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Variability and Character Association Studies Among Different Germplasm Sub-groups in Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

Principal componenet analysis was carried out on a set of 1680 soybean [Glycine max (L.) Merrill] germplasm accessions that were evaluated for various morphological and agro-economic traits. Further, sub-groups based on flower colour, seed coat colour and growth habits were also studied for their grouping behavior. First three principal components accounted for more than 80 per cent of total variation in data. Characters like 100 seed weight and seed yield per plant recorded maximum variability among the germplasm accessions. The distribution of germplasm accessions was scattered among all the four quadrants signifying the distinctness of germplasm accessions for the recorded traits indicating the utility of this information to select discreet types among germplasm accessions for further use in breeding programmes.

Key words: Character association, soybean, variability principal component analysis

Soybean [*Glycine max* (L.) Merrill], contributes to 25 per cent to the global vegetable oil production and about two thirds of the world's protein concentrate for livestock feeding and is also a valuable ingredient in formulated feeds for poultry and fish. In India it is cultivated in an area of more than 10 million ha area in 2012. The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh and Chattisgarh.

Principal component analysis (PCA) developed by Pearson (1901) is a mathematical procedure that uses An orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly un-correlated variables called principal components. It is a data reduction technique which utilizes information arising from inherent relationship among a number of related attributes and generates a few principal components which could then easily be deciphered.

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MATERIAL AND METHODS

The present investigation was carried out in the experimental fields of Directorate of Soybean Research (ICAR) Indore (Madhya Pradesh) during *kharif* season of 2011-12. Indore is situated between latitude 22°43' N and longitude 75°66' E and at an altitude of 555.7 metres above the mean sea level. Indore belongs to sub-tropical semi-arid region with an average annual rainfall of 954.5 mm. Most of the rains are received through South West Monsoon during rainy season (mid-June to third week of September). The total rainfall received during the crop season 2011-12 was 1377.8 mm with 56 rainy days, the maximum temperature ranged from 26.2^0 to 33.3^0C, minimum temperature from 14.8^0 to 24.5^0 C and range of relative humidity was 78 to 94.2 per cent.

A set of 1680 soybean germplasm accessions have been evaluated in augmented design. All the recommended package of practices was followed to harness the maximum potential of genotypes under study. The genotypes were planted in a row (single or double) length of 3 m The observations on the following agro-economical traits namely, plant height (cm), days to flowering, days to maturity, number of nodes per plant^{-1}, number of branches per plant^{-1}, number of pod clusters per plant^{-1}, number of pods per plant^{-1}, seed yield per plant^{-1} and seed index (g/100 seeds) were recorded on five randomly selected plants for following characters in each genotypes. The mean value for the treatment was computed by taking average. In present investigation, principal component analysis was taken up among total germplasm evaluated along with separately among sub-groups based on flower colour, seed coat colour and growth habit. The growth habit is an important trait defining suitability of a variety in any production niche while seed coat colour is the trait that affects its market value; moreover these traits are important in germplasm studies as categorization benchmark. The basic purpose of this study was to investigate whether variability pattern and character inter-relationship was same across these groups or formed a distinct pattern.

RESULTS AND DISCUSSION

Performing classificatory analysis on a group of entities based on observations on multiple variables is a tedious job even with an aid of a computer. If entities concerned are germplasm accessions, grouping analysis assumes special importance. The use of established multivariate statistical algorithms is an important strategy for classifying germplasm, ordering variability for a large number of accessions, or analyzing genetic relationships among traits in any breeding materials. Multivariate analytical techniques, which simultaneously analyze multiple measurements on each individual under investigation, are widely used in analysis of genetic diversity irrespective of the dataset (morphological, bio-chemical, or molecular marker data). Only if available genetic diversity could be categorized in to distinct categories along with an insight of genetic variability within each sub group, the information could be utilized in formulating a proper breeding strategy in a trait specific improvement programme. Principal Component Analysis (PCA) as a data reduction technique is one of the most important technique that helps in arriving at such meaningful information.

In the present investigation, PCA analysis was performed for entire collection as well as sub-categories based on flower colour, growth habit, seed coat colour *etc.* Principal component analysis in all these sets and sub-sets revealed that there is a tremendous variability among the germplasm accessions. There are a number of genotypes that are scattered far across the origin point, manifesting presence of many distinct types from the average representative. Presence of distinct types among the main set and various sub-sets could directly be utilized in secondary selections for the trait of interest or through hybridization in an appropriate breeding programme.

Among total 1680 germplasm evaluated, Figure 1 describes that first three principal components describe more than 80 per cent of total variation in data. As is evident from vector length for various quantitative traits; characters like seed yield per plant, total number of pods per plant and days to flowering recorded maximum variability among the germplasm accessions. Similarly, the distribution of germplasm accessions is also scattered among all the four quadrants signifying the distinctness of germplasm accessions for all the recorded traits. This information can very well be utilized while selecting discreet types among germplasm accessions for further use in breeding programmes. The traits that share same sign for PCA 1 and PCA 2 are positively correlated and this information can be taken account of while formulating selection indices. As is evident from Figure 1, seed yield is positively correlated with number of pod clusters per plant, total number of pods per plant and 100 seed weight. The accessions having higher number for these traits could be utilized in breeding programmes that aim at increasing seed yield through associated traits.

Among purple flower accessions also the trend depicted was very similar to that registered in case of whole group analysis (Fig. 2). The first three principal components explained more than 85 per cent variation in data. Among traits, 100 seed weight, seed yield per plant, total number of pods per plant and days to flowering recorded maximum variability among the pink flowered germplasm accessions. The character association also depicted the same trend as was evident in case of whole group. Among white flower accession, first three principal components explained only 60 per cent of variation among data and biplot depicting traits and accessions on PCA 1 and PCA 2 could only explain 50 per cent of variation through these two axes (Fig. 3). As per vector length, highest variability was recorded for 100 seed weight, seed yield per plant, total number of pods per plant and days to flowering; but character association among this group registered a different pattern. Days to flowering and 100 seed weight recorded a much higher significant association with seed yield per plant than previous two groups (Fig. 3).

