ISSN 0973-1830

Volume 15, Number 1 : 2017

SOYBEAN RESEARCH

Society for Soybean Research and Development
ICAR-Indian Institute 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. 600/-	US$ 125/-
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NAAS RATING 3.04

SOYBEAN RESEARCH

ISSN **0973-1830** **Volume 15(1): 2017**

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 and are linked to Google Scholar.

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 15(1): 01-17 (2017)

Emerging Trends in Soybean Industry

SIDDHARTHA PAUL TIWARI[1]
Google Asia Pacific Pte. Ltd., 70 Pasir Panjang Road, Mapletree Business City II, Singapore 117371
E mail: siddhartha@google.com

Received: 29.03.2017; Accepted: 22.05.2017

ABSTRACT

Soybean is the most globalized, traded and processed crop commodity. USA, Argentina and Brazil continue to be the top three producers and exporters of soybean and soymeal. Indian soy-industry has also made a mark in the national and global arena. While soymeal, soyoil, lecithin and other soy-derivatives stand to be driven up by commerce, the soyfoods for human health and nutrition need to be further promoted. The changing habitat of commerce in soy-derivatives necessitates a shift in strategy, technological tools and policy environment to make Indian soybean industry continue to thrive in the new industrial era. Terms of trade for soy-farming and soy-industry could be further improved. Present trends, volatilities, slowdowns, challenges faced and associated desiderata are accordingly spelt out in the present article.

Key words: Soybean, Indian soybean industry, soybean derivatives, soybean trends

Introduction

Soybean is one of the leading crop commodities produced, traded and utilized globally. Barring some small portion, the bulk of it needs industrial processing and value addition. Besides its numerous uses, soybean is predominantly used as soymeal typically as source of high protein for animal feed and as edible oil. A close and essential association between soybean farming and soy-industry including food and feed industry makes soybean a perfect global trade commodity. However, its best benefits can be reaped by turning it into value-added products for human health and nutrition.

Soybean and industry cannot be sundered. As a glaring example, Henry Ford, the noted industrialist, had a deep and continued inclination for soybean as realized by his efforts and achievements in establishing soybean plants in 1930s, putting soybean products to various industrial uses and promoting soybean as a whole (Shurtleff and Aoyagi 2011). A world famous photo dated November 1940 shows Henry Ford, dressed in coat and hat, swinging an axe at the plastic trunk lid of a car made of soy fibre. Industrial world, through three main industrial revolutions, has undergone a paradigm shift from hand tools and basic machines to (i) powered mechanization,

[1]*Solutions Consultant*

(ii) mass production along assembly lines, and (iii) automation and globalization. The Fourth Industrial Revolution (4 IR) is unfolding in the present early 21st century and is characterized by IT-based modern technologies with supporting IT structures, robotization, artificial intelligence, cyber-physical systems and global value chains (Schwab, 2016/2017, Micklethwait and Wooldridge, 2014). Overarching impact of 4 IR is expected on physical, digital and biological world. The present article overviews the present trends of the soybean trade, industry and commerce in this new industrial era.

Role of industry in Indian soy-revolution

Saga of success of soy-revolution in India has been told earlier (Tiwari *et al*., 1999) depicting the renaissance of traditional soybean to a commercial crop. For rapid spread of soybean, more than a score of causes and associated organisations have been identified (Tiwari *et al*., 1999; Chand, 2007; Dupare *et al*., 2008; Tiwari, 2014). This article does not intend a comprehensive coverage of soy-revolution and highlights the role of soy-industry alone. In early seventies, some businessmen of Indore in central India foresaw great profit in export of soymeal mainly to European countries. Soybean did not occupy a large area that time. Although a number of solvent extraction plants existed then, those were not used for getting soymeal, oil and lecithin out of soybean grains primarily because soybean's availability and its potential for oil and export of soymeal was not yet sizeably realized.

Entrepreneurship of Indian businessmen to go for investment, labour and risk is praiseworthy in starting the extraction and export of soymeal. A lot of credit goes to several businessmen of Indore particularly Shahras (Mahadeo Bhai and Kailash Shahra), N N Jain and several others. With the improved cultivation and availability of seeds, Shahras set up a 50 tonne per day (TPD) plant in 1973. This plant was modernized and upgraded in the next two years and, with the addition of more plants, the capacity increased. Soybean industry started gradually but soon took off with a boom. The farmers were paid fairly and that resulted in sharp increase in soybean area, filling-up rainy season fallow land in central India with Indore as its epicentre.

A little later in 1979, the Madhya Pradesh Oilseeds Growers' Federation (OILFED) was established. It had its own solvent extraction plants and was a foreign-exchange earner through export of soymeal. It was also one of the main organisations that helped spread the soy-revolution by procuring soybean from farmers at a remunerative price to them and providing inputs and knowledge on an overall basis. National Dairy Development Board (NDDB), the Rajasthan Oilseed Growers' Federation (Tilam Sangh/RAJFED), the National Agricultural Cooperative Marketing Federation of India (NAFED) and the state marketing federations also promoted soybean in Madhya Pradesh and adjoining areas in Maharashtra and Rajasthan particularly through market intervention and price support. The Soybean Processors Association of India (SOPA) was also established in 1979 with its headquarters in Indore. Besides promoting soy-processing and export of meal and value-added soyfood products from India, it provides technical backstopping through its analytical and research laboratories. It also promotes larger usage of soy-foods for better health and nutrition. It undertook a Soybean Development Programme to help farmers particularly in adopting new technology and using improved quality seed.

Eventual commercial success of Indian soybean owes much to the concurrent development of the soy-industry comprising the value chain from grain to solvent extraction plants to soymeal and other derivatives and export mechanism which provided remunerative market to soybean growers. The profit of the industry trickled down to farmers and other stakeholders. Soybean cultivation as a crop, thus, really began in India in the early seventies on an area of about 30,000 hectares. The acreage grew gradually and steadily over decades. The soybean crop presently covers an area of about 12 million hectares with a total production of about 14 million tonnes. The three largest soybean producing states are Madhya Pradesh, Maharashtra and Rajasthan (Directorate of Economics and Statistics, 2016). Owing to possessing and sustaining a major share of soybean area (about 57 % at present), Madhya Pradesh is called the 'Soy-State'.

Emulative Models supporting soybean industry as evinced by soybean revolution of India

Soybean, despite its short stay as a crop in India (1970s and thereafter), has served as a base in establishing some distinctive models such as (1) futures exchange (Soybean Board of Trade (SBoT) now National Board of Trade Ltd., (NBoT), (2) global value chain and global trade, (3) use of ICTs (*e.g.* ITC's e-Choupals/Soy-Choupals) towards the technology adoption and domestic trade facilitation, (4) farmer-friendly extension services by private sector (*e.g.* private extension of Dhanuka and participatory approach of 'Gramin Vikas Trust'), and (5) development of Indore as a 'neo-seed hub' dealing with high volume-low value seed. Some of these concomitant developments are briefly depicted below.

The NBoT is a commodity futures exchange especially for edible oil and oilseeds in India with needed automation, online trading platform in Indore, nation-wide screen-based trading system, *etc.* It was mainly due to soybean that Indore, the commercial capital of Madhya Pradesh, also developed as a neo-seed hub having several sizeable seed companies. The special feature of these seed companies is that they not only deal with low volume-high value crop hybrid and vegetable seed but also with a large amount of high volume-low value seed of crops like soybean, wheat, *etc.*

Madhya Pradesh became the first state in the country to have a private extension policy. Focus was on introduction of private extension services through building up private-public partnership in agricultural extension. The first Memorandum of Understanding (MoU) regarding implementation of public-private partnership in agriculture was signed by the Department of Agriculture with Dhanuka group for agricultural extension in Hoshangabad district of Madhya Pradesh. Another soybean-based model involving participatory approaches was that of 'Gramin Vikas Trust' (an arm of Krishak Bharti Cooperative Ltd, KRIBHCO) jointly with the National Research Centre for Soybean (ICAR) which undertook knowledge and technology dissemination in tribal-dominated Jhabua district of Madhya Pradesh. The model was unique in the sense that it involved the farmers fully in assessing their needs and disseminating required knowledge and technology in agriculture. The village level para-extension workers came from among the villagers themselves and were called "Jaankaars". They were, albeit, trained by the involved agencies. The Madhya Pradesh state also has built-in support of such para-extension workers, in their programmes, called as "kisan bandhus".

The distinctive model of 'Soy-choupals' or 'e-Choupals' mooted and implemented by Indian Tobacco Company (ITC) is well known as an early and successful use of ICTs in agriculture (Kumar, 2004; Rao, 2007; Tiwari 2008). e-Choupals functioned for soybean crop in the state of Madhya Pradesh and, hence, were also called as 'soy-choupals'. These e-Choupals were provided with internet connectivity with solar panel battery backup and VSAT (Very Small Aperture Terminal, a satellite communication system) equipment. Village internet kiosks were managed by farmers, called 'sanchalaks'. This system (i) enabled the agricultural community's access to information on the weather and market prices, (ii) disseminated knowledge on scientific farm practices and risk management, and (iii) facilitated the sale of farm inputs and purchase of farm produce at the farmers' doorsteps. It served primarily as a direct marketing channel, reduced the transaction costs and eliminated many intermediaries (Adhiguru and Mruthyunjaya, 2004; Rao, 2007). e-Choupals eventually got extended to a range of crops and covered several states to become one of the largest initiative among internet-based interventions in rural India.

Emerging new technologies in processing

Almost all soybean grain, barring farm-saved seed, reserves and stocks, is processed in solvent extraction plants to obtain soymeal and oil. Soymeal segment is the largest. Bulk of soymeal is consumed by poultry followed by the swine, beef, dairy, pet food and aquaculture industries. Protein derived from soybean is further processed to derive specialty products such as soy concentrate and soy isolates used for industrial, food and neutraceutical applications.

There are several emerging and new technologies. The food science related emerging technologies include high hydrostatic pressure technology, pulsed electric field applications, ultrasound and cold plasma that have already applications in the food industry and related sectors (Knorr *et al*., 2011). High hydrostatic pressure technology for food preservation and quality retention are the most advanced. Pulsed electric field applications are on the verge of industrial use. Ultrasound has some non-food safety applications and supercritical water and low temperature plasma treatment are in their developmental stage. Combinations of the above processes with either mild heat, with each other or with other means of food preservation agents (*e.g.* anti-microbials) are also being developed and tested. Currently, these technologies are mainly used and developed as alternatives to conventional thermal preservation methods such as pasteurization. However, they possess a great potential for food modification purposes and are generally more sustainable technologies than conventional thermal ones. Some recent attempts to re-introduce antimicrobial systems such as the use of ozone, UVC light, pulsed light or oxidized water still need to be validated regarding their feasibility and effectiveness.

For food uses, solvent extraction, particularly use of hexane, is being questioned on account of inflammatory nature of hexane solvent, its stated carcinogenicity and environmental hazard. Some of the current research and developments in soyfood technology are in the area of extrusion-expelling, super critical fluid extraction of oil, extruded soybased snack foods, expander technology, membrane technology, texturized soyproteins, coagulation and fermentation of soyproteins, chilling and freezing, electromagnetic waves, high pressure pasteurization and cooking, ohmic heating, retort and aseptic packaging among others. High shear extrusion does not require an external source of heat or steam because heat gets generated through friction in such extruder.

Fabricated foods and feeds from soybean and soybean derivatives using technologies like extrusion processing, modified atmosphere packaging and controlled atmospheric packaging are to be increasingly promoted as per changing consumer demand and ever-increasing urbanization in the modern era. The change in the retail market has induced the change in soybean food industries. Specifically, the emergence and dominance of supermarkets in the retail market has motivated large soybean food makers to invest in new technologies to produce uniform and standardized products. Even traditionally soy-food using countries (for example Japan with traditional soyfoods namely, tofu, miso and natto) are changing the production and packaging to suit the product selling in big metropolitan stores, supermarkets and shopping malls or through large scale urban home delivery mechanisms and agencies. The product attributes needed and the emergence of new markets is affecting the structure of industry.

The new era of biological/genetic modification, bioactive compounds and specialty soybean

The genetically modified (GM) or transgenic soybean is already covering one billion hectares area globally (ISAAA, 2015). However, the biological world has gone ahead of genetically modified (GM) or transgenic crops that are developed using *Agrobacterium* or particle bombardment for crop improvement. A new crop biotechnology called "genome or gene editing" is the recent development. There are different types of genome editing technologies. The most promising one is named CRISPR (Clustered Regularly Interspaced Short Palindromic Repeat). These new technologies consist of cutting the DNA at a pre-determined location and the precise insertion of the mutation, or single nucleotide changes at an optimal location in the genome for maximum expression. The real power of these new technologies is their ability to edit and modify single or multiple native plant genes (non-GM), coding for important traits. It is stated (ISAAA, 2015) that such developed improved crop varieties are not transgenics and retain their non-GMO status. Products already under development using this technology include several major foods and feed crops like soybean (for improving oil quality). More complex traits, coded by multiple genes, like improved photosynthesis, are planned in near future. A trident confluence of the new breeding technologies (NBT) comprising transgenic development, genome editing, and use of microbes (plant microbiomes) as a new source of additional genes will be increasingly used to enhance productivity and quality of crop produce and products. In the long run, the genome editing technologies have the potential to settle the GMO *vs* non-GMO debate in Indian soybean scenario. Organic soybean producing large states like Madhya Pradesh in central India could have co-existence of organic and genome-edited improved soybean production in future for high yield and quality attributes.

Soybean derivatives contain many bioactive compounds that have health implications (El-Shemy, 2013). Several of them, when processed and consumed appropriately, could impart significant health benefits (Isanga and Zhang, 2008). Already much has been talked and published for and against the food uses of soybean (Fallon and Enig, 2000; Daniel, 2005; Adams, 2007; Robbins, 2012, and many others). Even the loudest anti-soy voices believe that traditional fermented soyfoods such as miso, natto, shoyu, and tempeh are good. Anti-nutritional factors can be taken care of by genetics and breeding, processing, bio-processing and food and feed modifications. Interest in food-grade soybeans and soy-derived neutraceuticals will grow and the needed technologies will evolve to address the encumbrances in the way of augmented food uses of soybean.

Agronomic characters, particularly yield and stress resistance, in soybean varieties are very important for their adoption by farmers, but lack or moderation of these cannot be considered an exclusion factor, since other important variables, such as composition, functional characteristics (as in isoflavones) and absence of antinutritional compounds (as trypsin inhibitor) are now becoming desirable for their use by food industry. Such lines are available and some have been commercialized to an extent. However, these need to be further improved for yield and agronomic acceptance. There is less yet steady consumer demand for food-grade soybeans, including specialty varieties, organic, non-GMO, and Identity Preserved (IP) soybeans. Associated specific mechanisms have, therefore, to be put in place for segregation, identity preservation, a change in processing and packaging, certification and sustainable growing regimen.

As stated, many specialty soybean varieties for food uses have been developed globally. Indian scenario also has such soybean varieties. Lines namely, 'NRC 101' and 'NRC 102' which are free from 'kunitz' trypsin inhibitor along with 'IC 210', an indigenous line, which has high oleic acid (~42 %), and NRC 109 with null lipoxygenase-2 have been commercialized as well (Rani and Kumar, 2015; Kumar *et al.*, 2010). Thus, the first laudable step towards promoting specialty soybean and carving a new commercial niche market has been taken in India. Production, use and export of organic soybean in/from central India are also on increase. Area to be brought under organic farming should be carefully identified rather than abruptly claiming established high yielding regions. In order to meet the emerging demand for segregation and identity preservation, current infrastructure of solvent extraction plants will need to be modified or could co-exist with technologies like extrusion expelling.

The intellectual property rights (IPRs) have started covering wider areas than before leading to new IP-regime. The specialty soybeans in India are being produced under special agreements with private sector and thus indicating a need for different or hybrid intellectual property rights and mechanisms of benefit sharing. Contract farming for food uses could emerge as a potent tool to solve many problems such as those pertaining to farm-holding size, scale of enterprise, identity preservation, specialty soybean, organic farming, certification, technology adoption and overall farm and marketing management.

Soybean oil in graphene production – An example of new soybean use

A very recent report established an important use of soybean oil as a biomass precursor for the production of graphene, probably the hardest material with myriad potential uses. Graphene, an atomically thin film of crystalline carbon, is a highly promising nano-carbon material. Widely adopted techniques for the synthesis of such carbon nanostructures are primarily based on thermal chemical vapour deposition methods, in which purified gases are processed at very high temperatures (typically around 1,000 °C) over a prolonged period. The use of purified gases is, however, expensive, hazardous and requires extensive vacuum processing. A need was, therefore, felt to develop a process that is free of compressed gases for the production of graphene films. Recently, Dong Han Seo *et al.* (2017) of CSIRO, Australia, developed a method for single-step, rapid thermal synthesis of uniform and continuous graphene films in an ambient-air environment, using a cheap and renewable form of biomass, soybean oil, as the precursor. Importantly, the method offers the scope to potentially address the critical roadblocks towards large-scale and efficient graphene manufacturing.

Alternative protein sources of future for environmental and resource sustainability

Soybean is an established source of protein and currently dominates the plant protein market but it has to compete with other sources. Other than soymeal, there are several traditional plant protein sources of the world such as cottonseed meal, rapeseed meal, sunflower meal, groundnut meal, flaxseed meal, peas, faba beans and quinoa (*Chenopodium quinoa*). Besides plants, soybean has to compete with other non-plant protein sources. For example, soybean and fishmeal have traditionally been the main protein sources in poultry feeds. It would be desirable that vegetable protein from soybean and other plant sources is directly consumed by human beings as the conversion chain from vegetable protein to meat to humans is inefficient. Yet, world meat production is projected to double by 2050 particularly in developing countries like China and India where annual per capita consumption of meat has doubled since 1980. The proportion of land utilised to produce food for livestock to meet growing demand of meat is increasing. Future may see emergence of some yet uncommon alternative sources of protein *viz*., cultured meat, mealworms and other insects, microalgae and cyanobacteria. Synthetic amino acids have a long history and with advancement in technology their incorporation may increase for value addition in food and feed.

There is a small but growing entomophagy and flexitarian sections of human communities using as many as 1900 species of insects as food worldwide. Many insects possess protein comparable with meat, essential amino acid levels comparable with soybean proteins along with sustainability and resource use efficiency features such as higher food conversion efficiencies, lower environmental impact and higher potential to be grown on waste streams (Ramos-Elorduy, 1997; Ooninc x *et al.*, 2010; Lakemond *et al.*, 2013; van Huis, 2013). Mealworms, for example, have up to 48 per cent protein by weight and besides being taken as raw can be dried for grinding and added to the food. FAO has also been promoting insects for food and feed as viable protein source for humans as a way to reduce the environmental impact of meat.

Algae, both macroalgae and microalgae categories, have potential food and feed uses. These have not only proteins but also vitamins and nutrients. Spirulina (a form of Cyanobacteria) and Chlorella (a single-cell green algae) are called as 'superfoods'. The future of microalgae is promising but presently these are too costly a protein source to effectively compete with other plant proteins.

