Table 1. Yield components of soybean as influenced due to use of improved variety and integrated nutrient management

KVK Intervention	Pods (No/plant)		Seed yield (kg / ha)		Increase over local practice (%)	Cost of cultivation		Gross returns		B:C ratio	
	Demo-nstration	Local practice	Demo-nstration	Local practice		Demo-nstration	Local practice	Demo-nstration	Local practice	Demo-nstration	Local practice
Soil moisture conservation techniques and front line demonstrations with improved variety JS 93-05	99	68	2267.53	1408.39	61.00	17360	16725	77096	46477	4.60	2.77
Front line demonstrations (improved variety JS 93-05 + integrated nutrient management)	117	69	2562.18	1425.45	79.74	18135	16725	87114	47040	4.80	2.81
Common procurement of seed of improved variety and biofertilizers MAUS 158 and JS 93- 05	98	67	2075.80	1415.80	46.61	17475	16531	70577	46721	4.04	2.82
Improved varieties(JS 93-05 and MAUS 158) + recommended fertilizers	97	70	2153.60	1508.50	42.76	18230	16835	73222	49781	4.01	2.95
Average	**102**	**69**	**2264.77**	**1439.53**	**57.32**	**17800**	**1670.93**	**77002**	**47505**	**4.36**	**2.8**

Soybean from demonstration plot sold @ Rs. 34/kg; Soybean from local plot sold @ Rs. 33 /kg

Table 2. Impact of group approach in common procurement of critical inputs

Critical input	No. of farmers	Area (ha)	Variety	Quantity (kg)	Rate (Rs/kg)	Subsidized rate (Rs/kg)	Total savings (Rs)
Seed	305	133.20	MAUS 158	9990	58.00	46.00	119880
	50	20	JS 93- 05	1500	58.00	46.00	18000
	33	13.20	JS 93-05	995	58.00	46.00	11880
	67	26.80	JS 93-05	2010	58.00	46.00	24120
	34	13.60	JS 93-05	1020	58.00	46.00	12240
Total	**455**	**193.20**	**-**	**15515**	**-**	**-**	**186120**
Bio-fertilizers	210*	80.0	Rhizobium	150	80.00	60.00	3000
	210*	80.0	PSB	150	80.00	60.00	3000
Sub total	**210**	**80.0**	**-**	**300**	**-**	**-**	**6000**

** The users of Rhizobium and Phosphorus solubilizing bacteria*

group approach can successfully be adopted to transfer the research emanated production technology and thereby enhancing the productivity of crops, particularly soybean. Adoption of group approach for procurement of critical inputs paves the way for their timely availability associated with financial advantage to farmers.

ACKNOWLEDGEMENT

The authors thankfully acknowledge the support provided for successful conduct of the study by Maharashtra State Seed Corporation Ltd for providing seeds of the improved soybean varieties, Agriculture Development Officer, Zilla Parishad, Sholapur for allotment of seed quota for Dahitine cluster, Mahatma Phule Krishi Vidyapeeth, Rahuri and Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani for providing critical inputs and technical knowhow, Agricultural Technology Management Agency for financial assistance and National Bank for Rural and Agriculture Development for establishment of Shivtej Farmers club.

REFERENCES

Ayyappan S, Pitam Chandra and Tandan S K. 2007. *Agriculture Transformation through Public Private Partnership - An Interface*, ICAR-Industry Meet, pp 126-35

Reddy D D, Subba Rao A, Sammi Reddy K and Takkar P N. 1999. Yield sustainability and phosphorus utilization in Soybean-Wheat system in Vertisols in response to integrated use of manures and fertilizer phosphorus. *Field Crop Research* **62**: 180-90.

Yaragoppa S D, Desai B K, Halepyati A S and Pujari B T. 2003. Influence of plant densities and phosphorus management on growth and seed yield of *Sesbania acu*. (Wills) Poir. *Karnataka Journal of Agricultural Sciences* **16:** 297-9.

Society for Soybean Research and Development is thankful to following persons who helped as referees to review the research articles submitted to Soybean Research for their suitability and better presentation

Agrawal D K Dr; Principal Scientist (Genetics and Plant Breeding), Directorate of Seed Research (ICAR), Village Kushmaur, P O Kaithauli, Distt: Mau Nath Bhanjan, Uttar Pradesh

Ansari M M Dr; Principal Scientist (Plant Pathology), Directorate of Soybean Research, Indore 452 001, Madhya Pradesh

Billore SD Dr; Principal Scientist (Agronomy), Directorate of Soybean Research, Khandwa Road, Indore, Madhya Pradesh

Sharad Choudhary Dr; Professor (Agronomy), I/C, FSR, College of Agriculture, Indore 452 001, Madhya Pradesh

Devadas Ram Gopal Dr; Senior Scientist (Plant Breeding), Senior Scientist (Plant Breeding), National Research Centre for Orchids, Pakyong, Sikkim

Dravid MS Dr; Ex-Principal Scientist (Soil Science), Indian Agricultural Research Institute, New Delhi