Soybean is a photosensitive crop and has a narrow adaptation to varying climatic conditions; hence, the growth habit of genotypes to a large extent determines its specific adaptation to a given agro-ecological niche. Among growth habit patterns, for determinate growth habit, first three principal components explained only 51 per cent of variation among data and biplot depicting traits and accessions on PCA 1 and PCA 2 could only explain 42 per cent of variation through these two axes (Fig. 4). Traits namely, plant height, seed yield per plant, total number of pods per plant and days to flowering recorded highest variability among accessions. Similarly, the distribution of germplasm accessions is also very scattered among all the four quadrants signifying the distinctness of germplasm accessions for all the recorded traits. Among character association, seed yield per plant recorded significantly similar trends with number of pods, number of nodes, leaf length: breadth ratio and seed index (Fig. 4). Seed yield like determinate growth habit displayed a greater harmony with total number of pods per plant, number of pod clusters per plant and plant height (Fig. 5).

Seed coat colour is a factor that largely determines the consumer preference towards a variety. Therefore, the experimental lot was subdivided into two categories of black seeded and yellow/green seeded type to further subject them to PCA analysis so as to ascertain the variability parameters and character association among these two groups. Among black seeded types, first three principal components explained only 63 per cent of variation among data and biplot depicting traits and accessions on PCA 1 and PCA 2 could only explain 42 per cent of variation through these two axes (Fig. 6). Traits namely, seed yield per plant, total number of pods per plant and days to flowering recorded highest variability among accessions. Germplasm accessions were also scattered among all the four quadrants signifying the distinctness of germplasm accessions for all the recorded traits. Among character association, seed yield per plant recorded significantly similar trends with total number of pods and number of pod clusters per plant (Fig. 6).

Among yellow/green seeded types, first three PCA explained 55 per cent of variation in data while the biplot depicting first two components accounted for nearly 45 per cent of total variation. Similar to black-seeded types, traits namely, seed yield per plant, total number of pods per plant and days to flowering recorded highest variability among accessions (Fig. 7). While seed yield per plant among yellow/green seeded type appeared to be a function of 100 seed weight, total number of pods, number of pod clusters per plant and leaf length breadth ratio (Fig. 7).

Similar variability has been studied by a number of workers in soybean and other agricultural crops using principal component analysis. Broschat (1979) considered PCA as powerful technique for data reduction which removes inter-relationships among components. Results reported by various researchers showed multivariate analysis as a valid system to deal with germplasm collection. Smith *et al*. (1995) conducted average linkage cluster and principal component analyses, and reported the utility of these results in preservation and utilization of germplasm. Extent of diversity and relationship among *Brassica juncea* germplasm from Pakistan for 35 morphological characters in 52 accessions were determined by Rabbani *et al*. (1998) the using cluster and principal component analysis. Ghafoor *et al*. (2001) studied genetic diversity in blackgram germplasm accessions. In yet another study involving PCA, Elizabeth *et al*. (2001) investigated 19 sesbania accessions to characterize them on basis of morphological and agronomic data. Ghafoor *et al*. (2003) evaluated chickpea accessions by using multivariate techniques. The first three principal components with eigenvalues >1 contributed 83.3 per cent of the variability amongst genotypes.

Among soybean agronomic traits, Truong *et al*. (2005) studied yield and yield components. The metric observations were analysed using principal component analysis and significant diversity was observed for these traits. Zafar Iqbal *et al*. (2008) and Malik *et al*. (2011) also in their respective studies involving soybean germplasm accessions recorded significant diversity for yield and associated traits using principal component analysis. Principal component analysis is comparatively better than other diversity measures owing to its data reduction abilities which otherwise are possible with other techniques, hence, the classification of a large group for a number of attributes becomes less cumbersome.

The present investigation in light of results obtained and other germplasm studies based on Principal Component Analysis demonstrated that days to flowering, days to maturity, number of branches, number of nodes, number of pod clusters, total number of pods, number of seeds per plant and 100 seed weight are the important agro-economic traits that individually or as an yield associated trait hold special importance for all the soybean breeders. Principal component analysis among the whole set as well as subsets emphasized the presence of significant diversity albeit in varying magnitude among different groups for days to flowering, days to maturity, number of pod clusters, total number of pods, seed yield per plant and 100 seed weight. This variability could be significantly harnessed through a soybean breeding programme.