Animal protein coming from livestock has encumbrances of being an inefficient food conversion chain and environmentally contributing about 18 per cent of global greenhouse gas (GHG) emissions, having 27% of the global water footprint and occupying 33 per cent of the global land use (Tuomisto and Teixeira, 2011). Cultured edible meat produced through *in vitro* tissue culture technologies, has a potential to overcome these concerns. Cultured meat production has a maximum potential reduction in GHG emissions and water footprint between 78-99 per cent and 89-96 per cent, respectively. If the same quantity of protein is replaced with soybean protein, even higher reductions in GHG emissions could be achieved, but the water footprint and land use would be higher compared to cultured meat. Cultured meat technology is futuristic and presently in a research stage. The first commercial product is predicted to be available within a decade. To start with, it will be desirable for mankind to move from consuming livestock protein to soyprotein directly for environment and resource sustainability.

Present trends and perspective in soybean derivatives

Soybean is the most globalized, traded and processed crop commodity. Soybean derivatives market can be divided (1) by type comprising (i) soybean, (ii) soymeal (soy milk and soy protein concentrate), and (iii) soy oil (soy lecithin), (2) by application comprising (i) feed, (ii) food, and (iii) other industries including biodiesel, soy-based wood adhesives, soy ink, soy crayons, soy-based lubricants and many more, and (3) by lecithin processing comprising (i) water, (ii) acid, and (iii) enzyme, and (4) by region namely, North and South America, Europe, China, Japan, Southeast Asia and South Asia (India).

Wang *et al.* (2013) have concluded, using FAO data, that in the last 5 decades (1961-2010), the total production of soybean increased more than 8 times, mainly due to the increase of the cropping area, and contributed to the restructuring of agriculture in the world. The world soybean consumption patterns have changed over time; currently about 80 per cent went into processing industry and about 10 per cent is directly used for food purposes. The global export-orientation ratio (EOR *i.e.,* total export in per cent of production) of soybean is higher than that of wheat, maize and rice. United States and South America have emerged as the main producers and exporters now while Asia particularly China has changed into the biggest importer. Soybean transportation profile shows that the main exporting ports are Mississippi Gulf Coast in US, Port of Rosario in Argentina, and Porto de Santos and Porto de Paranaguá in Brazil. China is the largest importer of soybeans. China shares about 60 per cent of world imports almost all of which arrives in the port of Dalian. Modernization and up-gradation of ports and industrialization of port-hinterlands for exports is, therefore, essential and is happening (*e.g.,* improvements in the Port of Rosario in

Argentina, India's Sagar Mala Initiative, *etc*.).

Research and Markets (2015) estimates showed that soybean derivatives market was worth $ 176.92 billion in 2015, and projected to reach $ 254.91 billion by 2020, at a compound annual growth rate (CAGR) of 7.6 per cent. Asia-Pacific region was estimated to be the largest market and projected to grow to $ 125.85 billion by 2020, at a CAGR of 7.8 per cent. North America was estimated the second-largest market that is projected to grow at a CAGR of 9.2 per cent. USA, Argentina and Brazil are and will continue to be the top three producers and exporters of soybean and soymeal. Followed by these, Indian soy-industry has also made a mark in national and global arena.

Leading companies of soybean derivatives market such as Bunge Ltd (U.S.), Archer Daniels Midland Company (U.S.), Louis Dreyfus Commodities (The Netherlands), Cargill, Incorporated (U.S.), Noble Group Ltd (Hong Kong), Wilmar International Limited (Singapore), Noble Group Ltd., CHS Inc., AG Processing Inc., Ruchi Soya Industries Limited (India), and Du Pont Nutrition and Health are some of the key players presently which employ various strategies for their growth and development. Expansion, diversification, joint ventures and acquisition have been the key moves undertaken by them. In Indian scenario some prominent soy-processing industrial groups are Ruchi Soya Industries Limited (Ruchi Group of Companies), Prestige Feed Mills Ltd. (Prestige Group of Industries), Vippy Industries Ltd., Premier Industries Ltd., Divya Jyoti Industries, and several others. Most of them are based in Malwa (Madhya Pradesh) and also in other parts of the country. The soy-industry in totality manufactures high quality edible soybean oil, hydrogenated 'vanaspati', bakery fats and soyfoods (soy-chunks, -granules, and –flour) and export soymeal, lecithin and other derivatives. In the year 2010, the industry was found offering employment to 12 lakhs people and estimated to go up to 15 lakhs in 2015 and up to 18 lakhs in the year 2020 although the trickle down is much more than this.

In India, there are about 120 soybean processing plants. The installed capacity of over 25 million tonnes is much more than the present normal annual soybean production of 12 to 14 million tonnes. India normally exported soymeal plus other soy-products valued at around US $ 2.5 billion annually till 2013-14. In the year 2012-13, soymeal alone was exported to the tune of about 3.439 million tonnes with a value of Rs. 10,050 crores. Soymeal export for 2011-12 and 2010-11 was 3.829 and 3.838 million tonnes respectively (Source: SEA). After 2013-14, the exports declined severely due to decrease in soybean production, stiff global competition and several other reasons. Domestic consumption as feed (~ 3.9 million tonnes annually) is also substantial. Soyoil (~1.7 million tonnes per year) is almost entirely consumed domestically, with additional soyoil being imported for meeting the domestic demand. Owing to this very reason, the use of soyoil for biodiesel is unlikely in India. Consequently, the demand for corn ethanol could be the reason for competition between soybean and corn for acreage in US and other countries but not so in India.

Import of edible oil

The import of edible oil in India has soared in order to meet the felt need of a growing population with rising income levels. In the year 2014-15 (November-October), India imported about 14.4 million tonnes of edible oil (crude plus refined), with a huge import reliance of more than 60 per cent of our requirement (about 22 million tonnes) and with a high value of about US $ 10 billion. Palm oil constitutes more than 60 per cent of the import, mainly from Indonesia and Malaysia, followed by soybean oil mainly from Argentina and Brazil and sunflower oil mainly from Ukraine and Mexico. Soybean has come as an additionality to Indian oilseed scenario and in spite of it being more a protein than oilseed crop, it contributes about 1.7 million tonnes of edible oil every year. Efforts are being made on several fronts to increase soybean production. Regulatory aspects and tariff structures, however, have become sensitive for domestic companies. Organisations such as the Solvent Extractors' Association of India (SEA), the Central Organisation for Oil Industry and Trade (COOIT) and the Soybean Processors Association of India (SOPA) along with others have made suggestions from time to time in this regard. A high duty on import, particularly on a single large quantity, may probably be imposed. Soybean oil has a 45 per cent bound duty tariff under WTO. Current applied duties on crude palm oil have been decreased from 12.5 per cent to 7.5 per cent and on refined palm oil from 20 per cent to 15 per cent in the year 2016. A desirable tariff difference between crude and refined oil (a duty differential desirably higher than the present 7.5 %), particularly in case of palm oil, should be there so that domestic oil refineries, using crude imported oil, survive and thrive well.

A view may be taken as to whether we may offset the oil import bill by the export-earnings of oilseed sector itself, as was so decades ago. This is different from being self-sufficient *sensu stricto*. Globalisation of food commodities is taking place at a large scale, disconnecting production and consumption. Some deficient countries may use the land abroad to virtually increase their agricultural land and production. This is referred to as 'virtual land use' or 'displaced land use' (Rulli *et al*., 2013; Yu *et al*., 2013) and is one of the possible ways-out besides increasing the system-wide output.

Industry slowdowns due to uneven and low supply of raw material - instability in Indian soybean production

Soybean production fluctuates and experiences serious dips, mostly due to weather aberrations. Due to this, soybean farmers and industry have suffered most several times but two hard periods of slowdown that cannot be forgotten are (i) for 3 years from 2000-01 to 2002-03 and (ii) for 3 years from 2013-14 to 2015-16. Instability in soybean yields was found to be high (Sharma, 2016) in all major soybean growing states (ranging from 21 to 43 %) as well as on all India basis (about 20 %). Soybean is largely a commercial crop and an agro-industrial venture. Unstable and low supply of raw material to industry leads to depression in export of soymeal and other products as also in their availability for domestic consumption. It, then, becomes hard to compete globally on price in spite of non-GMO status and other USPs (unique selling points/propositions) of Indian soymeal. Resilience shown by soybean industry and re-gaining its strength (now in 2016-17) is praiseworthy. Domestic sale of oil also compensates to an extent for such volatility in soymeal prices but this recourse needs policy support as stated above. Availability of soybean as raw material for industry, adherence to quality and meeting global standards will decide the viability of our export slots and their size.

Climate change has been held responsible for instability in soybean production. The studies, however, show that in the backdrop of climate change, soybean fairs a degree better than other major crops. Rising carbon-dioxide may have some positive effect on soybean yield although a range of yield effects has been observed (Adams *et al*. 1998). Collateral improvement in the photosynthesis/transpiration ratio, amounting to water-use efficiency, would offset some of the negative effects of global warming in a C3 plant species like soybean. Keeping aside this argument, soybean research and development organizations should develop climate-resilient high yielding varieties and commensurate technologies and take them to farm level to provide stability and increase in production. Probably one million hectares more can be added in near future to the present Indian soybean area of about 12 million hectares but production intensification rather than area increase will be the principal means of meeting future demand. A yield gap of about one tonne per hectare already exists to be filled up by technology adoption. It is not deft to compare Indian soybean yield level with that of US and other countries owing mainly to major differences in the length of crop duration. Indian soybean, particularly in the major central Indian region, is grown under a very short duration of about 95 days after which other crops follow, the crop sequence being soybean-wheat or even intensive soybean-potato-late sown wheat with high system efficiency rather than high yield of a single crop. All comparisons should be made on the basis of per day productivity or overall system efficiency. The differences will, then, be not so wide. Also, there are several studies to show that the yield gap cannot be fully bridged in a rainfed crop like soybean. Still, farm-level yields need to be raised. Based on available yield gap (one tonne per hectare) and likely extent of bridging it up (60 to 80%), it has been estimated that the national average yields can be increased feasibly to reach about 1.6 tonnes per hectare and then with some more efforts to 1.8 tonnes per hectare despite the short growing period available in central India (Tiwari, 2001;

Tiwari, 2014). The National Mission on Oilseeds and Oil Palm (NMOOP) since 2014 (a new form of the legendary Technology Mission on Oilseeds that was established in May 1986), agricultural universities, ICAR centres and several other public and private initiatives/organisations are striving for increasing the production of oilseeds and other edible oil sources.

Future will see increased use of automated systems, precision agriculture, use of nanotechnology, GPS, remote and satellite-monitoring, market information systems and use of sensors and drones in farm operations. Meeting the needed scale of economy can be achieved by contract farming and by establishing famer producer companies and farmers' seed cooperatives. Input cost moderation, facilitated availability of inputs, crop insurance, easy loans, support price and market-intervention are being undertaken and should ideally contribute towards measures taken for improving terms of trade in farming.

Keeping in view the global export of Indian soy-derivatives, public sector guidelines such as Codex Alimentarius will remain important to ensure food safety, while private sector standards such as Global Good Agricultural Practices (GAP) may become increasingly significant. Expanding Asian markets may embrace these guidelines.

Sustainably produced food with fair trade - A new Consumer preference

Worldwide, an increasing number of consumers are showing a greater interest in the holistic quality attributes of the food that they consume. Beyond the immediate issues of food safety, a competitive price and the experiential quality attributes, the consumers are becoming more concerned about the manner in which their food has been produced. Besides nutritional and sensory aspects, urban consumers are increasingly inclined towards fair trade, sustainable, non-GMO and organic certified products when choosing foods and evaluating food quality. Certified non-GMO soybean meal and other soy products (certified by CERT ID for example) are already in demand (Freire A, 2013). Present major international voluntary sustainability standards include the Danube Soya Initiative, Fairtrade, the Round Table on Responsible Soy (RTRS), ProTerra, Organic, the International Sustainability and Carbon Certification (ISCC) and the Round Table on Sustainable Biomaterials (RSB). Brazil, China and Argentina are the largest standard-compliant producers (SSI Review, 2014). The multi-stakeholder association namely, Fairtrade Labelling Organizations International had split, in the year 2004, into Fairtrade International and FLOCert. Buyers of sustainably produced and fair-trade products state that it makes them sure that the environmental care has been taken in production along with no residual pesticides, no use of child labour, *etc.* High-priced products with such specific tags on sustainably produced and fair-trade products are now in vogue in developed countries. In developing countries like India also, sustainability certification programmes are being implemented. For example, South and South East Asia network of Solidaridad (a development agency with its headquarters in Utrecht, Netherlands) has a Farmer Support Program with its seven NGO partners in operation since 2013 in three major soybean growing states of India namely, Madhya Pradesh, Maharashtra and Rajasthan.

Despite a large area under genetically modified (GM) soybean in USA, Brazil and Argentina, future demand for non-GM soybean will continue in some regions like EU. This could be advantageous for India where no GM soybean is yet grown and some area is even under organic soybean. Also, value of the produce/products and income generated could decide the farming options for a crop and the variety within a crop in future rather than yield alone. These recent consumer preferences for fair trade and sustainable production point out that we need to expand single-minded yield-centric approach to address both sustainability and farm prosperity concerns in a system-wide mode.

Making economic activities upsurge – Incentivisation and Trickle down

The trickle down for welfare of the society at large, as happened in case of soybean revolution (Badal *et al*., 2000), will continue if the companies and stakeholders are incentivised to generate income, raise output and create better and more opportunities for entrepreneurship, self-employment and also jobs. Optimisation of tax-revenue and maximisation of economic activities are needed for continued growth and national prosperity. It is a known fact that economic activities upsurge and people (farmers, industrialists and entrepreneurs) work hard and efficiently when terms of trade are favourable and input-cost and taxation are in the desirable range. That range or point may or may not be consistent with that of the Laffer Curve (Fullerton, 2008; Laffer –The Heritage Foundation, 2016; Trabandt and Uhlig, 2011), which is otherwise debatable. Above all, it is not the tax rate alone that matters. In nutshell, what really matters for doing business and making investment is the potential profit (an incentive in itself) along with the degree of uncertainty in earning that profit. Some recent and upcoming reforms and policy decisions in India include the Goods and Services Tax (GST) legislation, Land Acquisition legislation, new Foreign Trade Policy adopted in 2015, trade facilitation measures (www.indiatradeportal.in), integration of 20 services for obtaining government clearances (through eBiz single window portal), timely tax and tariff rate reviews and other initiatives of the Ministry of Commerce and Industry and related ministries, which are significant and noteworthy. Continuation of a conducive policy environment and dynamic trade facilitation are needed to bring upsurge in the economic activities including those concerning soy-production and soy-derivatives business.

The pace of development has increased tremendously of late and the world is changing fast. New production and processing technologies, new and customized products, changing global standards and demands, operational innovations for slashing logistics and other costs, diversification, convergence and co-existence of interests and companies, and other efficient ways of doing business like increased use of IT-based applications and cyber-physical systems for execution of complete global value chain will continue to have widespread and expanding effect on production and commerce of soybean. The trends and minutiae pointed out in this article show that soybean, being a major global industrial crop, stands to benefit from the ramifications of the new industrial era. Present trends, volatilities, slowdowns, challenges faced and associated desiderata have been spelt out accordingly.

ACKNOWLEDGEMENT

The author is grateful to experts from several organisations especially IISR (ICAR), SOPA and some group of industries in Indore for their direct and indirect support. He is also thankful to the two anonymous referees for their suggestions.

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Soybean Research 15(1): 18-24 (2017)

Association Analysis for Yield Contributing and Morpho-Physiological Traits in Soybean

K S BAIG*[*1], *P P KAWARE*[*2], *D H SARANG*[*3] *and KULDEEP SINGH CHANDRAWAT*[**4]

[*]All India Coordinated Research Project on Soybean,
*****Department of Agricultural Botany,***
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani 431 402, Maharashtra, India
E mail: khizerbaig1@rediffmail.com

Received: 14.03.2017; Accepted: 26.05.2017

ABSTRACT

An experiment was conducted on soybean at experimental farm of All India Coordinated Research Project on Soybean, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during kharif, *2011 with a view to study the correlation and path analysis studies for yield contributing and morpho-physiological traits in thirty five different elite germplasm lines of soybean along with five checks. In the present investigation, the genotypic and phenotypic correlation of seed yield with number of branches per plant, number of pods per plant, 100 seed weight, harvest index, oil and protein content, seed yield per plant were positive and significant indicating increase in seed yield is mainly because of increase in one or more of the above characters. The path analysis indicated that the traits* viz., *number of pods per plant and 100 seed weight exerted highest direct effect on yield at genotypic level. The traits number of pods per plant, 100 seed weight, days to maturity, chlorophyll content, number of branches per plant, harvest index had strong association with seed yield per plant and showed positive direct effect and indirect effect through one or the other component traits. This indicates direct selection for these characters will be of more useful for enhancing the breeding efficiency for improvement of seed yield in soybean.*

Key words: Association, correlation, path analysis, soybean, yield

Soybean [*Glycine max* (L.) Merrill] is an important oil seed crop belonging to family Fabaceae. Soybean is one of the most important crops of the world largely grown in United States of America, Brazil, Argentina, China, and India and plays crucial role in international trade. Correlation studies provide an opportunity for critically assessing the relationship of different yield contributing characters with seed yield. The correlation over the wide range of environment is likely to give true picture about the relationship, which will help the breeder to formulate strategies for indirect selection. The information on correlation of seed yield with related traits is the prerequisite to form an effective selection strategy aimed at its genetic improvement (Agrawal *et al*.,

[1]*Cotton Specialist;* [2,3]*Research Scholar;* [3]*Assistant Breeder*

2001). To increase yield in soybean, the study of direct and indirect effect of yield and its components provides the basis for getting success in breeding programme. Path coefficient analysis measures the direct and indirect effect for one variable upon another and permits the separation of the correlation coefficient into component of direct and indirect effects. The correlation and path analysis studies are of great help in formulating efficient scheme for multiple traits selection as they provide means for direct and indirect selection of component characters. Thus, knowledge of correlation and path coefficient of important yield and yield contributing traits is essential for a breeder to choose best genotype and to decide the correct breeding methodology for crop improvement. Therefore, the present study was carried out to study the correlation and path analysis for yield, oil and morpho-physiological traits in thirty five different elite germplasm lines of soybean.

MATERIAL AND METHODS

Thirty five different elite germplasm lines of soybean along with five checks were sown during *kharif*, 2011 in an experiment laid out at experimental farm of "All India Coordinated Research Project on soybean," Marathwada Krishi Vidyapeeth, Parbhani. The experiment was conducted in Randomized Block Design with two replications. Row to row distance of 45 cm and plant to plant distance of 5 cm was maintained. All recommended agronomic package of practices and plant protection measures were followed for satisfactory crop growth. Five competitive plants were selected randomly from each treatment in each replication for recording of observations. Observations were recorded on morphological characters *viz.,* days to 50 per cent flowering, days to maturity, plant height (cm) and number of branches per plant. Physiological traits *viz.,* leaf area index, chlorophyll content (mg) and harvest index (%) and yield contributing characters *viz.,* number of pods per plant, 100 seed weight (g), oil content (%), protein content (%) and seed yield per plant (g). The data recorded on these characters analyzed using standard procedure. The inter-relationships of different yield contributing characters were worked out according to Johnson *et al.,* (1955). Path coefficient analysis was carried out according to method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Correlation

In the present investigation, the genotypic correlations were generally higher than the phenotypic correlation indicating the inherent association between various traits. Seed yield is a complex character and is dependent on number of component characters. Therefore, study of relationship of character with each other and with yield become more important in crop improvement programme. Therefore, it is essential to find out relative contribution of each of the component character in yield for giving due weightage during selection.