Dupare B U Dr; Senior Scientist (Agricultural Extension), Directorate of Soybean Research, Indore, Madhya Pradesh

Gupta G K Dr; Principal Scientist (Plant Pathology), Directorate of Soybean Research, Khandwa Road, Indore, Madhya Pradesh

Gupta Sanjay Dr; Principal Scientist (Plant Breeding), Directorate of Soybean Research, Indore, Madhya Pradesh

Husain S M Dr; Principal Scientist (Plant Breeding), Directorate of Soybean Research, Indore, Madhya Pradesh

Jain Rajni Dr; Senior Scientist (Computer Application in Agriculture), National Centre for Agricultural Economics and Policy Research, IASRI Campus, Library Avenue, PUSA, New Delhi

Joshi OP Dr; Ex-Principal Scientist (Soil Science),Directorate of Soybean Research, Indore 452 001, Madhya Pradesh

Khare S K Dr; Professor, Enzyme and Microbial Biochemistry Lab (Indian Institute of Technology), New Delhi

Kumar Vineet Dr; Principal Scientist (Biochemistry), Directorate of Soybean Research, Indore, Madhya Pradesh

Ramesh A Dr: Senior Scientist (Soil Science), Directorate of Soybean Research, Indore, Madhya Pradesh

Ratnaparkhe Milind B **Dr;** Senior Scientist (Biotechnology), Directorate of Soybean Research, Indore, Madhya Pradesh

Satpute Gyanesh Kumar Dr; Senior Scientist (Plant Breeding), Directorate of Soybean Research, Indore, Madhya Pradesh

Sharma AN Dr; Principal Scientist (Entomology), Directorate of Soybean Research, Indore, Madhya Pradesh

Sharma Purushottam Dr; Senior Scientist (Agricultural Economics), Directorate of Soybean Research, Khandwa Road, Indore, Madhya Pradesh

Sharma RA Dr; Ex-Dean, College of Agriculture (Rajmata Vijayaraje SindiaKrishi Vishwa Vidyalaya), Indore, Madhya Pradesh

Sharma Sushil K Dr; Principal Scientist (Agricultural Microbiology), National Bureau of Agriculturally Important Microorganisms, Village Kusmaur, PO Kaithauli, Distt: Mau Nath Bhanjan 275 101, Uttar Pradesh

Singh Guriqbal Dr; Senior Agronomist (Pulses), Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab

Singh Kamendra Dr; Professor (Plant Breeding), GB Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand

Singh RK Dr; Principal Scientist (Biotechnology), Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh

Sridhar Y Dr; Senior Scientist (Entomology), Directorate of Soybean Research, Khandwa Road, Indore, Madhya Pradesh

SOYBEAN RESEARCH

GUIDE LINES FOR SUBMISSION OF MANUSCRIPT

Where to submit?

The Society of Soybean Research and Development publishes full paper, short communications, and review articles related to soybean research and development in its official journal "SOYBEAN RESEARCH". The journal is published twice in a calendar year at present. All submissions should be addressed to: The Editor-in-Chief, Society of Soybean Research and Development (SSRD), Directorate of Soybean Research, Khandwa Road, Indore 452 001, India (Email: ssrdindia03@rediffmail.com). The submissions of the manuscripts may preferably be done on lineon Society's web-site (www.ssrd.co.in or www.soybeanresearch.in)

Editorial Policy

- All authors in a manuscript (MS) for publication in Soybean Research should be member of the society.

(a)	Annual member	Subscription
	Indian Foreign	₹. 500.00 US $ 125.00
(b)	Student member	
	Indian Foreign	₹. 250.00 US $ 100.00
(c)	Institution member	
	Indian Foreign	₹. 2, 000.00 US $ 150.00
(d)	Life member	
	Indian Foreign	₹. 3, 000.00 (1 or in 3 equal instalments. in a year) US $ 1000.00
(e)	Corporate member	
	Indian Foreign	₹. 20, 000.00 US $ 2,000.00

- An admission fee **of ₹.50/- for** Indian citizen and US $ 5.00 for Foreign National shall be paid at the time of enrollment.
- MS must be original and contribute substantially to the advancement of knowledge in soybean research and development.

- MS should have unpublished data and not submitted elsewhere (wholly or in part) for publication.
- MSs are subjected to 'peer review' by two experts in the relevant field and by the members of Editorial Board. The decision of Editor-in Chief in accepting the MS with major/minor revision or rejecting the paper would be final. MSs sent for revision to authors, should be returned within four weeks.
- All submission must accompany a self-addressed appropriately stamped envelope for sending the MS for revision/change if any or the proof for corrections.

Manuscript Format

- Manuscript should be initially submitted **in triplicate and it should also carry the E-mail address of the corresponding author** in addition to the postal address. MS should be printed in double space on A-4 size paper in Times New Roman with font size 12 with a 4 cm margin at top bottom and left. All pages including text, references, tables and legends to figures should be numbered. MS should be concise and devoid of repetition between Materials and Methods and Results or Results and Discussion. **Revised and corrected MS should be submitted with a soft copy in a CD/floppy diskette.**

Full Paper

- A full paper should not exceed 4000 words (up to 15 typed pages, including references, tables etc.) Its contents should be organized as: Title, Author(s), Address, Abstract, Key words, Introduction, Material and Methods, Results and Discussion, Acknowledgements and References.