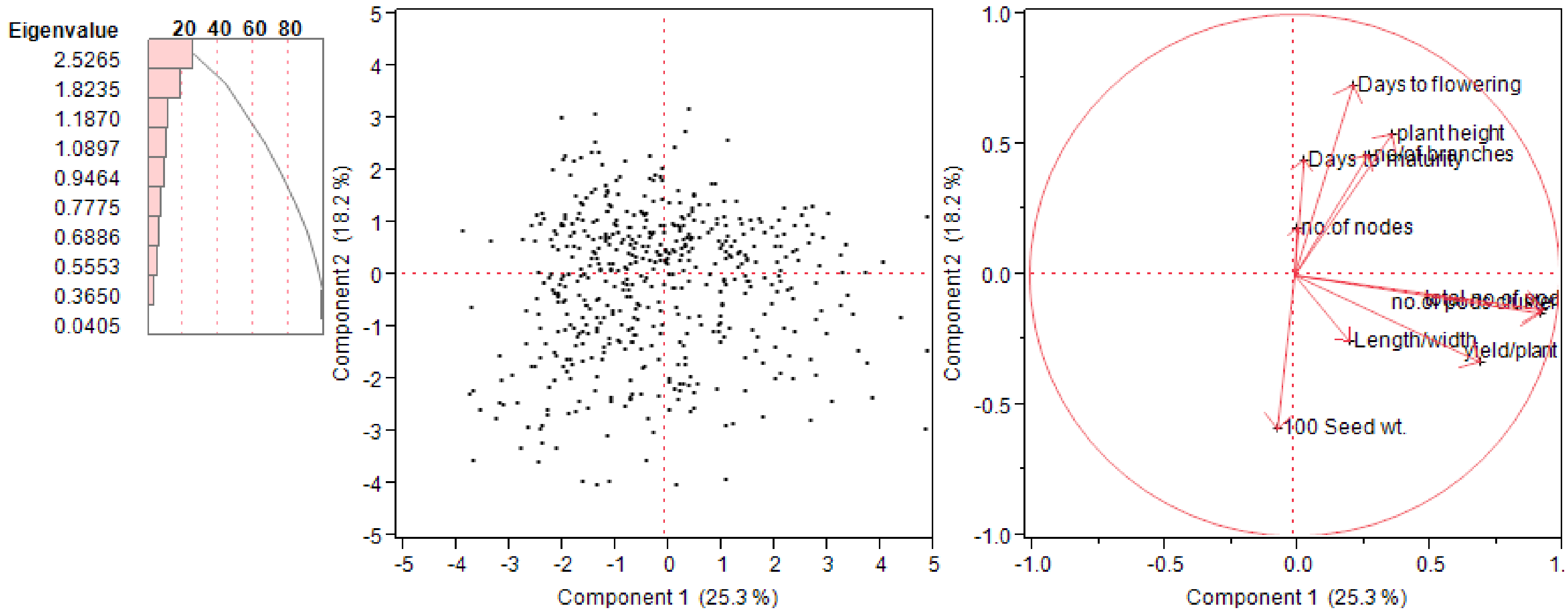

Fig. 1. Principal Componet Analysis for total germplasm evaluated

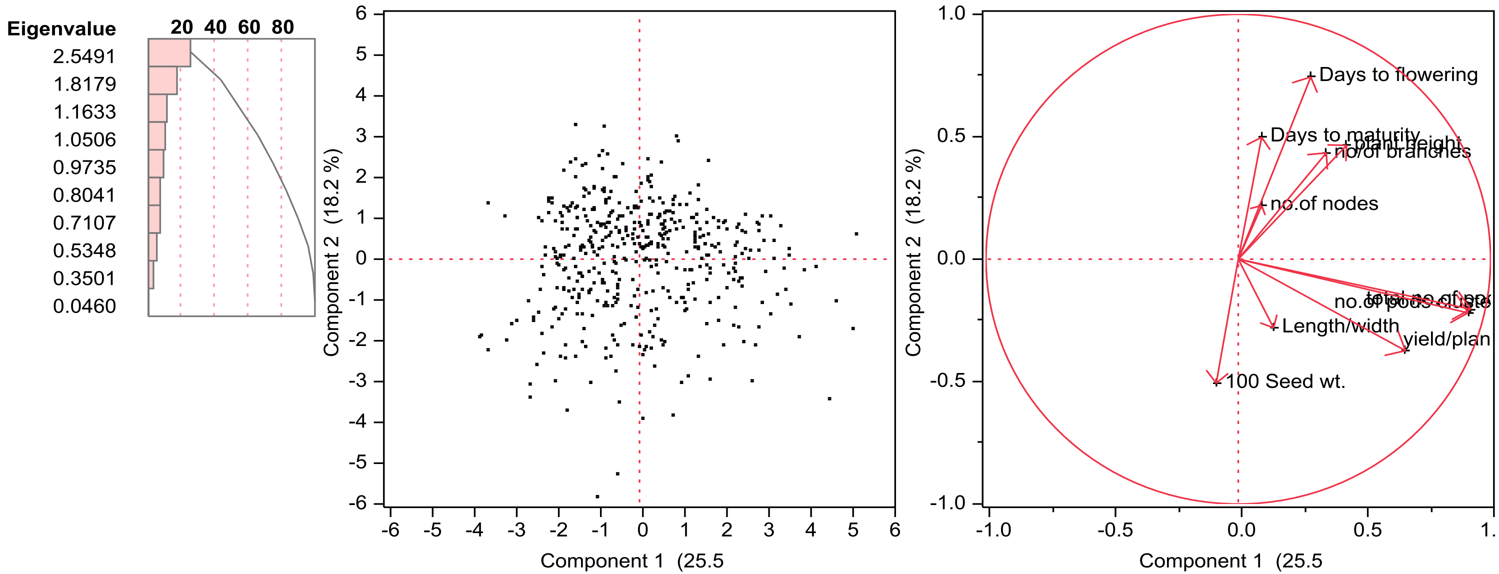

Fig. 2. Principal Componet Analysis for germplasm accessions sub-class –purple flowered