The characters *viz.,* days to 50 per

cent flowering, days to maturity and plant height exhibited negative correlation with the grain yield per plant at both phenotypic and genotypic level (Table 1 and 2). Similar results were reported by Muhammad *et al*. (2006) and Karnwal *et al*. (2009). Days to 50 per cent flowering exhibited positive and significant correlation with days to maturity and plant height at both genotypic and phenotypic level. Similar types of findings were reported by Chettri *et al*. (2003) and Sirohi *et al*. (2007).

Days to maturity showed positive and significant correlation with plant height at both genotypic and phenotypic levels. These results are in conformity with those reported by Taware *et al*. (1995) and Mukhekar *et al*. (2004). The positive and significant correlation of grain yield with number of branches per plant, number of pods per plant, harvest index, 100 seed weight was observed in the present investigation. Similar trend of results were reported by Karnwal *et al*. (2009) at genotypic and phenotypic level.

Oil content and protein content have significant negative correlation with each other. Protein content showed no association with seed yield. Similar findings were reported by Gohil *et al*. (2006).

It is important to note that the characters *viz.,* number of branches per plant, number of pods per plant, 100 seed weight, oil content, leaf area index, chlorophyll content and harvest index were positively correlated with seed yield. Selection based on the knowledge and direction of association between yield and one character will be very useful in identifying key characters which can be perfectly exploited in a short time to achieve yield improvement in soybean.

Path analysis

The path analysis indicated that the traits *viz.,* number of pods per plant and 100 seed weight exerted highest direct effect on yield at genotypic level (Table 3). Similar trend of results were reported by Mukhekar *et al*. (2004) and Karnwal *et al*. (2009).

Days to 50 per cent flowering and days to maturity expressed positive direct effect on yield at genotypic level, whereas, plant height exerted negative direct effect on grain yield. Similar trend of results were reported by Harer and Deshmukh (1992). Days to 50 per cent flowering, leaf area index, oil content and protein content exerted negative direct effect on yield, while, chlorophyll content shows positive direct effect on yield. These results were supported by Malik *et al*. (2007). Negative direct effect of number of branches on seed yield and positive direct effect of harvest index on yield was observed. Similar findings were also reported by Karnwal *et al*. (2009) and Mir and Tyagi (2010).

The present investigation clearly revealed that the traits, *viz*., number of pods per plant, 100 seed weight, days to maturity, chlorophyll content, number of branches per plant, harvest index had strong association with seed yield per plant and showed positive direct effect and indirect effect through one or the other component traits. This indicated direct selection for these characters will

Table1. Genotypic correlation of yield with oil, morpho-physiological and yield contributing traits in soybean

Character	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of branches / plant	No. of pods/ plant	100 seed weight (g)	Leaf area index	Chloro-phyll content (mg)	Harvest index (%)	Oil content (%)	Protein content (%)	Seed yield/ plant (g)
Days to 50% flowering	1.000	0.857**	0.792**	-0.250*	-0.279*	-.383**	0.015	-0.075	-0.307**	-0.445**	0.405**	-0.301*
Days to maturity		1.000	0.762**	-0.588**	-0.349**	-0.241*	0.159	-0.320**	-0.223	0.104	0.183	-0.429**
Plant height (cm)			1.000	-0.306**	-0.349**	-0.218	0.076	-0.175	-0.222	-0.304**	0.260*	-0.392**
No.of branches/ plant				1.000	0.696**	0.557**	-0.173	0.136	0.592**	0.474**	-0.026	0.734**
No. of pods/ plant					1.000	0.148	-0.100	0.361* *	0.392**	0.541**	-0.109	0.763**
100 seed weight (g)						1.000	-0.008	0.322**	0.548**	0.373**	0.048	0.862**
Leaf area index							1.000	0.973**	0.135	0.182	-0.046	0.033
Chlorophyll content (mg)								1.000	0.328**	0.501**	-0.079	0.422**
Harvest index (%)									1.000	0.725**	0.268*	0.556**
Oil content (%)									-	1.000	0.554**	0.587**
Protein content (%)											1.000	- 0.003
Seed yield/plant (g)												1.000

and: significant at 5 and 1 per cent, respectively.*

Table 2. Phenotypic correlation of yield with oil, morpho-physiological and yield contributing traits in soybean

Character	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	100 seed weight (g)	Leaf area index	Chloro-phyll content (mg)	Harvest index (%)	Oil content (%)	Protein content (%)	Yield /plant (g)
Days to 50% flowering	1.000	0.235**	0.448**	-0.191	-0.077	-0.191	-0.026	-0.060	-0.160	-0.250	0.152	-0.223
Days to maturity		1.000	0.403**	-2.46*	-0.177	-0.142	0.023	-0.151	-0.086	-0.126	-0.003	-0.284*
Plant height (cm)			1.000	-0.186	-0.275*	-0.212	-0.024	-0.191	-0.083	-0.189	0.079	- 0.322**
No. of branches/ plant				1.000	0.544**	0.345**	-0.130	0.152	0.443**	0.204	-0.070	0.631**
No.of pods/ plant					1.000	0.127	-0.026	0.228	0.328**	0.352**	-0.059	0.641**
100 seed weight (g)						1.000	0.218	0.171	0.361**	0.283*	0.004	0.650**
Leaf area index							1.000	0.616**	0.070	0.130	-0.069	0.033
Chlorophyll content (mg)								1.000	0.234*	0.176	0.50	-0.371**
Harvest index (%)									1.000	0.361**	-0.140	0.480**
Oil content (%)										1.000	-0.278*	0.338**
Protein content (%)											1.000	-0.010
Seed yield/plant (g)												1.000

and: significant at 5 and 1 per cent, respectively.*

Table 3. Direct and indirect effects (genotypic) for yield and yield components in soybean

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	100 seed weight (g)	Leaf Area Index	Chlorophyll content (mg)	Harvest index (%)	Oil content (%)	Protein content (%)	Seed yield per plant (g)
Days to 50% flowering	**-0.4303**	1.7744	-0.9327	-0.0861	-0.7625	-0.7491	0.0390	0.1518	-0.1402	1.3564	-0.5219	-0.3011
Days to maturity	0.3687	**2.0711**	-0.8976	-0.2026	-0.9551	-0.4708	0.4044	0.6427	-0.1019	-0.3159	-0.2352	-0.4294
Plant height (cm)	-0.3409	1.5790	**-1.1773**	-0.1056	-0.9541	-0.4271	0.1918	0.3529	-0.1014	0.9263	-0.3351	-0.3916
No. of branches/ plant	0.1075	-1.2174	0.3608	**0.3447**	1.9024	1.0886	-0.4391	-0.2735	0.2698	-1.4425	0.0332	0.7345
No. of pods/ plant	0.1200	-0.7235	0.4108	0.2398	**2.7340**	0.2898	-0.2527	-0.7263	0.1788	-1.6481	0.1407	0.7633
100 seed weight (g)	0.1648	-0.4986	0.2571	0.1919	0.4051	**1.9555**	-0.0207	-0.6472	0.2501	-1.1346	-0.0616	0.8617
Leaf Area Index	-0.0066	0.3302	-0.0890	-0.0597	-0.2724	-0.0160	**-2.5363**	-1.9563	0.0614	-0.5539	0.0591	0.0330
Chlorophyll content (mg)	0.0325	-0.6619	0.2066	0.0469	0.9874	0.6293	2.4671	**2.0111**	0.1497	-1.5265	0.1017	0.4215
Harvest index (%)	0.1323	-0.4626	0.3581	0.2039	1.0720	1.0724	0.3414	-0.6600	**0.4560**	-2.2069	0.3455	0.5557
Oil content (%)	0.1916	0.2148	0.3065	0.1633	1.4796	0.7285	-0.4613	-1.0081	0.3305	**-3.0455**	0.7131	0.5871
Protein content (%)	-0.1745	0.3784	-0.3065	-0.0089	-0.2990	0.0936	-0.1164	0.1589	-0.1224	1.2872	**-1.2871**	-0.0033

Residual effect = 0.6647

be of more useful for enhancing the breeding efficiency for improvement of seed yield in soybean.

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Soybean Research 15(1): 25-34 (2017)

Enhancing the Water Stress Tolerance in Soybean through Anti-transpirants and Mulches

***S D BILLORE*[1]**
ICAR-Indian Institute of Soybean Research, Indore, Madhya Pradesh 452 001
E-mail: billsd@rediffmail.com

Received: 10.06.2016; Accepted: 11.01.2017

ABSTRACT

Field experiments were conducted during rainy seasons of 2012 to 2014 at different locations with diverse agro-climatic conditions of India to study the effect of anti-transpirants and mulches to mitigate the impact of water deficit and sustainable soybean production. The application of straw mulch @ 5 t per ha enhanced the seed yield of soybean by 2.6 per cent, 2.28 per cent and 2.59 per cent in North plain, North Eastern and Central zones, respectively. On the contrary, the seed yield of soybean in Southern zone was higher (2.59 %) under without mulch treatment. The application of different anti-transpirants significantly increased soybean yield to the extent of 4.73 to 14.48 per cent in North plain zone, 6.33 to 15.80 per cent in North Eastern zone, 1.18 to 10.05 per cent in Central zone and 1.83 to 11.30 per cent in Southern zone. The maximum yield was recorded with the applied anti-transpirant $MgCO_3$ @ 5 per cent in North plain and North Eastern zone, glycerol @ 5 per cent in Central zone and KNO_3 @ 1 per cent in Southern zone. The coefficient of variation of yield over the years and sustainability yield index were found to be higher under straw mulch treatment than without mulch across the zones except for Southern zone. The sustainability yield index followed the trend similar to that of soybean yield. Application of straw mulch and anti-transpirants could produce more than 70 per cent of minimum guaranteed yield. The stability parameter (b) indicated that the treatment without mulch showed negative values in North plain and Southern zones, while straw mulch showed negative values in North Eastern and Central zones. The maximum net returns and B:C ratio were with glycerol @ 5 per cent and KNO_3 @ 1 per cent during all the four zones.

Key words: Anti-transpirant, coefficient of variation, mulch, soybean, stability, sustainable yield index

Soybean is a premier oilseed crop of the India as well as the world. By and large, this crop is cultivated during rainy season on Vertisols and associated soils. Current sub-optimal national yield (around 1 t /ha) is a matter of concern, which is mainly affected due to erratic and uneven distribution of rainfall and other aberrant weather conditions. Since, water is a primary limiting factor and, hence, an important management concern in soybean production (Deosthali *et al*., 2005).

Among the technologies available to combat moisture deficit, the use of straw mulch and anti-transpirants hold an important place. Anti-transpirants may reduce water loss from plants

[1]*Principal Scientist (Agronomy)*

either by decreasing absorption of radiant energy by reflecting incident light energy (thereby reducing leaf temperature and transpiration), or reduce cuticular and stomatal transpiration. Use of anti-transpirants has been reported to improve the water use efficiency and reduce leaf transpiration rate by 87 to 93 per cent (Bora and Mathur, 1998).

Mulches help to preserve moisture, repression of weeds, improving soil consistency, and insect-pest assault and guard roots from severe temperature. Organic mulches improve soil quality, regulates soil temperature, hinder weed growth, lessen soil moisture evaporation and improve the visual qualities of landscapes.

Since water is the main limiting factor for plant growth specifically in semi-arid regions of the country, there is a critical need to balance water availability, water requirements and water consumption. Actively growing plants transpire a weight of water equal to their leaf fresh weight each hour under conditions of arid and semi-arid regions, if water is supplied adequately (Moftah, 1997). This scare figure makes it necessary to find ways by which available water could be economically utilized. One way to achieve this goal is to reduce the transpiration rate in order to minimize the amount of irrigation water.

Keeping this in view, the present investigation was planned to determine the effect of different anti-transpirants and mulching (wheat straw) to mitigate the adverse impact of water deficit influencing the sustainable production of soybean.

MATERIAL AND METHODS

A field study was carried out for consecutive three *kharif* seasons of 2012, 2013 and 2014 in different agro-climatic conditions under All India Co-ordinated Research Project on Soybean to study the effect of different anti-transpirants and mulching on sustaining the soybean productivity under rainfed conditions. Spray treatments comprising of four anti-transpirants [$MgCo_3$ @ 5 %, glycerol @ 5 %, Na_2CO_3 @ 1 %, and KNO_3 @ 1 %] and a Water spray (control)] and two treatments of mulch (without and with straw mulch @ 5 t/ha) were laid out in factorial randomized block design with three replications. The water volume utilized for spraying the anti-transpirants at 15 days after flowering was 1,000 l per ha. The appropriate quantity of mulch (5 t/ha) was applied after soybean emergence. The experiment was conducted in four zones of country namely, North plain (Pantnagar, Ludhiana and Delhi), North Eastern (Ranchi, Medziphema, Bhawanipatna and Imphal), Central (Sehore, Kotaand Amravati) and Southern (Dharwad, Coimbatore, Bengaluru, Pune and Adilabad). The recommended package of practices was adopted for raising the soybean crop. The zone-wise recommended dose of nitrogen, phosphorus and potassium were applied to soybean crop. Soybean variety PS 1347 in North plain zone, RKS 18 in North Eastern and Southern zone and JS 95-60 in Central zone were used for the experiment.

The yield data was pooled over three years (2012 to 2014) and centres across each zone. The zone-wise additional returns and incremental cost benefit ratio (IBCR) were worked out by using the standard procedures. The sustainable yield index (SYI) and stability of the treatments were determined by using the centre-wise data of the respective zone. The yield stability was computed following simple regression coefficient and mean over the years (Finlay and Wilkinson, 1963). The sustainable yield index (SYI = mean yield of the treatment - standard deviation/maximum yield) was also computed (Singh *et al.*, 1990).For the calculation of economics of the treatments, the prevailing market prices of inputs were considered.

RESULTS AND DISCUSSION

North plain zone

All the anti-transpirants except Na_2CO_3 produced substantially higher yield than water spray (control) (Table 1). The maximum yield (14.48 %) was recorded with $MgCO_3$ @ 5 per cent followed by KNO_3 @ 1 per cent (10.01 %) and glycerol @ 5 per cent (4.73 %) as compared to water spray. Application of Na_2CO_3 @ 2 per cent yielded less than water spray. The higher variation in yield was observed when anti-transpirants were applied along with mulch treatments than without mulch. The values of SYI followed trend of yield. Application of $MgCO_3$ and KNO_3 were able to produce minimum guaranteed yield more than 80 per cent of the maximum achievable yield, while application of glycerol and water spray were able to produce minimum guaranteed yield more than 70 per cent.

Application of straw mulch significantly enhanced the soybean yield by 2.6 per cent as compared to without mulch (Table 1). The higher variability in soybean yield was recorded under straw mulch. However, applied straw mulch showed higher values of sustainable yield index (SYI), which indicated that the minimum guaranteed yield could be obtained by applying the straw mulch in soybean. Application of straw mulch and anti-transpirants both showed the positive values (> 1), while without mulch revealed negative values (close to the unity) for the stability parameter (b).

North Eastern zone

All the anti-transpirants were found to be effective for enhancing the soybean yield (Table 2). The maximum seed yield increment (15.80 %) was noted with $MgCO_3$ @ 5 per cent followed by glycerol @ 5 per cent (13.63 %), KNO_3 @ 1 per cent (7.12 %) and Na_2CO_3 @ 2 per cent (6.33 %) as compared to water spray. The yield variation was found to be higher when anti-transpirants were applied under straw mulch treatments than without mulch. The highest yield variation was recorded in $MgCO_3$ @ 5 per cent followed by glycerol @ 5 per cent. The lowest yield variation was associated with KNO_3 @ 1 per cent. The SYI values

Table 1. Effect of anti-transpirants and mulch on sustainable soybean production in North plain zone

Treatment	Yield (kg/ha)			SYI			CV (%)			b		
	Mulch	**Control**	**Mean**	**Mulch**	**Control**	**Mean**	**Mulch**	**Control**	**Mean**	**Mulch**	**Control**	**Mean**
$MgCO_3$ @ 5%	1625	1588	1621	0.82	0.80	0.83	10.91	9.45	9.45	3.66	-0.91	1.38
Glycerol @ 5%	1509	1468	1483	0.76	0.74	0.76	9.61	8.82	8.82	3.47	-0.86	1.31
Na_2CO_3 @ 2%	1372	1312	1306	0.71	0.67	0.67	7.30	7.70	7.70	3.43	-1.39	1.02
KNO_3 @ 1%	1557	1531	1559	0.81	0.80	0.82	7.52	5.97	5.97	3.04	-1.18	1.00
Control (Water spray)	1414	1390	1416	0.73	0.72	0.74	6.97	5.81	5.81	2.81	-1.04	0.89
Mean	1492	1454		0.77	0.75		7.59	6.58		3.28	-1.19	
CD (P=0.05)	Mulch	Anti-transparent	Interaction									
	33.08	**61.29**	**NS**									

Table 2. Effect of anti-transpirants and mulch on sustainable soybean production in North Eastern zone

Treatment	Yield (kg/ha)			SYI			CV (%)			b		
	Mulch	**Control**	**Mean**	**Mulch**	**Control**	**Mean**	**Mulch**	**Control**	**Mean**	**Mulch**	**Control**	**Mean**
$MgCo_3$ @ 5%	1990	1908	1920	0.74	0.73	0.74	13.06	9.08	9.05	-4.62	5.91	0.66
Glycerol @ 5%	1929	1884	1884	0.73	0.72	0.72	11.10	8.79	8.78	-4.72	6.41	0.85
Na_2CO_3 @ 2%	1808	1761	1763	0.67	0.68	0.68	11.09	8.22	8.28	-3.86	5.92	1.03
KNO_3 @ 1%	1777	1774	1776	0.69	0.69	0.69	6.96	6.84	6.93	-4.86	6.10	0.62
Control (Water spray)	1710	1681	1658	0.64	0.64	0.64	9.77	9.08	7.80	-3.92	6.02	1.05
Mean	1843	1802		0.70	0.70		9.82	7.85		-4.40	6.07	
CD (P=0.05)	Mulch	Anti-transparent	Interaction									
	104.20	**201.09**	**NS**									

followed the trend similar to that of yield. The minimum guaranteed yield was more than 65 per cent of the maximum yield by application of anti-transpirants.

Application of straw mulch @ 5 t per ha failed to bring appreciable improvement in soybean yield (Table 2), however, it increased the soybean yield by 2.28 per cent as compared to without mulch and also showed higher yield variation over the years. Identical values of SYI in above two treatments indicated that these were able to produce 70 per cent of minimum guaranteed yield. Application of straw mulch and anti-transpirants showed the negative value, while without mulch possesses the positive values more than unity as evidenced from the stability parameter (b).

Central zone

Application of anti-transpirants improved soybean yield appreciably (Table 3). The maximum yield was recorded with glycerol @ 5 per cent (10.05 %) followed by KNO_3 @ 1 per cent (6.05 %) and $MgCO_3$ @ 5 per cent (1.18 %) as compared water spray. Application of Na_2CO_3 @ 2 per cent yielded lower than water spray. The maximum and minimum yield variation was associated with Na_2CO_3 @ 2 per cent and $MgCO_3$ @ 5 per cent, respectively. The SYI values followed the trend of soybean yield. All the anti-transpirants produced more than 70 per cent minimum guaranteed yield than maximum achievable yield.