Title: It should be short, concise and informative, typed in first letter capital, Latin name italicized.

Authors: Name of the authors may be typed in all capitals.

Abstract: This should not exceed 150 words and should indicate main findings of the paper, without presenting experimental details.

Key words: There should be 4-5 key words indicating the contents of the MS and should follow the abstract. Invariably the name of host and pest should be included in key words.

Results: Data should be presented in text, tables or figures. Repetition of data in two or three forms should be avoided. All quantitative data should be in standard/metric units. Each table, figure or illustration must have a self-contained legend. Use prefixes to avoid citing units as decimals or as large numbers, thus, 14 mg, not 0.014 g or 14000 µg. The following abbreviations should be used: yr, wk, h, min, sec., RH, g, ml, g/l, temp., kg/ha, a.i., 2:1(v/v), 1:2 (w/w), 0:20: 10 (N:P:K), mm, cm, nm, cv. (cvs., for plural), % etc.

References: References should be cited by authors and year: Ansari (2000) or Ansari and Sharma (2000) in the text. References should be arranged in alphabetical order and listed at the end of the paper as follows:

Ansari M M and Sharma A N. 2000. Compatibility of *Bacillus thuringiensis* with chemical insecticides used for insect control in soybean (*Glycine max*). *Indian Journal of Agricultural Sciences* **70**: 48-9. **(Journal)**

Joshi O P, Billore S D, Ramesh A and Bhardwaj Ch . 2002. Soybean-A remunerative crop for rainfed forming. *In*: Agro technology for dry land forming, pp 543-68. Dhopte AM (Eds.). Scientific Publishers (India), Jodhpur. **(Book chapter)**

Ansari M M and Gupta G K. 1999. Epidemiological studies of foliar diseases of soybean in Malwa plateau of India. Proceedings, World Soybean Research Conference VI, Aug 4-7, 1999, Chicago, Illinois, USA, 611p. **(Symposium/ Conf./Workshop)**

Pansae V G and Sukhatme P V. 1978. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi. pp.186. **(Book)**

Table: Each table should be typed on separate page and numbered sequentially. Tables should have descriptive heading. Authors are advised to avoid large table with complex columns. Data are restricted to only one or two decimal figures only. Transformed values should be included if these are discussed in the text.

Illustrations: Number all illustrations consecutively in the text. Line drawing should be made in undiluted black ink on smooth white card or tracing paper. Original and two Photostat copies should be drawn approximately twice the size of reproduction. Original should not be labeled and should also not be numbered. Line diagrams of plants, fungi etc. should indicate the scale.

Photographs: Photographs should be on glossy paper and have good contrast. Trim unnecessary areas. Three copies of the photographs should be provided. On the back of the photographs write names of authors, figures numbers and indicate top of the photographs with an arrow using a soft pencil. Show magnification with a bar scale. **Coloured photographs can be printed on payment of full printing cost by the authors**. Legends for figures should be typed separately and numbered consequently.

Short research notes

They should not exceed more than 1300 words (total 5 typed pages, which deal with (i) research results that are complete but do not warrant comprehensive treatment, (ii) description of new material or improved techniques or equipment, with supporting data and (iii) a part of thesis or study. Such notes require no heading of sections. It should include key words. Figures and tables should be kept to a minimum.

Review articles

Authors with in-depth knowledge of the subject are welcome to submit review articles. It is expected that such articles should consist of a critical synthesis of work done in a field of research both in India and/or abroad, and should not merely be a compilation.

Proofs

Authors should correct the proof very critically by ink in the margin. All queries marked in the article should be answered. Proofs are supplied for a check-up of the correctness of the type settings and facts. Excessive alterations will be charged from the author, Proof must be returned immediately to shorten the reproduction time.

Application for Membership

SOCIETY FOR SOYBEAN RESEARCH AND DEVELOPMENT

(Registration No. 03/27/03/07918/04)

Directorate of Soybean Research

Khandwa Road, Indore452 001

Ph.: 0731-2478414; 236 4879; FAX: 2470520

(E-mail: ssrdindia03@rediffmail.com)

(Website: www.ssrd.co.in)

The General Secretary
Society for Soybean Research & Development
Directorate of Soybean Research
Khandwa Road, Indore –452 001

Dear Sir,

I wish to enroll myself as a Life Member/Annual Member of the **Society for Soybean Research & Development.** I remit Rupees (in words)--- -------------------------------------by Demand Draft No.---date------ -----------------of -----------------------------bank in favour of the Society for Soybean Research & Development, Indore as membership and admission fee for the year--------------------------. I agree to abide by the Rules and Regulations of the Society.

Yours faithfully,

Name (in Block letters) ---
Designation ---
Date of birth ---
Area of specialization --
Address (in Block letters) ---

Tel: ----- Fax: ---
E-mail :-----
Proposed by: Signature and Name------------------------------------
Address