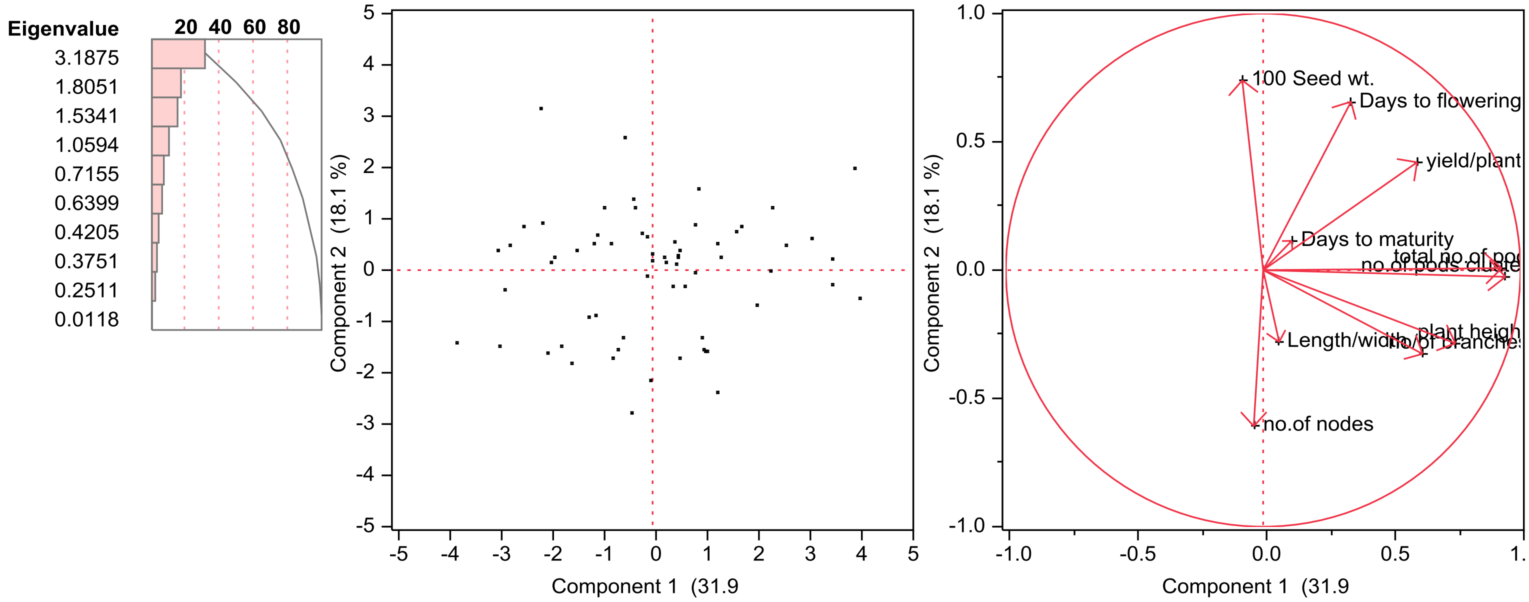

Fig. 3. Principal Componet Analysis for germplasm accessions sub-class –white flowered

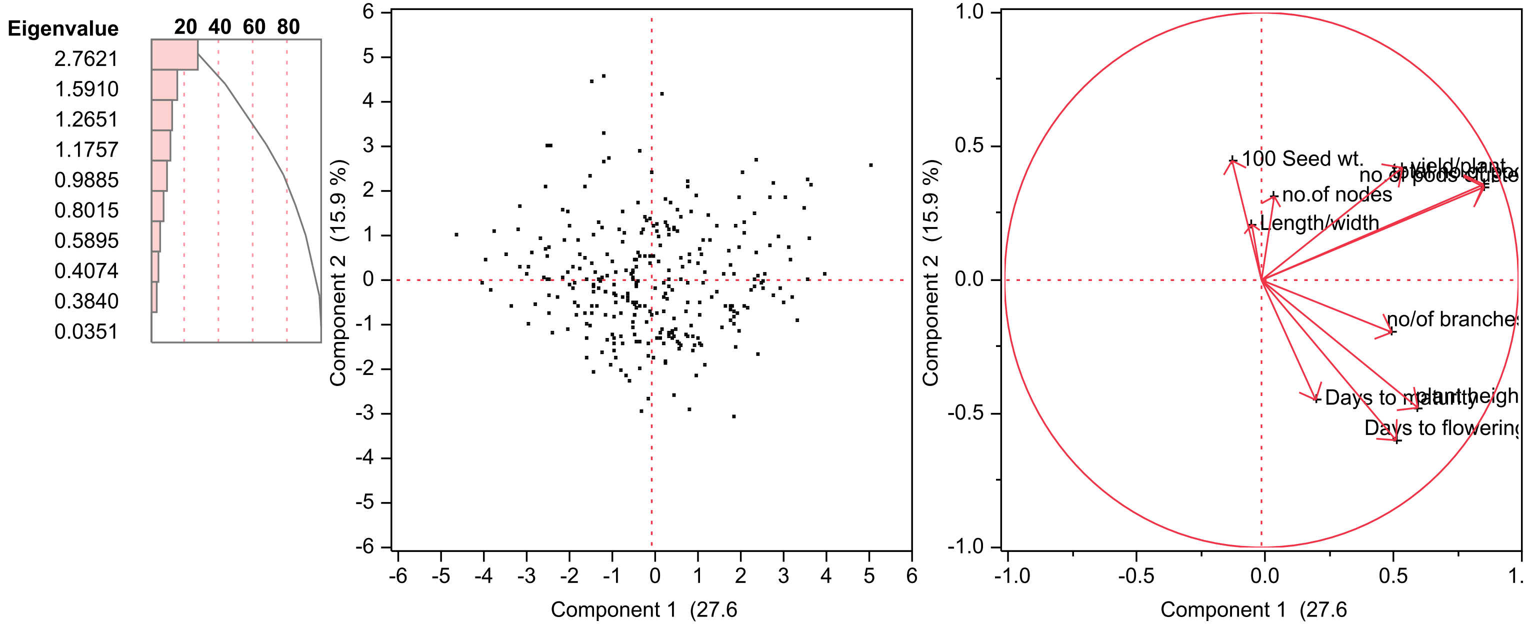

Fig. 4. Principal Componet Analysis for germplasm accessions sub-class – determinate