Application of straw mulch @ 5 t per ha did not cause appreciable improvement in soybean yield (Table 4), however, straw mulch application increased the soybean yield by 2.59 per cent as compared to without mulch and also showed higher yield variation over the years. Both the treatments showed the identical values of SYI, which indicated that application of straw mulch showed slightly higher SYI than without mulch. Both these treatments were capable of producing 74 per cent of minimum guaranteed yield as evidenced by the associated values of SYI. Application of straw mulch showed the negative while without mulch the positive values more than unity as evidenced from the stability parameter (b).

Southern zone

All the anti-transpirants enhanced the soybean yield (Table 4). The maximum yield hike was noted with KNO_3@ 1 per cent (11.30 %) followed by $MgCO_3$@ 5 per cent (9.94 %) glycerol@ 5 per cent (7.58 %) and Na_2CO_3@ 2 per cent (1.83 %) as compared to water spray.

The yield variation was found to be higher when anti-transpirants were applied under straw mulch treatments than without mulch. The highest and lowest yield variation was recorded in KNO_3 @ 1 per cent and water spray. The SYI values followed almost similar trend as was observed in yield, which indicated that the minimum guaranteed yield could be achieved more than 75 per cent of the maximum yield through application of anti-transpirants.

Application of straw mulch @ 5 t per ha did not appreciably improve soybean yield (Table 4), however, without mulch produced higher soybean

Table 3. Effect of anti-transpirants and mulch on sustainable soybean production in Central zone

Treatment	Yield (kg/ha)			SYI			CV (%)			b		
	Mulch	Control	Mean	Mulch	Control	Mean	Mulch	Control	Mean	Mulch	Control	Mean
$MgCo_3$ @ 5%	1663	1631	1621	0.74	0.75	0.74	6.25	3.89	3.78	-5.22	10.69	2.74
Glycerol @ 5%	1823	1787	1763	0.81	0.81	0.80	7.09	5.62	4.96	-5.57	12.01	3.22
Na_2CO_3 @ 2%	1593	1555	1534	0.67	0.67	0.66	11.11	9.45	8.47	-4.65	10.89	3.12
KNO_3 @ 1%	1749	1698	1699	0.74	0.75	0.75	12.11	7.69	7.70	-5.48	11.15	2.84
Control (Water spray)	1698	1642	1602	0.74	0.72	0.70	8.92	8.42	7.60	-5.28	11.32	3.02
Mean	1705	1662		0.75	0.74		8.41	6.04		-5.24	11.22	
CD (P=0.05)	Mulch	Anti-transparent	Interaction									
	59.64	**114.50**	**NS**									

Table 4. Effect of anti-transpirants and mulch on sustainable soybean production in Southern zone

Treatment	Yield (kg/ha)			SYI			CV (%)			b		
	Mulch	Control	Mean	Mulch	Control	Mean	Mulch	Control	Mean	Mulch	Control	Mean
$MgCo_3$ @ 5%	1971	2017	2102	0.74	0.76	0.83	13.15	13.15	9.53	4.61	-3.59	0.51
Glycerol @ 5%	1936	1983	2057	0.75	0.77	0.82	10.43	10.43	7.98	4.43	-3.68	0.38
Na_2CO_3 @ 2%	1820	1863	1947	0.67	0.69	0.76	12.93	12.93	9.39	4.30	-3.26	0.52
KNO_3 @ 1%	1982	2030	2128	0.73	0.75	0.83	14.88	14.88	10.71	4.70	-3.52	0.59
Control (Water spray)	1778	1833	1912	0.67	0.69	0.75	11.34	11.34	8.83	4.13	-3.33	0.40
Mean	1899	1946		0.71	0.73		12.30	12.30		4.43	-3.50	
CD (P=0.05)	Mulch	Anti-transparent	Interaction									
	29.30	**45.70**	**NS**									

yield by 2.47 per cent as compared to straw mulch and showed higher value of SYI. The SYI values indicated that both the treatments could be able to produce 70 per cent of minimum guaranteed yield. The coefficient of variation values showed that both the treatments had identical yield variation over years. Application of straw mulch and anti-transpirants under straw mulch showed the positive value, while without mulch the negative values (> 1) as evidenced from the stability parameter (b).

The soybean yield improvement due to applied anti-transpirants might be as a result of improved metabolic and enzymatic activities associated with these chemicals. In addition, the anti-transpirants were effective in reducing the transpiration rate without deleterious effects on carbon assimilation (Devenport *et al*., 1972). Using anti-transpirants, improved the water use efficiency and reduced leaf transpiration rate by 87 to 93 per cent was recorded by earlier workers (Bora and Mathur, 1998). Moreover, Shen *et al*. (1999) and Yancey *et al*. (2005) found that glycerol can function either as an osmolyte, contributing to the maintenance of water balance, or as an osmoprotectant, allowing the operation of many cellular processes during osmotic stress.

Water shortage, reduced stem height, node number, stem diameter in the control treatment (without spraying with anti-transpirants). This may be due to the negative effect of water stress on photosynthesis, nutrient metabolism and hormonal activities and plant water relations. The application of anti-transpirants could maintain the plant water potential and reduced the magnitude of negative impact of water stress (Fukutoka and Terai (1996).

The favourable effects of spreading the crop residue on soil surface (straw mulching) on soil environment enhanced yield of a number of crops, and yield gain ranged between 4 to 29 per cent (Sandhu *et al*., 1989). Reduction in soil water evaporation with straw mulching decreases crop water demands (Jalota and Arora, 2002) and saved 7-40 cm of irrigation water.Liu *et al*. (2002) concluded that mulch increases soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield. Despite these benefits of straw mulching, this practice does not find favour with farmers. One major factor appears to be variable crop response. In a review, Prihar and Arora (1980) concluded that response of crops to mulching depends on soil and climatic conditions. In general, crop responses are more on low-water retentive loamy sand compared to sandy loam soils; more intense hot and dry summer period than wet and humid conditions, and under limited than plentiful irrigation. Similar observations for rainfed maize were made by Sur *et al*. (1995).

Economics

The net returns and B:C ratio were found to be higher in case of without mulch as compared to mulch @ 5 t per ha in all the four zones included in the study (Table 5 and 6). The differences in net returns and B:C ratio might be due to the variations in cost of cultivation and

Table 5. Effect of anti-transpirants and mulch on economics of soybean in North Plain and North Eastern zone

Treatment	North plain zone						North Eastern zone					
	Net returns (Rs/ha)			B:C ratio			Net returns (Rs/ha)			B:C ratio		
	Mulch	Control	Mean	Mulch	Control	Mean	Mulch	Control	Mean	Mulch	Control	Mean
$MgCo_3$ @ 5%	21580	25295	23925	1.61	1.83	1.73	34340	36495	35463	1.97	2.20	2.09
Glycerol @ 5%	13645	17200	15423	1.35	1.50	1.43	28330	31765	30048	1.72	1.93	1.82
Na_2CO_3 @ 2%	21605	24525	23065	1.82	2.15	1.98	36875	40230	38553	2.40	2.88	2.64
KNO_3 @ 1%	28435	32520	30478	2.09	2.54	2.32	36155	41035	38595	2.39	2.95	2.67
Control (Water spray)	24200	28365	26750	1.96	2.40	2.17	34535	38535	36535	2.37	2.90	2.64
Mean	21769	25459		1.72	2.00		34054	37619		2.12	2.48	
			CD (P=0.05)			**CD (P=0.05)**			**CD (P=0.05)**			**CD (P=0.05)**
Mulch			**1270**			**0.09**			**876**			0.09
Anti-transparent			**2008**			**0.14**			**1385**			0.16
Interaction			**2840**			**0.19**			**1958**			0.22

Table 6. Effect of anti-transpirants and mulch on economics of soybean production in Central and Southern zones

Treatment	Central zone						Southern zone					
	Net returns (Rs/ha)			B:C ratio			Net returns (Rs/ha)			B:C ratio		
	Mulch	Control	Mean	Mulch	Control	Mean	Mulch	Control	Mean	Mulch	Control	Mean
$MgCo_3$ @ 5%	22915	26770	24842	1.65	1.88	1.77	33675	40285	36980	1.95	2.33	2.14
Glycerol @ 5%	24610	28365	26488	1.63	1.83	1.73	28580	35210	31895	1.73	2.03	1.88
Na_2CO_3 @ 2%	29350	33010	31180	2.11	2.54	2.33	37315	43795	40555	2.41	3.05	2.73
KNO_3 @ 1%	35165	38385	36775	2.35	2.82	2.59	43330	50015	46673	2.66	3.38	3.02
Control (Water spray)	34125	37175	35650	2.35	2.83	2.59	36935	43845	40390	2.46	3.16	2.81
Mean	29227	32737		1.96	2.29		36016	42676		2.18	2.68	
			CD (P=0.05)			**CD (P=0.05)**			**CD (P=0.05)**			**CD (P=0.05)**
Mulch			**1145**			**0.10**			**1415**			0.13
Anti-transparen			**1933**			**0.16**			**2240**			0.19
Interaction			**2735**			**0.23**			**3168**			0.29

yield of the respective treatments. Application of straw mulch @ 5 t per ha showed lower net returns and B:C ratio as compared to without mulch.

Among the anti-transpirants, the highest net returns and B:C ratio were with applied glycerol @ 5 per cent and KNO_3 @ 1 per cent in all the four zones included in the study (Table 3 and 6). The variations in results may be ascribed to the differences in cost of a particular anti-transpirant and their effect on yield.

On the basis of foregoing results it could be concluded that the application of straw mulch @ 5 t per ha along with any of the anti-transpirant could be able to mitigate the moisture deficit situations in soybean and enhance the soybean productivity and profitability.

ACKNOWLEDGEMENT

The author gratefully acknowledges the scientists of different centres of All India Coordinated Research Project on Soybean for conducting the experiments and providing the data.

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Soybean Research 15(1): 35-39 (2017)

Comparative Efficacy of Clomazone and Sulfentrazone Herbicides on Weed Control and Productivity of Soybean [*Glycine max* (L.) Merrill]

***MANJU RAWAT*[1]*, M D VYAS*[2] *and P S MARAVI*[3]**
R A K College of Agriculture (RVSKVV), Sehore 466 001, Madhya Pradesh
Email: vyasmd@rediffmail.com

Received: 17.12.2014; Accepted: 16.03.2017

ABSTRACT

Field experiment were conducted during kharif *2012 and 2013 at Sehore, Madhya Pradesh to evaluate the efficacy of pre-emergence herbicides sulfentrazone and clomazone on the extent of weed management, growth and yield of soybean. The major weed flora in the experiment field was* Echinochloa crusgalli, Brachiaria reptens, Cyperus rotundus, Commelina benghalensis, Corchorous acutangulus and Digera arvensis. *Application of sulfentrazone 48 SC @ 360 g a i per ha recorded higher weed control efficiency (92.59 %) followed by clomazone 1000 g a i per ha (91.62 %). The seed yield was higher in application of sulfentrazone 48 SC @ 360 g a I per ha (1,109 kg/ha) and it was at par with application of at sulfentrazone 48 SC @ 300 g a i per ha and clomazone 1000g a i per ha.*

Key words*:* Clomazone, soybean, sulfentrazone

Soybean (*Glycine max* (L) Merrill) is the most important rainy season oilseed crop of Madhya Pradesh, which has brought about a perceptible change in the economy of the farmers of the state. Being rainy season crop, it suffers from severe infestation of weeds which reduces its seed yield by 25-77 per cent (Kurchania *et al*., 2001) and may also reach to 86 per cent (Mishra and Singh, 2009). Although hand weeding is an effective method of weed control, prevailing incessant rains, inherent swell shrink nature of Vertisols, and unavailability and high wages of labour are some constraints, which do not permit farmers to go for this option. Application of herbicides is the alternative option for control of weeds. Therefore, application of new pre-emergence herbicides needs evaluation as a cheap, timely and quick method of weed management.

MATERIAL AND METHODS

Field experiment was conducted at the Research farm of R A K College of Agriculture, Sehore under All India Coordinated Research Project on soybean under rainfed condition during *kharif* 2012 and 2013. The soil was Vertisols (Chromosterts) clay loam with organic carbon content (0.42 %) and available N,

[1]Reserch Scholar; [2]Principal Scientist; [3] Field Extension Officer

P_2O_5 and K_2O were 210.6, 15.80 and 285 kg per ha, respectively. Soil was neutral in reaction. The experiment was laid out in randomized block design with three replications. Soybean variety JS 95-60 was sown on 6th July 2012 and 11th July 2013 keeping row to row spacing of 45 cm. The seven treatments comprising three levels of sulfentrezone 48 EC (@ 240, 300 and 360 g a i/ha), two levels of clomazone (@ 750 and 1000 g a i/ha), pendimethelin 30 EC @ 1.0 kg a i per ha (check herbicide) and a weedy check were evaluated.

Herbicides were applied as pre-emergence on the same day of sowing of soybean. The spray volume of for herbicide application was 600 ml per ha and knapsack sprayer fitted with flat fan nozzle was employed. The weed counts were recorded for each weed species present in a quadrate of 0.25 m^2 and weed dry weight was taken at 30 days after application. The weed control efficiency (WCE) was calculated as below.

WCE = DWC – DWT/DWC x100,

Where, DWC- dry weight of weeds in control plot, DWT- dry weight of weeds in treated plot

Observations on plant height, branches per plant, dry weight per plant, pods per plant, seeds per pod, seed yield per plant, were recorded on randomly selected five plants at harvest. Crop growth rate and relative growth rate (RGR) were recorded at 45-60 days interval. Seed and straw yield was recorded for each treatment and expressed as kg per ha.

RESULT AND DISCUSSION

Effect on weeds

The weed flora of the experimental fields comprised *Echinocloa crussgali* Link., *Brachiaria* reptans, *Cyperus rotundus* Linn., *Digera arvensis* Forsk., *Commelina benghalensis* Linn., *Corchorous acutangulus, Acalypha indica, Euphorbia geniculata, Commelina cummins, Cyperus esculentus* Linn., constituting on an average 45.69, 12.79, 9.40, 9.40, 6.01, 4.96, 3.39, 3.39, 2.61, 2.09 and 0.26 per cent share of the total weed flora, respectively. Kushwaha and Vyas (2006) also reported similar weed flora in soybean.

The different doses of sulfentrazone and clomazone reduced the density of monocot and dicot weeds over check herbicide (pendimethalin @ 750 g a i/ha) and weedy check treatments. The intensity of total monocot and dicot weeds was minimum under pre-emergence application of sulfentrazone 48 SC @ 360 g a i per ha followed by sulfentrazone 240 g a i per ha. The finding confirms the results of Dricks (2000)

All the treatments resulted in significant reduction in the weed biomass and recorded higher weed control efficiency compared with the control. Application of sulfentrazone 48 SC @ 360 g a i per ha recorded higher weed control efficiency (92.59 %) followed by clomazone 1000 g a i per ha (91.62 %).

Effect on crop

Growth and yield attributes namely branches per plant, CGR, pods per plant, seeds per pod and seed yield

Table 1. Effect of weed-control treatments on weed density, weed dry weight, weed-control efficiency and growth attributes of soybean (pooled data of 2 years)

Treatment	Dicot weeds (No/ 0.25m² at 30 DAA*	Monocot weeds (No/ 0.25m²) at 30 DAA	Weed dry weight (g/0.25m²)	WCE (%)	Plant population (No/ m²)	Plant height (cm)	Branches (No/ plant)	Dry weight (g/ plant)
Sulfentrazone 48 SC @ 240 g ai/ha	4.00 (2.05)	15.41 (3.98)	6.75	86.18	58	43.52	2.17	6.00
Sulfentrazone 48 SC @ 300 g ai/ha	2.41 (1.62)	12.92 (3.65)	5.00	89.54	60	43.58	2.61	6.33
Sulfentrazone 48 SC @ 360 g ai/ha	1.98 (1.24)	9.25 (3.1)	3.50	92.59	59	43.75	2.66	7.11
Clomazone 50 EC @ 750 g ai/ha	7.92 (2.81)	17.58 (4.07)	5.08	88.54	59	44.52	1.89	5.67
Clomazone 50 EC @ 1000 g ai/ha	6.43 (2.53)	14.42 (3.81)	3.75	91.62	58	42.89	2.54	6.22
Pendimethalin 30 EC @ 750 g ai/ha	9.0 (3.06)	19.67 (4.72)	5.42	88.62	60	44.91	1.83	5.56
Weedy check	17.50 (4.20)	53.75 (7.35)	48.08	-	59	44.08	1.38	4.78
S.Em (±)	(0.37)	(0.52)	1.04	-	2.21	2.07	0.25	0.81
C D (P = 0.05)	**(0.96)**	**(1.50)**	**3.10**	**-**	**NS**	**NS**	**0.76**	**NS**

*DAA-Days after application ***Figures in parentheses are* $\sqrt{x + 0.5}$ *transformation*

Table 2. Effect of weed-control treatments on Physiological parameters, yield attributes and yield of soybean (pooled data of 2 years)

Treatment	Crop growth rate (g/m2/ day)	Relative growth rate (g/g/day)	Pods (No/ plant)	Seeds (No/ pod)	Seed yield (g/ plant)	Seed index (g/100 seeds)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Net return (Rs/ha)	C:B ratio (Per Rs invested)
Sulfentrazone 48 SC @ 240 g ai/ha	10.34	0.056	11.22	2.51	3.61	10.89	991	1256	44.16	18454	1:2.27
Sulfentrazone 48 SC @ 300 g ai/ha	10.01	0.051	12.00	2.76	3.78	11.66	1103	1304	45.84	21948	1:2.50
Sulfentrazone 48 SC @ 360 g ai/ha	12.33	0.058	12.11	2.84	3.94	11.72	1109	1422	43.80	22082	1:2.49
Clomazone 50 EC @ 750 g ai/ha	11.67	0.063	11.00	2.49	3.50	11.76	977	1184	45.04	17016	1:2.10
Clomazone 50 EC @ 1000 g ai/ha	11.01	0.053	11.67	2.73	3.66	11.91	1072	1274	45.73	19648	1:2.23
Pendimethalin 30 EC @ 750 g ai/ha	12.00	0.070	10.67	2.33	2.67	10.81	891	1232	42.40	14901	1:2.00
Weedy check	7.33	0.056	9.00	2.29	2.22	10.04	457	691	39.84	1392	1:1.10
S Em (±)	1.30	0.005	0.84	0.13	0.39	0.35	46	62	2.2	-	-
C D (P = 0.05)	**3.90**	**NS**	**2.52**	**0.39**	**1.16**	**1.04**	**138**	**187**	**NS**	**-**	**-**

per plant were influenced significantly with weed control treatments and higher values of these parameters were obtained in application of sulfentrazone @ 360 g a i per ha. Plant height, plant dry weight (g) relative growth rate (RGR) and harvest index were not influenced significantly by weed control treatments (Table 1 and 2).

Application of sulfentrazone 48 EC @ 360 a i per ha resulted significantly higher seed yield (1,109 kg/ha) over check herbicide pendimethalin and weedy check. It remained at par with application of sulfentrazone 300 g a i per ha and clomazone 1000g a i per ha. The higher net returns and cost: benefit ratio were also obtained with application of sulfentrazone 360 g a i per ha. Vidrine *et al* (1996) reported that sulfentrazone effectively controlled broad leaf weeds and enhance yield of soybean.

The results suggested that application of sulfentrazone 48 SC 360 g per ha effectively controlled weed infestation and enhanced all growth, yield components and yield in soybean.

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Soybean Research 15(1): 40-45 (2017)

Efficacy of Bio-agents, Botanicals and Insecticides in Suppression of *Spodoptera litura* on Vegetable Soybean

B PRAMOD SASVIHALLI[1], C MANJA NAIK[2] and K NATARAJ[3]
AICRP on Soybean, ZARS, GKVK, UAS, Bangalore 560 065, Karnataka
E mail : natarjk@gmail.com

Received: 20.05.2016 : Accepted: 10.01.2017

ABSTRACT

Field experiments were conducted for two consecutive seasons during kharif *2011 and 2012, to assess the effectiveness of bio-agents, botanicals and insecticides against* Spodoptera litura*(Fab.) on vegetable soybean. The results indicated that the sequential spray of Chlorpyriphos (0.05 %) – SlNPV (2 ml/l) was effective in reduction of larval population of* S. litura*. The mean number of larvae were 2.47 and 1.53 per meter row length. Whereas the next best sequence was Spinetoram (0.02 %) – SlNPV (2ml/l), which registered 2.49 and 1.63 larvae per meter row length after first and second spray during* kharif *2011 and the similar trend was observed in these two sequential sprays during* kharif *2012.*

Key words: Bio-agents, botanicals, *Spodoptera litura* and vegetable soybean

Soybean [*Glycine max* (L.) Merrill] is a unique crop with high nutritive value, providing 40 per cent protein and 20 per cent edible oil besides minerals and vitamins. It supports many industries; in manufacturing antibiotics, paints, varnishes, adhesives and lubricants and also used as protein supplement in human diet, cattle and poultry feed (Alexander, 1974).

The luxuriant crop growth, soft and succulent foliage attracts many insects and provides unlimited source of food, space and shelter. About 380 species of insects have been reported on soybean crop from many parts of the world. About 65 insect species have been reported to attack soybean from cotyledon stage to harvesting stage from Karnataka (Rai *et al*., 1973; Adimani, 1976; Thippaiah, 1997). The defoliators [*Spodoptera litura* (Fab.), *Thysanoplusia orichalcea* (Fab.), *Spilarctia obliqua* (Walk.)] and *Helicoverpa armigera* (Hubner) are feeding on foliage, flower and pods causing significant yield loss (Singh and Singh, 1990).

The tobacco caterpillar, *S. litura* is a serious and regular pest in Madhya Pradesh. It damages soybean from mid-August to October in *kharif* and from November to March in *rabi* (Anonymous, 2007). Higher population was noticed in Dharwad and Belgaum districts of Karnataka and the pest was active during grand growth stage of the crop. After damaging the leaves, they start feeding on younger parts, subsequently damaging 30 to 50 per cent of the pods (Anonymous, 2007).

[1]Student; [2] Professor; [3]Senior Research Fellow

To avoid losses caused by these defoliator pests, various chemical control measures attempted earlier were found effective temporarily. However, indiscriminate use of chemicals led to the problems like pest outbreak, development of resistance by pest to insecticides, elimination of natural enemies, risk to human and animal health besides environmental pollution. Hence, in the present investigation involving bio-agents, botanicals and insecticides were used to manage *S. litura* on vegetable soybean.

MATERIAL AND METHODS

Field trials were conducted at the Zonal Agricultural Research Station, Gandhi Krishi Vigyana Kendra, University of Agricultural Sciences, Bengaluru during *kharif* 2011 and 2012 under rainfed condition. The effectiveness of botanicals, bio-agents and insecticides were evaluated against *S. litura* on vegetable soybean variety 'Karune'. The experiment was laid out in a completely randomized block design and twelve treatments, which were replicated thrice (Table 1). Treatment combinations were imposed at 40 and 60 days after germination in sequence. The individual plot size for each treatment was 4.5 m x 4 m. Recommended package of practices were followed to raise the crop except plant protection measures.

Observations on larval population were made on five randomly selected vegetable soybean plants of one meter row length in each plot, leaving the border rows. Larval count was made by shaking plants gently over a white cloth placed between the rows and the visual observations on plants. Pre-treatment counts were made a day prior to imposition of the treatments and subsequently the larval population (No/mrl) was observed on, fifth, tenth and fifteen days after each spray.

Table 1. Botanicals, bio-agents and insecticides evaluated against *Spodoptera litura*

Treatment	Concentration
NSKE – NSKE*	5 % -5 %
PSKE – PSKE**	5 % -5 %
Spinetoram12 % SC - *Sl* NPV	0.02 % - 2 ml/l
Spinetoram12 % SC - *Beauveria bassiana*	0.02 % - 2 ml/l
Chlorpyriphos 20 % EC - *Acacia Arabica*	0.05 % - 5 %
Chlorpyriphos 20 % EC - *Eucalyptus globules*	0.05 % - 5 %
Spinetoram 12 % SC -*Lantana camara*	0.02 % - 5 %
Spinetoram 12 % SC - *Nicotiana tabacum*	0.02 % - 5 %
Spinetoram 12 % SC- *Acacia Arabica*	0.02 % - 5 %
Chlorpyriphos 20 % EC - *Sl* NPV	0.05 % - 2 ml/l
Chlorpyriphos 20 % EC - *Beauveria bassiana*	0.05 %- 2 ml/l
Untreated check	-

**NSKE - Neem Seed Kernel Extract, **PSKE - Pongamia Seed Kernel Extract*

Table 2. Efficacy of bio pesticides and insecticides against *S. litura* on vegetable soybean under field (after 1^{st} and 2^{nd} spray)

Treatment	**Concentration**	**After 1^{st} spray No. of larvae/mrl (Mean of two seasons)**					**After 2^{nd} spray No. of larvae/mrl (Mean of two seasons)**				
		1 DBT	**5 DAT**	**10 DAT**	**15 DAT**	**Mean**	**1 DBT**	**5 DAT**	**10 DAT**	**15 DAT**	**Mean**
NSKE - NSKE*	5% -5%	13.55	3.97	2.60	3.35	3.50	10.62	2.14	1.12	2.08	1.78
		(4.23)	(1.99)^{cd}	(1.61)^{bc}	(1.83)^{d}	(1.86)^{b}	(3.07)	(1.46)^{a}	(1.06)^{ab}	(1.44)^{ab}	(1.32)^{a}
PSKE - PSKE*	5 % - 5 %	13.60	3.96	2.62	3.40	3.87	10.68	2.18	1.14	2.12	1.81
		(4.23)	(1.99)^{cd}	(1.62)^{c}	(1.84)^{d}	(1.94)^{bc}	(1.63)	(1.48)^{ab}	(1.07)^{ab}	(1.46)^{ab}	(1.33)^{a}
Spinetoram 12 % SC -	0.02 % -	12.25	2.85	1.84	2.45	2.49	9.20	2.00	0.98	1.90	1.63
Sl NPV	2ml/lit	(4.13)	(1.68)^{ab}	(1.36)^{ab}	(1.57)^{ab}	(1.74)^{ab}	(2.80)	(1.38)^{a}	(0.97)^{ab}	(1.38)^{ab}	(1.26)^{a}
Spinetoram 12 % SC -	0.02 % -	12.70	3.48	2.20	3.15	3.62	9.30	2.23	1.18	2.16	1.86
B. bassiana	2ml/lit	(4.17)	(1.84)^{bc}	(1.48)^{bc}	(1.77)^{bcd}	(1.87)^{b}	(2.82)	(1.49)^{ab}	(1.08)^{ab}	(1.47)^{ab}	(1.35)^{a}
Chlorpyriphos 20%	0.05 % - 5%	12.65	3.13	1.98	2.50	2.71	9.40	2.10	1.08	1.85	1.68
EC - *A. arabica*		(4.17)	(1.77)^{abc}	(1.41)^{abc}	(1.58)^{abc}	(1.63)^{ab}	(2.84)	(1.45)^{a}	(1.04)^{ab}	(1.34)^{ab}	(1.28)^{a}
Chlorpyriphos 20 %	0.05 % - 5 %	13.88	3.75	2.45	3.30	3.00	9.52	2.30	1.24	2.24	1.93
EC - *E. globules*		(4.25)	(1.93)^{bc}	(1.57)^{bc}	(1.82)^{cd}	(1.73)^{ab}	(2.84)	(1.51)^{ab}	(1.11)^{b}	(1.5)^{b}	(1.38)^{a}
Spinetoram 12 % SC- *L.*	0.02 % - 5 %	12.60	3.67	2.42	3.22	3.40	10.48	2.28	1.22	2.20	1.90
camara		(4.17)	(1.91)^{bc}	(1.56)^{bc}	(1.80)^{bcd}	(1.83)^{ab}	(3.02)	(1.51)^{ab}	(1.10)^{ab}	(1.48)a^{b}	(1.37)^{a}
Spinetoram 12 % SC -	0.02 % - 5 %	13.23	3.51	2.30	3.20	2.91	10.44	2.25	1.20	2.18	1.88
N. tabacum		(4.20)	(1.87)^{bc}	(1.52)^{bc}	(1.79)^{bcd}	(1.70)^{ab}	(3.02)	(1.50)^{ab}	(1.09)^{ab}	(1.48)^{ab}	(1.36)^{a}
Spinetoram 12 % SC-	0.02 % - 5 %	12.55	3.78	2.50	3.33	3.13	10.55	2.20	1.16	2.14	1.83
A. arabica		(4.20)	(1.94)^{bc}	(1.58)^{bc}	(1.82)^{cd}	(1.76)^{ab}	(3.84)	(1.48)^{ab}	(1.08)^{ab}	(1.46)^{ab}	(1.34)^{a}
Chlorpyriphos 20% EC	0.05 % -	12.85	2.33	1.33	2.23	2.47	8.10	1.90	0.90	1.80	1.53
- *Sl* NPV	2ml/lit	(4.19)	(1.51)^{a}	(1.15)^{a}	(1.49)^{a}	(1.54)^{a}	(2.18)	(1.48)^{a}	(0.95)^{a}	(1.34)^{a}	(1.33)^{a}
Chlorpyriphos 20% EC	0.05 % -	13.20	3.33	2.10	3.10	3.07	8.38	2.12	1.10	2.00	1.74
- *B. bassiana*	2ml/lit	(4.20)	(1.82)^{bc}	(1.45)^{bc}	(1.76)^{bcd}	(1.74)^{ab}	(2.20)	(1.46)^{a}	(1.05)^{ab}	(1.38)^{ab}	(1.31)^{a}
Untreated check	-	13.50	13.60	13.72	13.80	13.70	11.20	11.24	11.26	11.67	11.39
		(4.23)	(4.25)^{d}	(4.25)^{d}	(4.27)^{e}	(4.25)^{c}	(3.86)	(3.86)^{c}	(3.86)^{c}	(3.88)^{c}	(3.86)^{b}
CV (%)		-	9.34	8.92	8.20	8.70	-	7.30	8.81	9.45	7.03
CD (P = 0.05)		**-**	**0.30**	**0.24**	**0.20**	**0.26**	**-**	**0.18**	**0.16**	**0.23**	**0.16**

**NSKE - Neem Seed Kernel Extract, **PSKE - Pongamia Seed Kernel Extract; DBT- Day Before Treatment; DAT- Day After Treatment; Means followed by same letter do not differ significantly by DMRT (p=0.05); Values in the parentheses are $\sqrt{x+0.5}$ transformed*

Table 3. Per cent leaf damage by *S. litura* due to application of bio pesticides and insecticides under field (after 1st and 2nd spray)

Treatment	Concentration	After 1st spray: Per cent leaf damage (Mean of two seasons)					After 2nd spray: Per cent leaf damage (Mean of two seasons)				
		1 DBT	5 DAT	10 DAT	15 DAT	Mean	1 DBT	5 DAT	10 DAT	15 DAT	Mean
NSKE - NSKE*	5% -5%	59.85	37.98	26.84	27.98	30.93	49.22	27.00	24.00	24.33	25.11
		(36.86)	(38.01)^{bc}	(31.13)^{b}	(31.81)^{b}	(33.77)^{b}	(32.7)	(31.17)^{bc}	(29.27)^{a}	(29.53)^{ab}	(30.05)^{a}
PSKE - PSKE*	5 % - 5 %	59.90	38.90	27.10	28.20	30.84	49.40	27.40	24.10	24.90	25.47
		(36.87)	(37.58)^{b}	(31.36)^{b}	(32.05)^{b}	(33.72)^{b}	(32.81)	(31.54)^{bc}	(29.34)^{a}	(29.91)^{b}	(30.23)^{a}
Spinetoram 12 % SC -	0.02 % -	60.15	32.20	22.10	23.20	25.83	49.30	22.10	19.20	20.12	20.47
Sl NPV	2ml/lit	(34.3)	(34.55)^{ab}	(28.03)^{ab}	(28.75)^{ab}	(30.52)^{ab}	(32.75)	(28.01)^{ab}	(25.96)^{a}	(26.62)^{ab}	(26.60)^{a}
Spinetoram 12 % SC -	0.02 % -	60.10	35.80	24.42	25.60	28.61	49.20	25.22	21.90	22.80	23.31
B. bassiana	2ml/lit	(34.27)	(36.71)^{ab}	(29.56)^{ab}	(30.31)^{ab}	(32.31)^{ab}	(32.69)	(30.12)^{ab}	(27.56)^{a}	(28.5)^{ab}	(28.83)^{a}
Chlorpyriphos 20%	0.05 % - 5%	58.90	34.10	23.35	24.30	27.25	49.10	23.33	20.12	21.20	21.55
EC - *A. arabica*		(36.86)	(35.69)^{ab}	(28.86)^{ab}	(29.51)^{ab}	(31.45)^{ab}	(32.62)	(28.84)^{ab}	(26.64)^{a}	(27.39)^{ab}	(27.63)^{a}
Chlorpyriphos 20 %	0.05 % - 5 %	59.42	37.00	25.9	27.87	30.26	48.90	26.00	23.00	23.90	24.30
EC - *E. globules*		(36.87)	(37.45)^{b}	(30.58)^{b}	(31.84)^{b}	(33.35)^{ab}	(32.50)	(30.63)^{b}	(28.62)^{a}	(29.24)^{a}	(29.51)^{a}
Spinetoram 12 % SC- *L.*	0.02 % - 5 %	58.50	36.96	25.82	26.88	29.89	49.67	25.90	22.50	23.00	23.80
camara		(36.82)	(37.43)^{b}	(30.45)^{b}	(31.21)^{ab}	(32.96)^{ab}	(32.99)	(30.51)^{b}	(28.29)^{a}	(28.62)^{ab}	(29.16)^{a}
Spinetoram 12 % SC -	0.02 % - 5 %	59.20	35.95	24.49	25.82	28.75	47.50	25.80	22.10	22.90	22.82
N. tabacum		(36.84)	(36.81)^{ab}	(29.59)^{ab}	(30.52)^{ab}	(32.40)^{ab}	(31.61)	(28.94)^{ab}	(28.01)^{a}	(28.56)^{ab}	(28.51)^{a}
Spinetoram 12 % SC-	0.02 % - 5 %	58.50	37.90	26.82	27.88	30.87	47.80	26.90	23.95	24.00	24.95
A. arabica		(36.81)	(37.92)^{bc}	(31.18)^{b}	(31.74)^{b}	(33.54)^{ab}	(31.80)	(31.22)^{bc}	(29.28)^{a}	(29.31)^{ab}	(29.91)^{a}
Chlorpyriphos 20% EC	0.05 % -	58.20	30.10	20.10	21.10	23.77	48.10	20.20	18.90	19.10	19.40
- *Sl* NPV	2ml/lit	(35.78)	(33.23)^{a}	(26.63)^{a}	(27.32)^{a}	(29.14)^{a}	(31.99)	(26.68)^{a}	(25.74)^{a}	(25.48)^{a}	(26.10)^{a}
Chlorpyriphos 20% EC	0.05 % -	59.40	35.40	24.22	25.10	28.24	48.00	24.10	21.15	22.30	22.74
- *B. bassiana*	2ml/lit	(36.84)	(36.46)^{ab}	(29.42)^{ab}	(29.98)a	(32.08)^{ab}	(31.93)	(29.34)^{ab}	(27.82)^{a}	(28.15)^{ab}	(28.45)^{a}
Untreated check	-	62.00	64.00	66.50	68.80	66.43	50.50	52.10	54.20	56.28	54.19
		(37.12)	(38.10)^{c}	(39.17)^{c}	(39.39)^{c}	(39.93)^{c}	(33.31)	(34.49)^{c}	(35.75)^{b}	(36.98)^{c}	(35.75)^{b}
CV (%)		-	6.32	7.15	8.03	8.10	-	7.48	9.27	8.34	9.03
CD (P = 0.05)		**-**	**3.95**	**3.73**	**4.30**	**4.55**	**-**	**3.82**	**4.48**	**4.10**	**4.47**

**NSKE - Neem Seed Kernel Extract, **PSKE - Pongamia Seed Kernel Extract; DBT- Day Before Treatment; DAT- Day After Treatment; Means followed by same letter do not differ significantly by DMRT (p=0.05); Values in the parentheses are $\sqrt{x+0.5}$ transformed*

Foliage damage by *S. litura* larvae was noted at fifth, tenth and fifteen days after the first and second spray, on randomly selected five plants, extent of leaf damage was based on visual grade (1-9 scale) per meter row length by following the procedure laid out by (Wightman and Ranga Rao, 1994).

The data obtained from the field experiments were statistically analyzed. The per cent values were transformed to corresponding arcsine transformation and the larval counts in field experiments to square roots ($\sqrt{x + 0.5}$) before analysis, and means were separated by DMRT [Duncan's Multiple Range Test].

RESULTS AND DISCUSSION

Studies on the efficacy of bio-agents, botanicals and insecticides in suppression of *S. litura* on vegetable soybean revealed that the sequential sprays of Chlorpyriphos (0.05 %) - *Sl* NPV (2ml/l) recorded high larval reduction of 2.47 and 1.53 per meter row length after first and secondspray, respectively. The next best treatment was Spinetoram (0.02) - *Sl* NPV (2ml/l) by registering 2.49 and 1.63 larvae per meter row length (Table 2).

Different sequential sprays gave varying degrees of control of *S. litura.* Among the sequential sprays, least per cent leaf damage was registered in Chlorpyriphos (0.05 %) - *Sl* NPV (2ml/l) (23.77 and 19.40 %) followed by Spinetoram (0.02 %) - *Sl* NPV (2ml/l) sequential spray (25.83 and 20.47 % permeter row length) after first and second spray, respectively (Table 3). The literature pertaining to efficacy of Spinetoram on vegetable soybean ecosystem is lacking, as it is a newer insecticide. However, Sunilkumar *et al.* (2012) reported Spinetoram 12 SC @ 60 g a.i. per ha as effective in suppressing the larval population of *S. litura on* soybean.