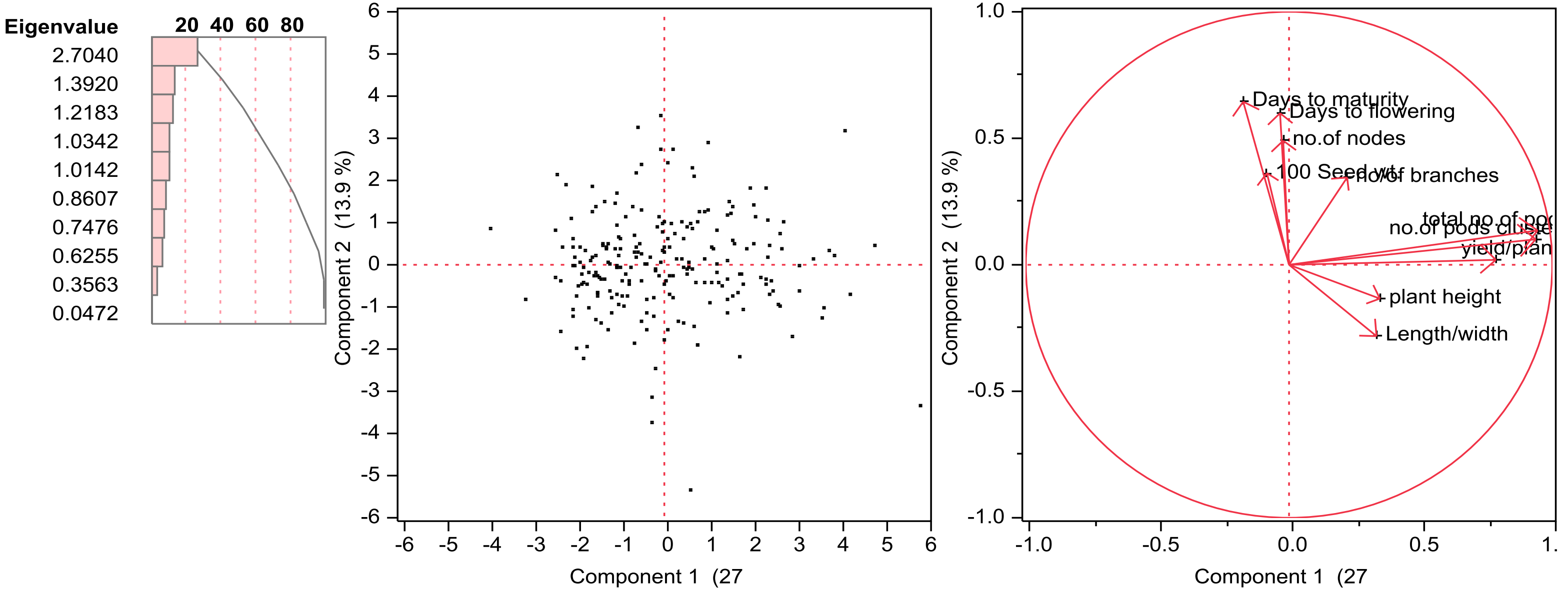

Fig. 5. Principal Componet Analysis for germplasm accessions sub-class – semi and indeterminate

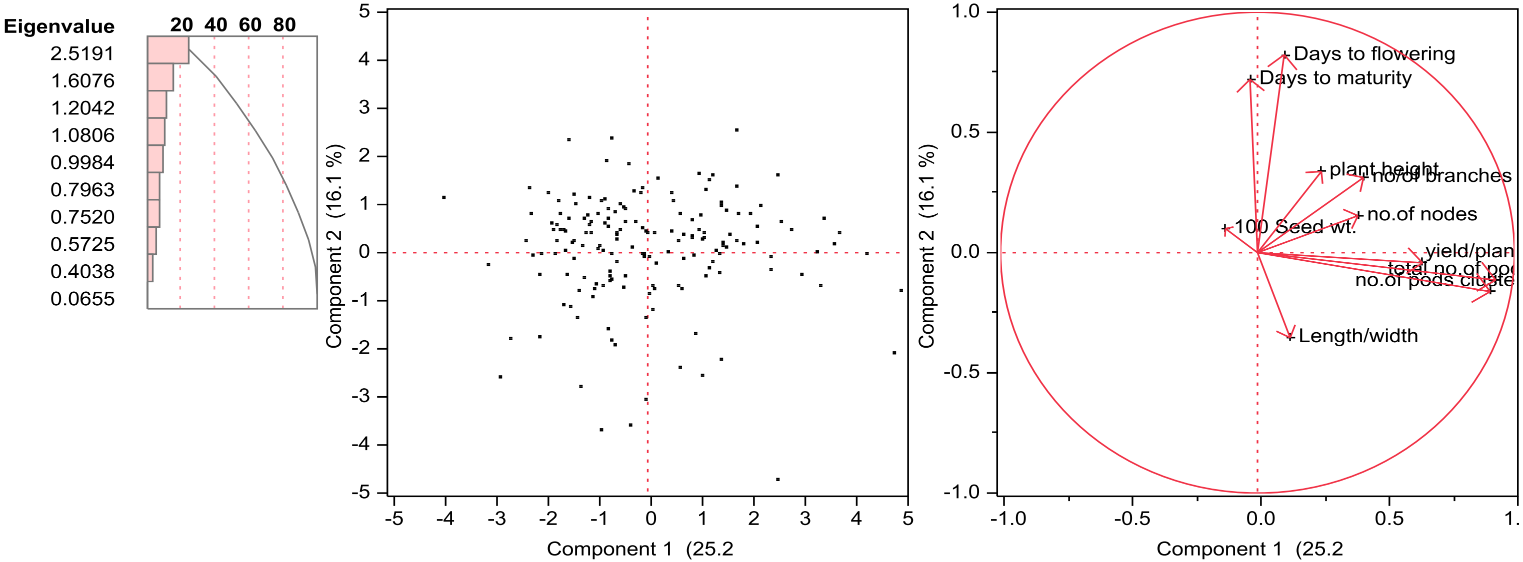

Fig. 6. Principal Componet Analysis for germplasm accessions sub-class –black seeded

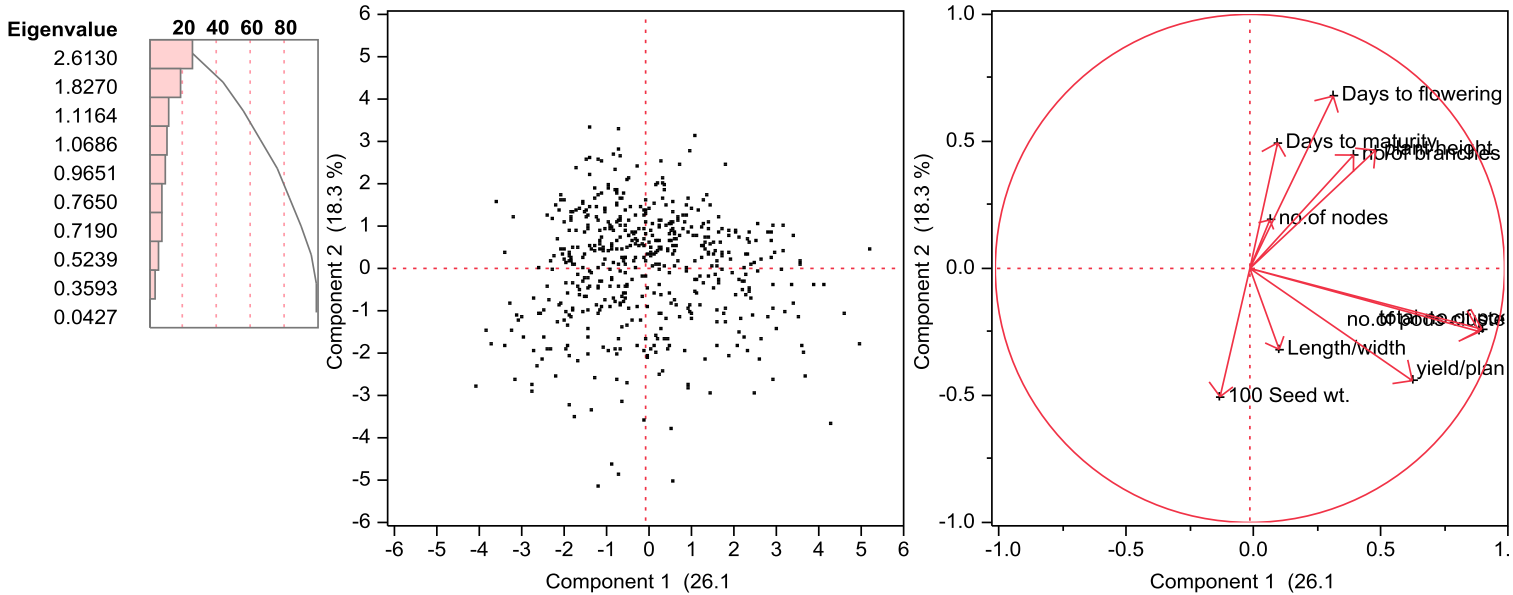

Fig. 7. Principal Componet Analysis for germplasm accessions sub-class – yellow and green seeded

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Soybean Research 11(1): 14-21 (2013)

Effect of Sulphur and Boron Levels on Productivity, Quality and Profitability of Soybean [*Glycine max* (L.) Merrill] in Vertisols under Rainfed Conditions

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ABSTRACT

A field experiment was conducted on clayey loam soil of Sehore, Madhya Pradesh, during kharif *seasons of 2007 and 2008, to study the effect of sulphur and boron levels on physiological parameters, productivity, soil fertility and economics of soybean under rainfed conditions. The twenty five treatment combinations comprised of five sulphur levels* viz., *0, 10, 20, 30, 40 and five boron levels* viz., *0, 0.5, 1.0, 1.5, 2.0 kg per ha as basal. Progressive increase in sulphur and boron levels increased crop growth rate, total chlorophyll content, pods per plant and seed yield. But significant response of sulphur application was obtained up to 20 kg per ha and it gave CGR (10.94 g/m²/day), total chlorophyll content (2.55 mg/g/fresh weight), number of pods per plant (24.19), harvest index (42.91 %), and seed yield (2 059 kg/ha), being 33.74, 13.33, 9.35, 4.92 and 12.14 per cent higher, respectively over control. The crop responded up to 0.5 kg boron per ha which increased the pods per plant by 7.04 and seed yield by 6.33 per cent over non application of boron. CGR and total chlorophyll content were found significantly superior at 1.5 kg B per ha. The uptake of sulphur in seed (6.82 kg/ha) and straw (4.8 kg/ha 9) was significantly higher up to 10 kg S per ha. The significant higher value of oil was obtained at 10 kg S per ha and 0.5 kg B per ha whereas, protein was significantly higher at 30 kg S per ha and 2.0 kg B per ha. The interaction effect between sulphur and boron in all the parameters was not significant.*

Key words: Boron, economics, nutrient uptake, soybean, sulphur

Soybean (*Glycine max* L. Merrill) with its 40-42 per cent protein and 20-22 per cent oil has already emerged as one of the major oilseed crop in India. In spite of its high yield potential (4.5 tonnes/ha), soybean productivity is much less in India (1.07 tonnes/ha) than the world average of 2.43 tonnes per ha (FAOSTAT, 2011).

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Among the factors responsible for low productivity, inadequate fertilizer use and emerging secondary and micronutrient deficiencies play an important role. Several workers reported sulphur deficiency in soybean crop in Madhya Pradesh due to use of S–free fertilizers and adoption of high yielding varieties that remove more S from soil. Besides, sulphur requirement of soybean crop is high which remains uncared because of practice of applying high analysis fertilizer like di-ammonium phosphate. Adequate supply of sulphur has been reported to enhance photosynthetic efficiency and productivity of *Brassica* genotypes (Ahmad and Abdin, 2000). Boron is one of the essential micronutrient and it enhances the crop yields. It has seen that places of high metabolic activities i.e. cell division, flowering, fruiting and seed development etc. in a plant requiring more quantities of sugar. It is believed that boron facilitates the translocation of sugars in plants. Moreover, due to low crop productivity in the rainfed regions, it is assumed that mining of secondary and micronutrients are much less as compared to irrigated agriculture (Rego *et al.,* 2003). A field experiment was, therefore, conducted to study the effect of sulphur and boron levels on crop growth, yield, nutrient uptake, soil fertility status and economics of soybean.