Narasimhamurthy *et al.* (2012) recorded 81.66 per cent of *S. litura* larval reduction followed by *Sl* NPV + neem oil (0.1 %) (73.33 %), whereas, the botanicals *mustard* oil (0.2 %), chilli garlic extract (2.5 %), *Calotropis* leaf extract (2 %) and *Pongamia* leaf extract (2 %) along with *Sl* NPV recorded 62.78, 60.26, 55.38 and 53.75 per cent larval reduction respectively, on cabbage after first spray. Least per cent larval reduction of (45.60) was observed in *Sl* NPV. The addition of NSKE (5 %) or neem oil (0.1 %) with *Sl* NPV spray solution had additive effect and also avoided deterioration of NPV in the sun light and favoured in bringing down the larval population of *S. litura* immediately after each spray.

The investigations on the effectiveness of bio-agents and insecticides could be concluded that the sequential spray of insecticides and the bio-agents reduces the insecticidal pressure on the environment. It favours the built up of population of the natural enemies, brings down the population of insect pests and use of bio-agents on vegetable soybean helps in harvesting of the produce free from insecticidal residue.

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Soybean Research 15(1): 46-55 (2017)

Isolation, Identification and *In vitro* Evaluation of Fungicides against *Fusarium* Leaf Blight of Soybean Caused by *F. oxysporum**

SANJAY YADAV[1] and M M ANSARI[2]
Rajmata Vijayaraje Sindia Krishi Vishwavidyalaya, Gwalior 474 002, Madhya Pradesh
E mail: ansarimasud@rediffmail.com

Received 08.02.2017.; Accepted: 20.04.2017

ABSTRACT

Fusarium leaf blight of soybean caused by Fusarium oxysporum *Schltdl. appeared at flowering to pod formation stage in the field under of soil moisture saturation coupled with low temperature conditions. Macro- conidia were sickle shaped, curved and 3-5 septate 9 to 77 µm in length. Of the eight fungicides evaluated* in vitro *conditions against the pathogen using poisoned food technique, four (carbendazim, benomyl, thiophanate methyl and propiconazole) completely inhibited the radial growth of the mycelium at all concentrations* viz., *250 ppm, 500 ppm and 1000 ppm, whereas mancozeb, captan, and hexaconazole inhibited at 500 and 1000 ppm and copper oxychloride was least effective. Spore germination was tested against five of these fungicides* viz., *carbendazim, benomyl, thiophanate methyl, mencozeb and propiconizole. Carbendazim, benomyl and thiophanate methyl were lethal and killed spores. Hence, these fungicides can be used to effectively control the Fusarium blight of soybean.*

Key words: *Fusrium oxysporum*, fungicides, leaf blight, soybean

Soybean suffers from several diseases caused by bacteria, fungi and viruses. Annual yield losses due to these diseases are in the tune of 12 per cent of the total production (Wrather *et al.,* 2001). The severity of diseases varies season to season and area to area. In Madhya Pradesh, during *kharif* 2015, the monsoon was initially delayed a little and then there was a long dry spell followed by a continuous heavy downpour for about a month leading to a serious attack of foliar blight. Most of the cultivated varieties suffered due to this disease. Since there were neither resistant varieties nor effective chemical control measures available to contain this disease, the present study was undertaken with twin objectives- (i) to isolate and identify pathogen involved and (ii) to identify the effective fungicides against the pathogen.

MATERIAL AND METHODS

Isolation and Identification

Infected leaves collected from the field, were cut in to small pieces (5 mm size) with the help of sterile blade, containing half diseased and half healthy portions. Pieces were then sterilized

**Part of M. Sc (Ag) Thesis; [1,] M. Sc. Student; [2,] Principal Scientist (ICAR-IISR)* with 0.1 per cent mercuric chloride for 30-40 seconds and then thoroughly washed with sterile distilled water to remove excess mercuric chloride and then the pieces were transferred aseptically in Petri plates containing Potato Dextrose Agar (PDA) medium. The plates were incubated at 27 ± 1^0 C for 6 days. After the fungal growth, the pure culture was further transferred to PDA slants and incubated as described above. Morphological observation of the pathogen like growth, appearance, radial growth, colour, *etc*. after 7 days of incubation on PDA were recorded visually; and mycelium structure, shape and size of spore were recorded under microscope.

Pathogenicity test

The pathogenicity of the fungus was confirmed by artificially inoculating 30-35 day-old-plants of the soybean cultivar JS 335 raised in 30 cm earthen pots. Before inoculation the plants were covered with the moist polythene bag for 24 h to maintain high humidity.

Preparation of inocula

All the seven isolates prepared from diseased samples were taken for this purpose. The culture were grown on PDA plates and 48 h old fungal growth was washed thoroughly with 50 ml sterile distilled water individually in a conical flask and mixed thoroughly with the help of mechanical shaker and filtered through muslin cloth. The concentration of inocula was maintained to 10^6 conidia per ml by observing under binocular microscope. After that the inoculum was sprayed with the help of atomizer. The control plants were sprayed with sterile distilled water and the plants were covered again by moist polythene bag for 24 h to maintain high humidity. Plants were irrigated daily to maintain saturated soil condition.

***In-vitro* evaluation of fungicides**

Eight fungicides *viz*., thiophanate methyl, carbendazim, benomyl, mancozeb, captan, copper oxychloride, hexaconazole and propiconazole (Table 1) were evaluated against *Fusarium oxysporum*, using standard poisoned food technique. Three different concentrations *viz*., 1000 ppm, 500 ppm and 250 ppm, were tested individually for each fungicide. Required quantity of fungicide was mixed in 100 ml pre-molten PDA medium and mixed thoroughly under aseptic condition and Petri plates were poured. After solidifying 5 mm size of 7-day-old fungal culture maintained on PDA medium were transferred aseptically in the centre of plates. Three replications were made for each treatment. Control plates (un-amended fungicide) were inoculated with 5 mm size of fungal mycelia maintained on PDA. Plates were sealed with Para film to avoid contamination and incubated in BOD incubator at 27 ± 1^{0}C for 7 days. Observations were recorded at 48, 96 and 144 h intervals. Per cent growth inhibition was calculated with the help of following formula (Datta *et al*., 2004).

Per cent growth inhibition (I) = C – T/C x 100

Where: C= Growth in control (Untreated); T= Growth in treated

Effect on spore-germination

The conidia of *F. oxysporum* were harvested from 7-day-old culture grown on PDA in sterilized distilled water. Stock solutions of the test fungicides thiophanate methyl, carbendazim, benomyl, mancozeb and propiconazole were prepared and each one was diluted to achieve required concentration (1000, 500, and 250 ppm). A drop of the test solution was placed on a glass cover slip and allowed to dry. A drop of spore suspension was placed on it. The cover slip was inverted on a cavity slide to give a hanging drop preparation. Three replications for each treatment were maintained and the slides were placed in Petri dishes lined with moist blotting paper. Appropriate control was maintained using sterile water in place of the fungicide test solution. The Petri dishes were incubated at 27 ± 1^{0}C for 24 h and slides were examined for counting total and germinated spores. The per cent spore germination was recorded using following formula (Kiraly *et al.*, 1974).

Per cent spore germination = No. of spores germinated/Total no. of spores examined x 100

RESULT AND DISCUSSION

Fusarium leaf blight appeared in the susceptible variety at flowering to pod formation stage in the field under over saturation of soil moisture coupled with low temperature conditions, which happened due to continuous rain in 2nd week of July (Fig. 1). Symptoms were prominent on the leaves, in the form of blight. Blight symptom started with margin of leaf (Fig. 2) and covered whole leaf. In severe conditions the leaves dried up and drop prematurely. Similar types of symptoms due to leaf blight pathogen in soybean have earlier been reported (Crowmell, 1917; Nelson *et al.,* 1997; Steven *et al.*, 2005). Seven isolates were prepared from the samples collected from different places.

Pathogenicity of the fungus was confirmed by applying Koch's postulate. The pathogen was found to be highly pathogenic with initiation of blight symptoms after 5 days of incubation and later blighting occurred on the whole leaf. Re-isolation made from these artificially inoculated leaves consistently yielded *F. oxysporum*.

Identification and characterization of the pathogen

The mycelia were cottony, fluffy and white to pinkish in colour with light yellow pigmentation on reverse of the Petri plate. Mycelium was septate with three types of spores, macro-conidia, micro-conidia and chlamydospore, which were observed under the microscope. Macro-conidia were sickle shaped, curved and septate (3-5 septa). Micro-conidia were round to rod shaped and with or without septa. The macro-conidia were found in the range of 9 to 77 µm and the micro-conidia in the range of 3 to 11.5 µm (Fig. 3). On the basis of cultural and microscopic characters, which coincided with the characters described by Booth (1971), it was identified as *F. oxysporum*.

Table 1. Details of fungicides and their source

Chemical Name	Common Name /Trade Name	Active ingredient	Composition	Manufacturer
Dicopper chloride trihydroxide	Copper oxychloride /Blue Copper	50 % WP	Copper oxycholoride- 88% Other ingredient - 12%	Syngenta India Ltd.
Methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate	Benomyl /Benofit	50 % WP	Benomyl -50% Adjuvants+carries-50%	Coromandal International Ltd.
Dimethyl[(1,2-phenylene)bis-(iminocarbonothioyl)]bis[carbamate]	Thiophanate methyl /Intop	70 % WP	Thiophanate methyl-74 % Precipitated silica-17.54 % Sticking agent- 2 % Suspended agent- 2 % Wetting agent- 2 %	Biostadt India Ltd.
Methyl1H-benzimidazol-2-ylcarbamate	Carbendazim / Hilzim	50 % WP	Carbendazim – 50 % Other relevant ingredient- 50 %	Hindustan Insecticide Ltd
Manganese ethylene bisdithiocarbamate	Mancozeb / Stargem-45	75 % WP	Mancozeb- 88 % Suspended- 2 % Disperring agent- 2 % Surface active – 2 % China clay- 5.77 %	Swal Corporation Ltd.
N-trichoromethylthio-4-cyclohexene-1,2-dicarboximide	Captan / Captan	50 % WP	Captan- 50 % Magnesium sulphate -1 % Wetting&suspended – 10 % China clay- Q.S.	Arysta Life Science Corporation, Japan
2-(2,4-Dichlorophenyl)-1-(1H-1,2,4-triazol-1-yl)hexan-2-ol	Hexaconazole /Revolt plus	5 % EC	Hexaconazole - 5.34 % Propyleneglycol-55 Emulsifiers – A.- 3 %; B.- 3 %; C.- 2.5 % Potassium phosphate-10 % Water- 68 %	Safex Chemical India Ltd.
1-[[2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl]methyl]-1,2,4-trizole	Propiconazole / Tilt	25 % EC	Propiconazole - 25 % Emulsifying agent - 10 % Wetting agent - 3 % Cyclohexan - 25 % Organic solvent - Q.S.	P.I. Industries Ltd.

In-vitro evaluation of fungicides against *F. oxysporum*

Effect of fungicides on radial growth

In vitro toxicity test revealed that four fungicides *viz.,* carbendazim, benomyl, thiophanate methyl and propiconazole completely inhibited the mycelial growth of *F. oxysporum* at all the concentration tested, whereas mancozeb and captan completely inhibited the fungal growth at 500 and 1000 ppm, and at 250 ppm little growth was observed at 144 h of incubation. Copper oxychloride being a non- systemic fungicide was less effective and inhibited the mycelial growth at 1000 ppm only (Fig. 4). Mancozeb completely inhibited the fungal growth at 500 and 1000 ppm concentration, whereas at 250 ppm limited growth was observed at 144 h of inoculation (87.54 % inhibition). Copper–oxychloride, at 1000 ppm showed maximum inhibition (77.09 %) followed by 500 and 250 ppm (58.27 % and 38.11 %, respectively). Captan completely inhibited the mycelial growth at 500 and 1000 ppm and 65-70 per cent inhibition at 250 ppm. Hexaconazole also inhibited the growth at 1000 and 500 ppm but at 250 ppm the inhibition was about 76 per cent (Fig. 2).

Begum *et al.* (2010) evaluated six chemical fungicides and 15 locally available plant extracts against three fruit rot pathogens *viz. Fusarium oxysporum* f. sp. *capsici, Rhizopus artocurpi* and *Alternaria tenuis* for the inhibition of spore germination and mycelial growth. Among the fungicides tested, all the concentration of ridomil inhibited 100 per cent of spore germination and the least inhibition was recorded in case of treatment with bavistin for *F. oxysporum* f. sp. *capsici.*

Gangwar and Kumar (2012) found carbendazim most effective at 50 ppm, inhibiting the radial growth of *F. semitectum* completely followed by thiophanate methyl and propiconazole. Shah *et al*. (2006) conducted study to see the effect of some fungicide *viz.,* carbendazim, mancozeb, sulphur, and conjoint carbendazim and mancozeb against *F. oxysporum*. All the treatments significantly reduced the growth of *F. oxysporum* compared to control but it was significantly less in 10,000 ppm concentration than 10, 100 and 1000 ppm. It was also observed that the longer the incubation period more the growth inhibition.

Taskeen-Un-Nisa *et al*. (2011) studied effect of carbendazim, hexaconzol, bitertanol, myclobutanil, mancozeb, captan and zineb on the inhibition of mycelial growth and spore germination of *F. oxysporum*. They found that all systemic fungicides at different concentrations significantly inhibited the mycelia growth of *F. oxysporum.* However, hexaconozole at highest concentration (1000 ppm) caused highest reduction of mycelial growth followed by carbendazim, bitertanol and myclobutanil at the same concentration. It was also observed that amongst the non-systemic fungicides, mancozeb was found most effective in reducing mycelia growth of the fungus followed by captan and zineb. Again the results reported in the present study in case of carbendazim, thiophanatemethyl, benomyl, captan and

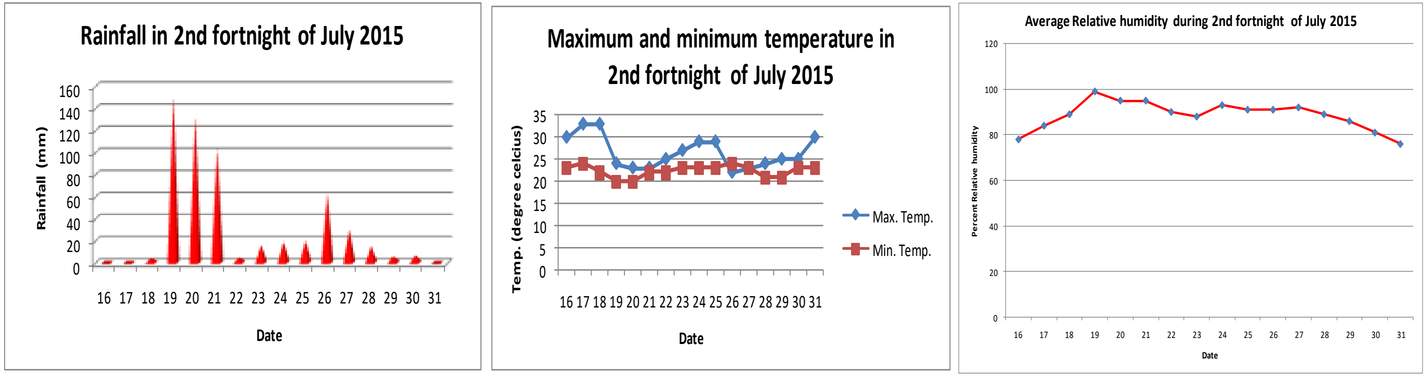

Fig 1. Rainfall, Maximum, Minimum Temp and Relative Humidity during 2nd fortnight of July 2015

Fig. 2. Fusariaum leaf blight

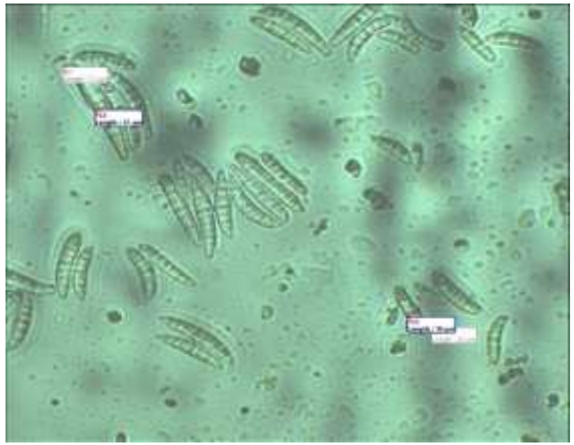

Fig. 3. Macroconidia of *F. oxysporum*

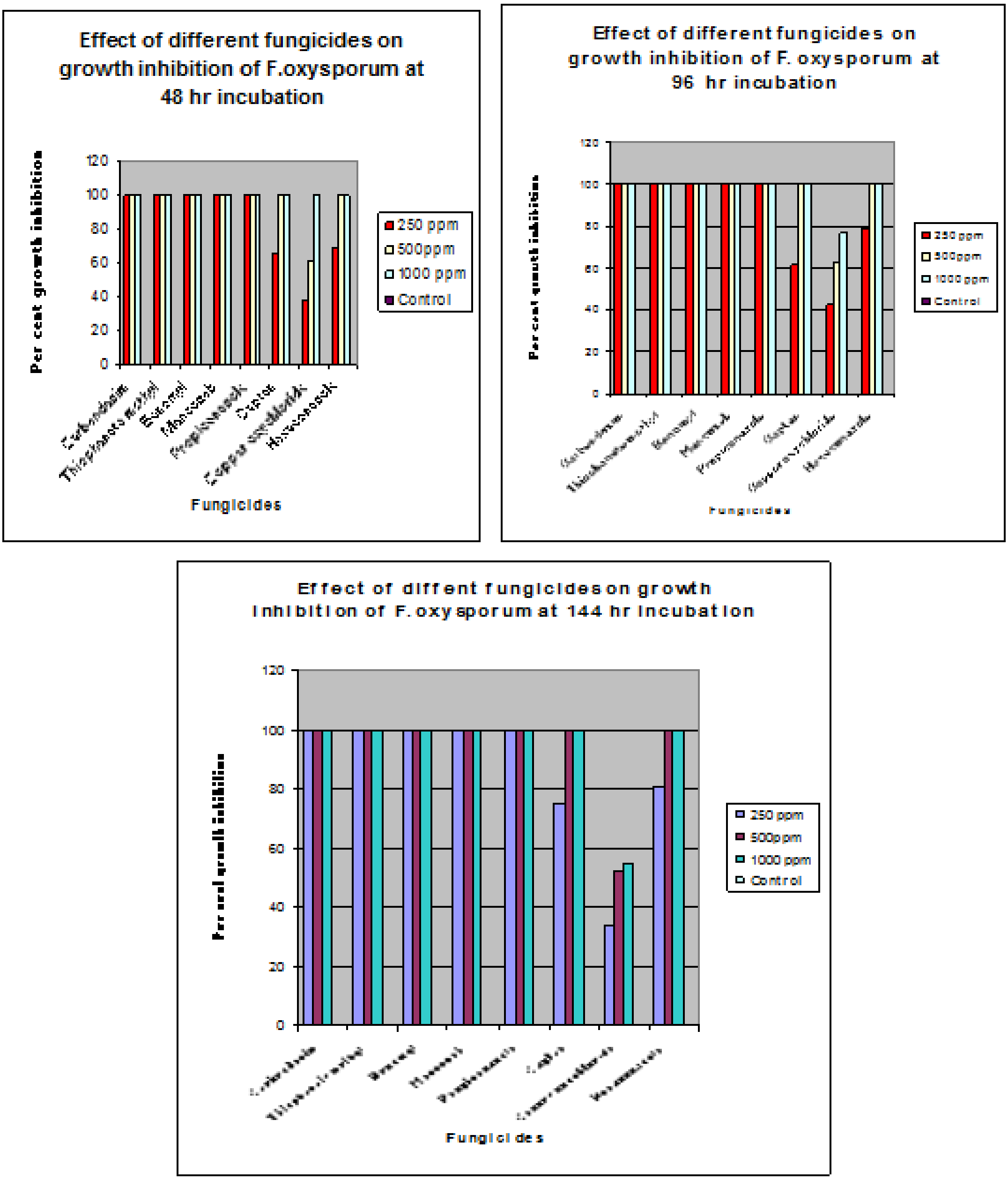

Fig. 4. Effect of different fungicides on radial growth of *F. oxysporum*

Hexaconazole are in accordance with the results reported by Taskeen-Un- Nisa *et al*, (2011) and Dar *et al*. (2013).