MATERIAL AND METHODS

The field experiment was conducted during the *kharif* seasons of 2007 and 2008 at College of Agriculture, Sehore, replicated three times in factorial randomized block design. The soil was Vertisols (Chromusterts) clayey loam with organic carbon content 0.42 per cent and available N, P_2O_5 and K_2O 210.6, 15.80 and 285 kg per ha, respectively. Soil was neutral in reaction (pH 7.50) with initial status of sulphur 5 ppm and boron 1.09 ppm. The twenty-five treatment combination comprised of five sulphur levels *viz.*, 0, 10, 20, 30, 40 kg per ha and five boron levels *viz.*, 0, 0.5, 1.0, 1.5, 2.0 kg per ha as basal application through gypsum and borax, respectively. A uniform basal dose of NPK fertilizers and all the recommended package of practices were followed for raising the crop. Seeds of soybean 'JS 93-05' inoculated with *Bradyrhizobium japonicum* and PSB were sown at 45 cm row spacing on 29th June, 2007 and 27th June, 2008. The total rainfall received during the crop season was 766 and 706 mm in 2007 and 2008, respectively. Chlorophyll content in leaves of soybean was determined at 45 DAS using standard procedure (Yoshida *et al.,* 1972). The crop growth rate was worked out in between 30 - 45 and 45 - 60 DAS (Watson, 1952), and economics was calculated as per prevailing market prices.

RESULTS AND DISCUSSION

Morphological and physiological parameters

The significant effect of sulphur on CGR and total chlorophyll content with successive increase of S levels was noted.

While non-significant differences were recorded with plant height and branches per plant. The maximum CGR (8.60 and 11.52 g/m^2/day) was recorded with highest S level 40 kg per ha and the lowest (CGR 5.35 and 8.18 g/m^2/day) with control in between 30–45 and 45–60 days after sowing (DAS), respectively (Table 1). Total chlorophyll content differed significantly with S levels 20, 30 and 40 kg per ha over control and 10 kg S per ha. Tandon *et al.* (2007) reported that sulphur functions in many ways resembling those of nitrogen in enhancement of crop growth and formation of chlorophyll that permits the photosynthesis.

Application of boron @ 1.5 and 2.0 kg per ha increased CGR by 8.70 and 8.85 g per m^2 per day at 30–45 DAS, 11.08 and 11.16 g per m^2 per day at 45–60 DAS and total chlorophyll content 2.55 and 2.58 mg per g fresh weight at 45 DAS, respectively. However, the differences among 0, 0.5 and 1.0 kg B per ha were recorded statistically non-significant. Molegarrd and Hardman (1980) also reported that B deficiency caused flowering and reproductive failure, rosetting of terminal buds, small leaves and chlorosis.

Yield and yield attributes

Sulphur @ 30 and 40 kg per ha increased the pods per plant by 11.88 and 14.33 per cent, seeds per pod by 2.10 and 3.60 per cent, harvest index by 6.77 and 7.77 per cent and straw yield by 4.73 and 4.54 per cent, respectively over the control (Table 1). The increase in seed yield by 17.32 and 18.57 per cent was recorded with 30 and 40 kg S per ha, respectively over the control. The difference in yield between 30 and 40 kg S per ha levels was statistically non-significant. The increased yield under sulphur fertilization might be ascribed to increased pods per plant and seeds per pod with heavier seeds. A significant and positive correlation was noted in between seed yield with pods per plant (r = 0.99) and seeds per pod (r = 0.85). It indicated that when sulphur was applied, a significant and strong correlation was observed. Similarly, when boron was applied, a significant positive correlation was noted between seed yield and pods per plant (r = 0.98). Whereas, non-significant weak correlation were observed between seed yield and seeds per pod (r = 0.64). Thus, significant improvement in yield obtained under sulphur fertilization seems to have resulted owing to increased concentration of sulphur in various parts of plant that helped maintain the critical balance of other essential nutrients in the plant and resulted in enhanced metabolic processes. Vyas *et al.* (2006) and Khatik *et al.* (1992) also noticed increased yield of soybean with application of sulphur. Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structures and production of assimilates to fill economically important sink (Sharma and Singh, 2005).

Application of boron 0.5, 1.0, 1.5 and 2.0 kg per ha significantly increased

Table 1. Effect of levels of sulphur and boron on morphological, physiological parameters, yield attributes and yield on soybean (Pooled data of 2007 and 2008)

Treatments	Plant height (cm)	Bran-ches (No/ plant)	CGR ($g/m^2/day$)		Total chlorophyll (mg/g fresh weight)	Pods (No/plant))	Seeds (No/pod)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
			30 -45 DAS	45 -60 DAS						
Sulphur level (kg/ha)										
0	59.04	2.32	5.35	8.18	2.25	22.12	3.33	1836	2638	40.87
10	61.14	2.35	7.82	10.88	2.48	23.29	3.36	1937	2675	41.89
20	60.54	2.33	8.10	10.94	2.55	24.19	3.35	2059	2721	42.91
30	61.48	2.38	8.30	11.16	2.78	24.75	3.40	2154	2763	43.64
40	60.47	2.32	8.60	11.52	2.80	25.29	3.45	2177	2758	44.04
SEm (±)	0.91	0.15	0.70	0.90	0.10	0.53	0.04	36.89	88	0.91
CD at 5%	**NS**	**NS**	**2.18**	**2.65**	**0.30**	**1.53**	**NS**	**105.62**	**NS**	**2.57**
Boron level (kg/ha)										
0	59.54	2.30	5.90	8.38	2.22	22.00	3.30	1910	2661	41.46
0.5	60.64	2.37	6.92	9.30	2.38	23.55	3.45	2031	2624	43.59
1.0	60.57	2.32	7.25	9.45	2.45	24.40	3.38	2054	2733	42.68
1.5	60.08	2.30	8.70	11.08	2.55	24.53	3.39	2064	2734	42.77
2.0	60.84	2.40	8.85	11.16	2.58	25.34	3.38	2102	2801	42.76
SEm (±)	0.91	0.15	0.70	0.90	0.10	0.53	0.04	36.89	88	0.91
CD at 5%	**NS**	**NS**	**2.18**	**2.65**	**0.30**	**1.53**	**NS**	**105.62**	**NS**	**NS**

Table 2. Effect of levels of sulphur and boron on available sulphur in soil and sulphur uptake