Effects of fungicides on the spore germination

Spore germination was carried out by hanging drop technique. Three concentrations (250, 500 and 1000 ppm) of each fungicide were assayed against *F. oxysporum*. Observations on spore germination were recorded after 4 and 6 hr intervals.

The results revealed that different fungicides showed different result in inhibiting the spore germination (Table 2). Minimum spore germination was found with benomyl, followed by carbendazim, propiconazole and mancozeb. In control, it was maximum. As the incubation period increased there was an increase in the spore germination at a particular concentration but it was reverse in case of concentration of fungicides. This may be due to the reason that the spores became acclimatized and germinated after longer period of incubation whereas the chemicals became more toxic at higher concentration and hence, less germination occurred. As compared to control (100 % germination), no spore germination was recorded at 1000 ppm concentration with carbendazim, benomyl and thiophanate methyl, while little germination occurred with mancozeb and propiconazole. Begum *et al.* (2010) evaluated six chemical fungicides and 15 locally available plant extracts against three fruit rot pathogens viz. *Fusarium oxysporum* f. sp. *capsici, Rhizopus artocurpi* and *Alternaria tenuis* for the inhibition of spore germination and mycelial growth. Among the fungicides tested, ridomil and bavistin inhibited spore germination and growth of*F. oxysporum* f. sp. *capsici.* Dar *et al*. (2013) evaluated nine fungicides namely,

Table 2. Effects of fungicides on the spore germination of *F. oxysporum* at different concentrations

Fungicide	Per cent spore germination at different intervals* Concentration of fungicides					
	50 ppm		500 ppm		1000 ppm	
	4 h	6 h	4 h	6 h	4 h	6 h
Carbendazim	0.00 (0.00)	3.33 (12.41)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Benomyl	0.00 (0.00)	2.00 (10.40)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Thiophanate methyl	0.00 (0.00)	11.11 12.41)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Mancozeb	4.67 16.34)	11.33 (21.40)	0.00 (0.00)	7.33 (15.59)	0.00 (0.00)	0.00 (0.00)
Propiconazole	5.78 (14.04)	8.00 (20.75)	3.33 (10.40)	8.00 (16.34)	0.00 (0.00)	3.33 (10.40)
Control	21.33 (27.02)	45.33 43.45)	21.33 (27.46)	45.33 (42.30)	20.00 (26.54)	47.33 (43.44)
Factors	**SEm (±)**	**C D**	**SEm (±)**	**C D**	**SEm (±)**	**C D**
Factor(A)	0.25	**0.70**	0.22	**0.63**	0.21	**0.60**
Factor(B)	0.20	**0.57**	0.18	**0.51**	0.17	**0.49**
Factor(A X B)	0.10	**0.29**	0.09	**0.26**	0.09	**0.25**

**Data as the average of three replications; Figures in parenthesis are transformed value; C D (P = 0.01* carbendazim, hexaconazole, thiophonate methyl, triadimefan, metalaxyl, mancozeb, captan, copper oxychloride and chlorothalonil *in vitro* for their effect on the inhibition of mycelial growth and spore germination of *F. oxysporum* f. sp. *pini.* Among systemic fungicides maximum inhibition of mycelial growth and spore germination was observed with carbendazim followed by other fungicides. Among non-systemic fungicides maximum mycelial growth inhibition and spore germination were observed with mancozeb. Hamini-Kadar *et al*. (2014) also evaluated fungicides against *Fusarium* sp. causing root rot in tomato and found that they were effective to control the pathogen. Our findings are in agreement with the results reported by Begum *et al.* (2010), Dar *et. al.* (2013) and Hamini- Kadar *et al*. (2014)

Thus, based on our study, it was observed that *Fusarium* blight of soybean appeared in severe condition under low temperature coupled with high soil moisture conditions. The fungicides carbendazim, benomyl and thiophanate methyl were highly effective in inhibiting the fungal growth as well as in killing spores and hence, can be used for effective control of *Fusarium* blight of soybean.

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Soybean Research 15(1): 56-62 (2017)

Virulence variability in *Colletotrichum truncatum* (Schwein.) Andrus and W. D. Moore Isolates of Soybean in India

M M ANSARI[1]
ICAR-Indian Institute of Soybean Research,
Indore 452 001, Madhya Pradesh
E mail: ansarimasud@rediffmail.com

Received: 22.02.2017: Accepted 16.05.2017

ABSTRACT

Colletotrichum truncatum *(Schwein.) Andrus and W.D. Moore causes anthracnose/pod blight/stem blight and shepherd's crook symptom in soybean. It is one of the serious problems in most of the soybean growing areas. The isolates collected from different agro-climatic zones exhibited variation in morphology and virulence to a set of selected soybean genotypes The colour of mycelium varied from white to dark grey. Based on the growth behavior, the isolates have been grouped into fast, medium and slow growing, and into pathotypes to VI based on virulence to the test genotypes. Pathotype I was most virulent while pathotype VI was least virulent. There were no correlation between growth behaviour and virulence of the isolates.*

Key words: Anthracnose, *Colletotrichum truncatum,* pathogenic variability, pod blight, stem blight, shepherd's crook, soybean

Colletotrichum truncatum (Schwein.) Andrus and W. D. Moore is the causal organism of anthracnose/pod blight/ stem blight and shepherd's crook symptoms in soybean. This species is most geographically widespread in soybean growing areas and is most frequently isolated from soybean plant parts. It is an important disease under warm (20-25° C) humid conditions causing up to 30 per cent yield loss (Backman *et al,* 1982; Mahmood and Sinclair, 1992). The severity and losses caused by the disease varies from location to location within a geographical area. In this context, Roy (1996) reported that the falcate spore isolates of *Colletotrichum* from different parts of soybean resulted in two colony types. In view of little information on variability of pathogenic isolates infecting soybean in major soybean growing areas, the present study was aimed to identify the variability among different isolates of *C. truncatum* based on morphological and pathological characteristics.

MATERIAL AND METHODS

Isolation of the fungus

A number of isolates were prepared using standard mycological procedures. The diseased of the various soybean cultivar showing different types

[1]***Principle Scientist***

of symptoms collected from different regions were thoroughly washed with tap water and separately cut into small pieces. These pieces were surface sterilized with 0.5 per cent sodium hypochlorite for 40-50 seconds followed by 3 - 4 washings with sterilized distilled water. The surface sterilized diseased pieces were then aseptically transferred separately to the plates containing potato dextrose agar (PDA) medium and then incubated at 25 ± 2° C. After 60-72 h of incubation, the growing mycelium from the margin of apparently distinct colonies was sub-cultured on fresh PDA slants. The cultures of different isolates thus obtained were purified by further transfer and maintenance on PDA medium to keep them viable and sub-culturing was done at an interval of 15-20 days and preserved at low temperature (5 ± 1° C) before use.

Identification of the fungus

Slides were prepared from fully grown fungal cultures and mounted on cotton blue for identification of the fungus with the help of conidial characters like shape and size, and the presence of setae described by Corda (1831).

Pathogenicity test

Isolates of representative region/area were further multiplied and pathogenicity of each isolate was tested on JS 335 by detached leaf inoculation methods (Backman *et al*., 1982).

Screening of soybean lines

Three randomly selected leaves at the time of flowering from each of the 97 soybean genotypes grown in field during *kharif* 2015 were sampled. After removing the leaflet, the petioles were kept in sterilized wet plate of 150 mm size and each petiole was inoculated artificially with 5 mm size 10–day old cultures of highly virulent Dhar isolate of *C. truncatum* maintained on PDA medium and plates were incubated at room temperature for 4-6 days. Control was inoculated with 5 mm PDA disc and maintained under similar conditions. The browning/growth of fungus on the petioles was indicative of susceptibility while no change in petiole colour (green) was indicative of resistance.

Morphological and cultural characters

The growth pattern and cultural characters of the isolates were recorded after full growth at 20 days after incubation and simultaneously the conidial morphology (size and shape) was also recorded after harvesting the conidia and mounting in cotton blue using compound research microscope. Tests to characterize conidia of all isolates on PDA were repeated twice. Ten conidia of each isolate were measured each time.

Variations in virulence to a set of soybean lines

Selected seven soybean lines showing different degrees of disease reaction were inoculated individually with all the 13 isolates collected from different regions using detached leaf method described earlier. The variation in virulence was recorded.

RESULTS AND DISCUSSION

Eleven isolates were prepared from the different sources of different regions (Table 1).

Table 1. Details of *Colletotrichum* isolates

Isolate	Place of origin	Affected parts
Ct1	Indore	Stem
Ct2	Palampur	Pod
Ct3	Umiam	Pod
Ct4	Nagaland	Pod
Ct5	Amravati	pod
Ct6	Dharwad	Stem/pod
Ct7	Indore	Pod
Ct 8	Dhar	Seed
Ct9	Jabalpur	Stem
Ct10	Raipur	Stem
Ct 11	Ugarkhurd	Pod

All the isolates were pathogenic to JS 335. The colour of mycelium varied from grey, whitish grey, creamy white to white. The reverse pigmentation also varied from white grey to dark black in colour (Fig. 1, Table 2). Grouping of the eleven isolates based on growth characters revealed that seven of them were in the category of fast growing and produced more dry mycelium (322 to 363 mg/100 ml culture filtrate), while two were medium growing and produced 265-317 mg per 100 ml culture filtrate and remaining two were slow growing and produced 124 - 209 mg per 100 ml culture filtrate (Table 3). The relationship between colour and growth of the mycelium was non-existent. All the isolates formed falcate/curved, hyaline conidia with acute ends (Fig. 2), which is a characteristic of *C. truncatum*. As per Corda (1831) *Colletotrichum* forms fusi-from, curved hyaline conidia with acute ends and brown setae with acute tips. Roy (1996) reported that the falcate spore isolates of *Colletotrichum* isolated from different parts of soybean resulted in two colony types.

Recording of conidial morphology (shape and size) for each group revealed that length of fast growing isolates varied from 21.11 to 24.20 µm and width 3.5 to 4.00 µm and in slow growing the length varied from 20.00 to 24.50 µm and width 3.5 to 4.20 µm, while in medium growing isolates the length varied from 20.5 to 23.21 µm and width 3.2 to 4.5 µm (Table 3). Jagtap and Sontakke, (2009) and Nagraj and Jahagirdar (2014) while studying the morphology of both conidia and setae of *C. truncatum* isolates from soybean, recorded distinct variation among the isolates, which congruence our results.

A Total of 97 lines, including varieties and genetic stock were screened and classified using 0-9 scale (Anonymous, 2014). Most of them were susceptible while few [VLS 1, GP 109, TAMS 38, RVS 2001-4, JS 79-811, AMS 25-11, Hardee, Shilajeet, PS 1347, Palam Soya, LSB 1 (Brown pods and JS 95-60] were moderately susceptible (MS) and four lines (GP 339, BS 1, Lee, and JS 20-49) were moderately resistant (MR) (Table 4). Seven lines showing different degree of disease reaction (Table 5) were utilized for studying the virulence variability among the isolates.

Virulence variability

For studying virulence variability 13 isolates (Table 5) of *C. truncatum* originating from different soybean growing regions were of seven varieties showing different degree of disease reaction (Table 4). A disc of 5 mm diameter of 7-10 days old culture was inoculated to petioles of every plant (detached leaf method) and incubated at room temperature in a sterile wet plate. The virulence was recorded.

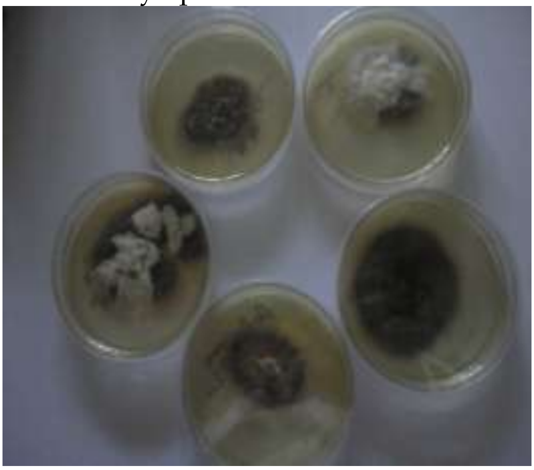

Fig. 1. Cultural characters of representative isolates of *C. truncatum* on PDA

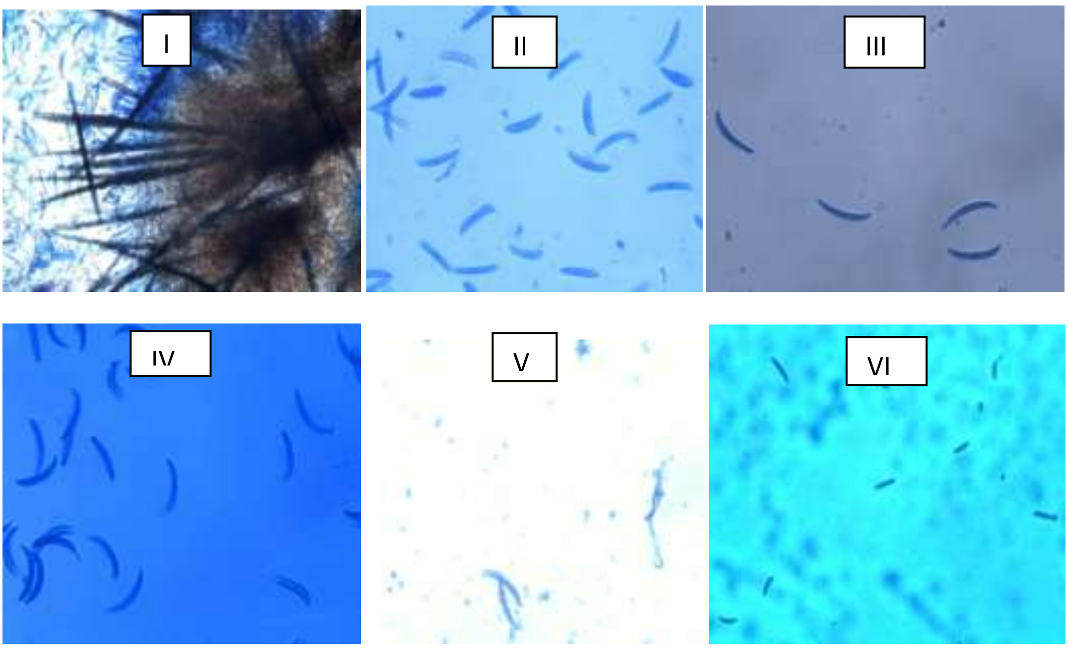

Fig 2. Conidia and setae of different isolates of *C. truncatum* grown on PDA

Table 2. Morphological and cultural characters of different *Colletotrichum* isolates on PDA

Characters	*Colletotrichum* isolates and their origin										
	Ct1 Indore	**Ct2 Palam-pur**	**Ct3 Umiam**	**Ct4 Naga-land**	**Ct5 Amravati**	**Ct6 Dharwad**	**Ct7 Indore Anth**	**Ct8 Dhar**	**Ct9 Jabalpur**	**Ct10 Raipur**	**Ct11 Ugarkhurd**
Growth	medium	fast	fast	medium	fast	Fast	fast	slow	fast	slow	fast
Shape	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular	Circular
Margin	Irregular	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Irregular	Smooth
Colour	Greyish	White grey	White	Greyish white	White	Grey	Cottony grey	White grey	Grey white	White	Cream white
Reverse pigmentation	Dark black	Grey	Black	Black	Black	Black	Black	Black	Light grey	White	White
Mycelium dry weight (mg/100 ml culture)	317	322	363	265	330	355	374	209	310	124	355

Table 3. Variation in conidial dimension of *C. truncatum*

Type of isolates	Conidial size (µm)			
	Length	**Mean**	**Width**	**Mean**
Fast growing	21.11- 24.20	22.65	3.5-4.00	3.95
Slow growing	20.0- 24.50	22.25	3.5-4.20	3.85
Medium growing	20.5- 23.21	21.85	3.2- 4.50	3.65

Table 4. Screening of soybean varieties against *C. truncatum* (artificial inoculation)

Category	Varieties
Susceptible (S) (scale 7)	Pb 1, PS 1029, Pusa 24, Pusa 20, PS 1241, MACS 450, PS 564, PK 262, NRC 7, ADT 1, Improved Pellican, MAUS 61-2, PK 472, MAUS 1, MAUS 47, MAUS 2, NRC 37, CO Soya 2, Alankar, Pusa 40, TAMS 98-21, Shivalik, Pusa 22, PS 1024, Durga, T 49, NRC 7, Indra Soya 9, Pusa 37, SL 96, DS 228, JS 335, JS 76-205, PS 1225, Ankur, NRC 12, RKS 24, SL 295, Pusa 16, MAUS 61, Bragg 13, PS 1092, VLS 65, VLS 21, MAUS 79, KB 79, Harasoya, JS 97-52, Pusa 97-12, RKS 18, LSB 1, Karuna, JS 71-05, MACS 57, MAUS 71, PRS 1, PS 1042, PS 1225, GS 2, NRC 2, Gaurav, SL 688, MAUS 81, PK 327, Kalitur, GS 1, CO 1, MACS 13, PK 416, JS 90 41, RAUS 5, MAUS 32, MACS 124, JS 75-40, VLS 47, JS 93-05, CO Soya 3, VLS 2, JS 2, Monetta, MAUS 158, JS 80-21, PK 471, SL 525, MACS 58, Pusa 98-14, GP 118-275, Bragg 13
Mod Susceptible (MS) (scale 5)	VLS 1, GP 109, TAMS 38, RVS 2001-4, JS 79-811, AMS 25-11, Hardee, Shilajeet, PS 1347, Palam soya, LSB-1 (Brown Pods), JS 95-60
Mod Res (MR) (scale 3)	GP 339, BS 1, Lee, JS 20-49

Though all the isolates were found pathogenic to JS 335 and caused disease. They showed variation in virulence when were inoculated on a group of soybean lines exhibiting having different degree of disease reaction. Isolates Ct 8, Ct 7, Ct 1 and Ct 6 were virulent to all the soybean lines and forms pathotype I. Isolates Ct 5 , Ct 3 and Ct 4 were virulent to GP 118-275, PS 1225, AMS 25-11 and GP 339 and avirulent to GP 109, Bragg 13, and JS 20-49 and formed pathotype II. Isolate Ct 12 and Ct 9 were avirulent to GP 118-275, PS 1225, Bragg 13, JS 20-49 and GP 339 and virulent to AMS 25-11 and GP 109 and forms pathotype III. Isolate Ct 2 was avirulent to GP 118-275, PS 1225, AMS -25-11, GP 109, and Bragg 13 and virulent to JS 20-49 and GP 339 and formed pathtype IV. Isolate Ct 11 and Ct 13 were virulent to all except JS 20-49 and GP 339 and formed pathotype V. One isolate (Ct 10) from Raipur which was virulent to GP 118—275 and PS 1225 and avirulent to the rest was white and slow growing and produced less dry mycelium formed pathotype VI (Table 5). Thus, on the basis of virulence, isolates were grouped in to 6 pathotypes. The pathotype I was most virulent and pathotype VI least virulent. Pathotype I was found to be distributed in major soybean growing areas. Pathotype II occurred mostly in Northeast region. In Amravati both Pathotypes II and III were found. Pathotype V was recorded from Ugarkhurd and Dharwad while pathotype VI from Raipur. Variability in morphology and colony size (Roy, 1996) and conidial size (Jagtap and Sontake, 2009; Nagaraj and Jahagirdar, 2014) of *C. truncatum* isolates of soybean in India were recorded earlier.

Table 5. Reaction of selected soybean lines to different isolates

S. No	Isolate	GP 118-275 (S)	PS 1225 (S)	AMS-25-11 (MS)	GP109 (MS)	Bragg-13 (S)	JS 20-49 (MR)	GP 339 (MR)	Patho-type
1	Dhar seed Ct8	S	S	S	S	S	S	S	I
2	Ind-Anth Ct7	S	S	S	S	S	S	S	I
3	Indore coll Ct 1	S	S	S	S	S	S	S	I
4	Dharwad Collet Ct 6	S	S	S	S	S	S	S	I
5	Amrawati-2 Ct 5	S	S	S	R	R	R	S	II
6	Umiam Ct 3	S	S	S	R	R	R	S	II
7	Nagaland Ct 4	S	S	S	R	R	R	S	II
8	Amrawati Ct 12	R	R	S	S	R	R	R	III
9	Jabalpur Ct 9	R	R	S	S	R	R	R	III
10	Palampur Ct 2	R	R	R	R	R	S	S	IV
11	Ugar Khurd Ct11	S	S	S	S	S	R	R	V
12	Dharwad-1 Ct 13	S	S	S	S	S	S	R	V
13	Raipur -1 Ct10	S	S	R	R	R	R	R	VI

Thus, the results revealed new information that based on morphology and virulence variability exists among the isolates of *C. truncatum* of soybean in India, which can be grouped in to different pathotypes/races. This could help in breeding durable resistance in soybean against anthracnose/pod blight disease.

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Soybean Research 15(1): 63-68 (2017)

Developing Mobile Application for Advance Yield Estimation of Soybean and its Validation through Front Line Demonstrations

SURESH MOTWANI[1], HIMANSHU BIAS[2] and ASHISH[3]
Solidaridad, South and South East Asia, New Delhi 110 018, India
E mail: suresh.motwani@solidaridadnetwork.org

Received: 17.03.2017; Accepted: 24.04.2017

ABSTRACT

The results of 115 front line demonstration conducted during kharif *2016 in three blocks of Agar Malwa District revealed 9-12 per cent average increase in yield over farmers' practice. The peak seed yield of soybean recorded was 3,223 kg per ha in one of the demonstration as compared to 2,450 kg per ha under farmers' practice demonstrating the achievable yield through varietal potential and impact of recommended technology. The validation of developed mobile application brought out that the seed yield of soybean can be advance estimated with precision of less than 3 per cent and can be used for the advance yield estimation purpose.*

Key words: Front line demonstrations, mobile application, validation, validation

Solidaridad South and South East Asia is operating through its stakeholders in states of Madhya Pradesh, Maharashtra and Rajasthan to sustain the productivity of soybean in the state since 2009. In order to advance estimate the productivity of crop and acquisition of data rapidly in the central unit of Solidaridad, a user friendly mobile based application was developed based on observations in the farmers' fields. The registered farmers on their own or with the help of field staff of stakeholders can enter the data on mobile and communicate the same to central unit for information on the estimated productivity from the maturing crop in advance. An early estimate of crop productivity information is useful for crop insurance purpose, delivery, planning harvest and storage requirements and cash-flow budgeting. The developed mobile application was validated by taking observations on 115 front line demonstrations organised front line demonstrations organised by Solidaridad during *kharif* 2016, which were financially supported by Ministry of Agriculture Cooperation and Farmers Welfare, Government of India through ICAR-Indian Institute of Soybean Research, Indore.

MATERIAL AND METHODS

A total of 115 front line demonstrations, each on 0.4 ha land, were conducted in district Agar Malwa covering three selected blocks, namely Agar (52 Nos), Barod (55 Nos) and Susner

[1]*Programme Head, Soy and Palm Oil;* [2]*Program Officer;* [3]*Program Associate*

(8 Nos) and the productivity achieved was compared with farmers' practice on equal area on each farm. For the conduct of the demonstrations, care was taken to select the fascinated farmers and on fields which were located on the road side so that the other farmers in the area can see and get convinced on the impact of technology. A training session for the selected farmers and the field staff was as well organised before the season on05thJune, 2016 at Agar-Malwa to brief on sustainable production technology and requirements of ideal conduct of demonstrations. Selected farmers were supplied with seed of improved early maturating variety JS 95-60 (maturity duration 85 days) and other inputs along with time to time advisory to resolve problem faced by the farmers during crop growth period. This variety was purposely selected as farmers demand for early maturing variety. The technology for demonstration involved optimum use of seed rate, seed treatment with fungicides and biofertilizers, balanced use of nutrients following integrated approach, water conservation measures like planting of crop on broad bed furrow method/opening a dead furrow after every six rows of soybean, planting against slope, use of integrated components for pest-management and timely harvesting. The farmers were allowed to use their method for cultivation of soybean wherein they use above optimum seed rate, by and large no seed treatment or inoculation with biofertilizers, sowing on flat land, skewed fertilization, and non-judicious use of agro-chemicals, particularly pesticides.

For advance estimation of productivity, an exercise was made to validate the developed mobile application to judge its preciseness before the harvest of soybean crop. The mobile app is factored on scientific basis to analyse the yield at R6 stage of crop growth. To estimate the yield with the help of mobile application, the sequential steps involve feeding information on row to row spacing (cm), random selection of ten 10 meter row length and counting number of plants in each row, and record number of pod bearing plants, Once the average number of pod bearing plants is entered, counting of the pods per plant for 10 random plants from selected rows, regardless plant growth. Next step is to work out the number of seed per pod by taking 10 pods from each of these selected 10 plants and enter the value in mobile application. Care was taken to exclude the chaffy pods in the exercise. Since the seed index of each variety is different, the name of the variety is required to be entered in the application. Once the above data is entered, the application calculates and displays the seed yield of soybean in kg/hectare. Thus the data obtained from demonstrations and farmers plot can be transmitted to Solidaradad Centre in advance. The objective of the study is to report the efficacy of recommended technology and validated the developed mobile application for its preciseness in advance estimation of soybean seed yield.

RESULTS AND DISCUSSION

All 115 demonstrations resulted in productivity increment (147 kg/ha) over

Table 1. Yield Improvement in through front line demonstrations in three blocks of Agar Malwa District of Madhya Pradesh

Block	Number of trials	Yield (kg/ha)							Yield increment over Farmers' practice	% increase over Farmers' practice
		Demonstration				Farmers' practice				
		Estimated (deviation %)	Average	Highest	Lowest	Average	Highest	Lowest		
Barod	55	1496 (2.13%)	1451	2488	1181	1329	1598	1075	122	9.18
Agar	52	1687 (2.30%)	1649	3223	1225	1471	2450	1038	178	12.10
Susner	8	1426(3.86)	1373	1601	1269	1262	1530	1175	111	8.80
Total	115	1577 (2.73%)	1535	3223	1175	1388	2450	1038	147	10.59

Table 2. Yield Improvement in through front line demonstrations in three categories of farmers of Agar Malwa District of Madhya Pradesh

Category	Number of trials	Yield (kg/ha)							Yield increment over Farmers' practice	% increase over Farmers' practice
		Demonstration				Farmers' practice				
		Estimated (deviation %)	Average	Highest	Lowest	Average	Highest	Lowest		
General	15	1577 (2.73%)	1535	1995	1375	1388	1600	1293	147	10.59
SC	20	1504 (2.31)	1470	1663	1175	1311	1520	1118	159	12.13
OBC	80	1581(3.12 %)	1532	3223	1181	1395	2450	1038	137	9.82
Total	115	1577 (2.73)	1535	3223	1175	1388	2450	1038	147	10.59

Table 3. Economic evaluation of front line demonstrations in three blocks of Agar Malwa District of Madhya Pradesh

Block	No of demons-tration	Yield (kg/ha)		Gross returns (Rs/ha)*		Cost of cultivation (Rs/ha)		Net returns (Rs/ha)		Additional returns (Rs/ha)	B:C ratio		ICRR**
		Demons-tration	Farmers' practice	Demons-tration	Farmers' practice	Demons-tration	Farmers' practice	Demons-tration	Farmers' practice		Demons-tration	Farmers' practice	
Barod	55	1451	1329	43536	39861	20215	18643	23321	21218	2013	2.15	2.14	2.34
Agar	52	1649	1471	49470	41130	20421	18978	29049	25152	3897	2.42	2.32	3.70
Susner	8	1373	1262	41190	37860	19744	17963	21435	19897	1538	2.09	2.11	1.86
Total	115	1535	1388	46060	41652	20421	18978	25662	22673	2909	2.25	2.19	3.05

**Current average rate of soybean seed Rs 30/kg was considered for the calculation of gross returns; **ICBR = Gross returns from demonstrations – Gross returns from farmers' practice/Cost of cultivation for demonstrations – cost of cultivation from farmers' practice*

Table 4. Economic evaluation of front line demonstrations in three categories of farmers of blocks of Agar Malwa District of Madhya Pradesh

Block	No of demons-tration	Yield (kg/ha)		Gross returns (Rs/ha)		Cost of cultivation (Rs/ha)		Net returns (Rs/ha)		Additional returns (Rs/ha)	B:C ratio		ICRR
		Demons-tration	Farmers' practice	Demons-tration	Farmers' practice	Demons-tration	Farmers' practice	Demons-tration	Farmers' practice		Demons-tration	Farmers' practice	
Gen.	15	1535	1388	46050	41640	20421	18978	25629	22662	2920	2.25	2.19	3.06
SC	20	1470	1311	44100	39330	20237	18811	23863	20519	3344	2.18	2.09	3.35
OBC	80	1532	1395	45960	41850	20308	18896	25652	22954	2698	2.26	2.21	2.91
Total	115	1535	1388	46060	41652	20421	18978	25662	22673	2909	2.25	2.19	3.05

**Current average rate of soybean seed Rs 30/kg was considered for the calculation of gross returns; **ICBR = Gross returns from demonstrations – Gross returns from farmers' practice/Cost of cultivation for demonstrations – cost of cultivation from farmers' practice* farmers' practice. The improvement in the productivity in the blocks of Agar Malwa (Table 1) revealed that there was an increase was between 111 and 178 kg/ha (9.18-12.10%) over farmers' practice. The average highest yield and lowest yield recorded in the demonstration plot was 3,223 and 1,175 kg per ha as compared to 2,450 and 1,038 kg/ha, respectively under farmers' practice. Among the blocks, Agar recorded higher average productivity (1649 kg/ha) followed by Barod (1,451 kg/ha) and Susner (1,373 kg/ha) under demonstrations. The differences in performance of soybean productivity can be attributed to the variation in land characteristics and the microclimate changes in the blocks. The impact of adoption of similar technology with change in area on variable productivity has been reported by Mankar *et al.* (2014). The results are also in confirmity of findings of Joshi *et al.* (2004), Billore *et al.* (2005), Raghuwanshi *et al*. (2010) and Bhargav *et al*. (2015), who reported higher yield, net returns, and B:C ratio for front line demonstrations as compared to farmers' practice.

On viewing the data on different categories of farmers (Table 2) to see if any change in pattern showed that the demonstrations irrespective of categories yielded higher than farmers' practice. The productivity increment ranged between 137 and 159 with an average of 147 kg per ha. However, the scheduled cast category of farmers' realised higher increase (12.13 %) as compared to general (10.59 %) and other backward class (9.82 %)

The estimated yield by mobile application was in three blocks was little higher (between 2.13 and 3.86) with overall 2.74 per cent than the realised productivity. In case of category of farmers it ranged between 2.31-3.12 per cent. This indicated that the mobile application can conveniently be used to have fair advance estimate the productivity of soybean. It may be possible to be more precise by either increasing the number of spots for observation or by increasing the number of pods per plant and number of pods taken for working out the seeds per square meter.

The demonstrations were also economically evaluated for different blocks as well as for different categories of farmers (Table 3 and 4). For 115 demonstrations, the additional returns over farmers practice worked out to Rs 2,909 per ha. It ranged between Rs 1,538 and 3,897/ha for the three blocks and Rs 1,698 and 3,344 per ha for the three categories of farmers. Maximum additional returns were associated with Agar Block and SC category of farmers. The overall B:C ratio was 2.19 for the total number of demonstrations. The value for Incremental Cost Benefit Ratio (ICBR) for the total number of trials was 3.05. This indicated that the by incurring additional cost of Rs 1, Rs 3.05 can be realised.

The front line demonstrations conducted in the Agar Malwa District indicated that the sustainable technology adopted by the farmers led to higher yield concomitant with higher net/additional returns and high cost benefit ratio. The developed mobile application can be utilized to advance estimation of soybean seed yield conveniently within variation of 3 per cent**.**

ACKNOWLEDGEMENTS

We would like to express our earnest gratitude and thanks to Dr V S Bhatia, Director, ICAR-Indian Institute of Soybean Research, Indore, for providing opportunity to organise the front line demonstrations sponsored by MoA, GoI. We owe our deepest gratitude to Dr **S** D Billore and Dr B U Dupare, Principal Scientists (ICAR-IISR, Indore), for his unconditional support and cooperation for the implementation of this programme. We would also like to express our sincere thanks to Dr O P Joshi, Technical Advisor, Solidaridad for his guidance on capturing field data, training to our service providers and lead farmers on technical aspects of soybean sustainable production and consolidation and analysis of field recorded data. We would also like to thank Mr Ram Singh (CEO, Samarth Kisan Producer Company**)**, for his helping hands in carrying out various field operations during execution of the front line demonstration trials. The cooperation from farmer participants is also acknowledged.

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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

Ali Nawab Dr; Former Deputy Director General, (Agricultural Engineering), ICAR, Bhopal 462 023, Madhya Pradesh

Billore SD Dr; Principal Scientist (Agronomy), ICAR-Indian Institute of Soybean Research, Indore 452 001, Madhya Pradesh

Chandel A S Dr; Ex-Prof (Agronomy), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar 263 145, Uttarakhand,

Choudhry S K Dr; Principal Scientist (Agronomy), Dryland (ORP) Project, College of Agriculture (RVSKVV), Indore 452 001, Madhya Pradesh

Choudhary SK Dr; Principal Scientist (Agronomy), Dryland (ORP) Project, College of Agriculture (RVSKVV), Indore 452 001, Madhya Pradesh,

Dixit AK Dr; Project Coordinator, Krishi Vigyan Kendra (RVSKVV), Dewas, Madhya Pradesh

Dupare B U Dr; Principal Scientist (Agricultural Extension), ICAR-Indian Institute of Soybean Research, Indore, Madhya Pradesh

Husain. S M Dr; Ex Principal Scientist (Plant Breeding), ICAR- Indian Institute of Soybean Research, Indore, Madhya Pradesh

Gupta GK Dr; Ex-Principal Scientist (Plant Pathology, ICAR-Indian Institute of Soybean research, Indore, Madhya Pradesh

Kuchlan Mrinal Dr.; Scientist (Seed), ICAR-Indian Institute of Soybean Research, Indore 452 001, Madhya Pradesh,

Gupta Sanjay Dr; Principal Scientist (Plant Breeding), ICAR-Indian Institute of Soybean Research, Indore 452 001, Madhya Pradesh,

Mishra A N Dr; Ex-Head, ICAR-Regional Station, Indian Agricultural Research Institute, Indore 452 001, Madhya Pradesh

Pandey Sushil Dr; Principal Scientist (Seed Technology), National Bureau of Plant Genetic Resources, Indian Agricultural Research Institute, New Delhi 110 012,

Prabhakar Dr; Project Coordinator (Small Millets), ICAR-All India Coordinated Small Millets Improvement Project, Coordinating Unit, Gandhi Krishi Vigyan Kendra, Bangalore 560 065, Karnataka

Rajput Dr; Ex-Dean, College of Agriculture (RVSKVV), Indore 452 001, Madhya Pradesh

Shrivastava A N Dr; Principal Scientist (Plant Breeding), College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, Madhya Pradesh

Sharma A N Dr; Principal Scientist (Entomology), ICAR-Indian Institute of Soybean Research, ICAR- Indore 452 001, Madhya Pradesh,

Singh R K Dr; Associate Professor (Plant Pathology), College of Agriculture (RVSKVV), Indore 452 001, Madhya Pradesh

Singh Pratap Dr, Professor (Agronomy), Agricultural Research Station (MPUA&T), Kota 324 001, Rajasthan

Singh S K Dr; Principal Scientist (Entomology), ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh

Srivastava C P Dr; Professor and Head, Institute of Agricultural Sciences, Banaras Hindu University, Varanashi, Uttar Pradesh

Sridhar Y Dr; Senior Scientist (Entomology), ICAR-Directorate of Rice Research, Hyderabad, Telengana

Taware Prabhakar Sunil Dr; Soybean Entomologist, Agharkar Research Institute, Pune 411 004, Maharashtra

Veda O P Dr: Ex Director of Instruction (Entomologist), Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur 482 004, Madhya Pradesh,

Vinayagam S S Dr; Principal Scientist (Agricultural Extension), ICAR-NAARM, Hyderabad 500 030, Andhra Pradesh

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(a)	Annual member	Subscription
	Indian Foreign	₹. 600.00 US $ 125.00
(b)	Student member	
	Indian Foreign	₹. 300.00 US $ 100.00
(c)	Institution member	
	Indian Foreign	₹. 2, 500.00 US $ 200.00
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	Indian Foreign	₹. 3, 500.00 (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 enrolment.
- 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 on line on E-mail address (ssrdindia03@rediffmail.com) or web-sites (www.ssrd.co.in or www.soybean research.in) of the Society/journal. The manuscript should also carry the E-mail address of the corresponding author in addition to the postal address. MS should be formatted 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 also be submitted on line.

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 and Discussion: 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 selfcontained 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)

ICAR-Indian Institute of Soybean Research

Khandwa Road, Indore 452 001

Ph.: 0731-2478414; 236 4879; FAX: 2470520

(E-mail: ssrdindia03@rediffmail.com)

(Website: www.ssrd.co.in; www.soybeanresearch.in)

The General Secretary
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I wish to enrol myself as a Life Member/Annual Member of the **Society for Soybean Research & Development.**
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