Treatments	Available sulphur at harvest (ppm)	S content (%)		S uptake (kg/ha)		
		Seed	Straw	Seed	Straw	Total
Sulphur levels (kg/ha)						
0	4.54	0.21	0.12	4.69	3.42	8.11
10	5.14	0.30	0.17	6.82	4.89	11.72
20	6.81	0.40	0.23	9.75	6.55	16.31
30	7.56	0.48	0.30	12.32	8.46	20.78
40	8.12	0.54	0.37	13.53	10.39	23.93
SEm ($\pm$)	0.05	0.003	0.002	0.13	0.28	0.22
CD at 5%	0.16	0.009	0.006	0.37	0.63	0.62
Boron levels (kg/ha)						
0	6.21	0.35	0.21	8.07	6.19	14.27
0.5	6.44	0.38	0.23	9.12	6.42	15.54
1.0	6.48	0.40	0.24	9.80	6.95	16.58
1.5	6.49	0.41	0.26	10.19	7.38	17.58
2.0	6.55	0.40	0.24	9.93	6.78	16.71
SEm ($\pm$)	0.05	0.003	0.002	0.13	0.28	0.22
CD at 5%	**0.16**	**0.009**	**0.006**	**0.37**	**0.63**	**0.62**

the pods per plant and seed yield but harvest index, straw yield and seeds per pods showed statistically non-significant differences. The significant enhancement in seed yield with boron application was obtained only up to 0.5 kg B per ha, thereafter the response of boron was non-significant and all application rates 0.5, 1.0, 1.5 and 2.0 kg B per ha remained at par (Table 1). Ahmad Khan *et al.* (1990) also reported that increase in yield attributes of some oilseeds crop with the boron application. This might be because of the role of boron in fertility improvement and translocation of photosynthate from sources to sink and growth of pollen grain thereby markedly increased seed yield of crops (Sakal *et al.*, 1991).

The relationship between nutrients and soybean yield was worked out by using the quadratic equation and the relationship was found to be curvilinear. The equations were as follows.

Sulphur: $Y = 1826 + 14.21x - 0.130x^2$

Boron: $Y = 1923 + 185.60x - 51.14\, x^2$

The physical optimum level of sulphur and boron was worked out to be 61.78 and 1.81 kg per ha, respectively.

Table 3. Effect of levels of sulphur and boron on oil and protein content, net returns and cost benefit ratio (Pooled data of 2007 and 2008)

Treatments	Oil content (%)	Protein content (%)	Net returns (INR/ha)	B:C ratio
Sulphur level (kg/ha)				
0	18.02	35.55	18824	2.92
10	19.15	36.66	20388	3.07
20	19.37	37.77	22178	3.24
30	19.75	38.74	23558	3.35
40	19.79	39.66	23910	3.36
SEm (±)	0.01	0.95	--	--
CD at 5%	0.05	2.86	--	--
Boron level (kg/ha)				
0	18.62	35.29	21269	3.47
0.5	19.06	37.51	22510	3.41
1.0	19.33	37.76	22114	3.20
1.5	19.36	37.94	21530	3.00
2.0	19.37	38.39	21435	2.86
SEm (±)	0.01	0.95	--	--
CD at 5%	**0.05**	**2.86**	**--**	**--**

However, the economic optimum level of sulphur and boron was 56.83 and 1.58 kg per ha with the yield levels of 2, 213.70 and 2, 088.58 kg per ha, respectively.

Nutrient uptake

Sulphur application induced marked increase in the S content and uptake in seed and straw. Sulphur levels 10 to 40 kg per ha recorded significant differences with S content in seed and straw and S uptake by seed, straw and total uptake over control. Successive increase in S fertilization significantly increased the S uptake up to 40 kg S per ha. The crop fertilized with 10, 20, 30 and 40 kg S per ha recorded 44.44, 100.99, 156.11 and 194.94 per cent higher total S uptake, respectively over the control (8.112 kg/ha). Increase in net depletion of soil S was not only by the removal of the seed, but also by the straw from the field (Tandon *et al.*, 2007). Similarly the increase in B levels from 0 to 2.0 kg per ha, improved the S content in seed and straw and S uptake by seed, straw and total biomass produced but the margin between successive level was significant only up to 1.5 kg B per ha.

Available S at harvest ranged from 5.14 to 8.12 and 6.44 to 6.55 ppm with application of 10 to 40 kg S per ha and 0.5 to 2.0 kg B per ha, respectively (Table 2). This increase in S can be ascribed to the influence of applied S on availability of S in the soil and its extraction by plants as well as increase in crop yield

Quality parameters

The increasing levels of sulphur significantly improved the quality of soybean in terms of protein and oil content. The increase in oil content by 1.77 percentage points and protein by 4.11 percentage points with the application of 40 kg S per ha over control (18.02 and 35.55 %, respectively) was noticed (Table 3). Increase in oil content due to sulphur application can be attributed to the key role played by sulphur in biosynthesis of oil in oilseed plants. The increase in protein content may be accounted for the increase in synthesis of sulphur containing amino acids. Such beneficial effects of sulphur fertilization were also reported by Sharma (2003), Tandon *et al.* (2007) and Raghuwanshi *et al*. (2009). Boron application up to 2 kg per ha increased the protein and oil content but was at par with 1.5 kg per ha dose. Similar results have also reported by Chaturvedi *et al.* (2010).

Economics

Among the S levels, maximum net returns was recorded with 40 kg S per ha, whereas benefit cost ratio 3.36 and 3.35 was mostly equal with 40 and 30 kg S per ha, respectively. In case of boron, net returns increased with successive fertilization rate. However, the cost benefit ratio recorded with control was superior 3.47 followed by 3.41, 3.20, 3.00 and 2.86 with 0.5, 1.0, 1.5 and 2.0 kg B per ha.

This behaviour of economic parameters due to S and B levels was change in marginal seed yield of the crop with successive increase in fertilizer nutrient and relative cost of inputs in relation to output. Tandon *et al.* (2007) also reported that S application is highly profitable as shown by value cost ratio of 21.2 in soybean under field condition.

Thus, it may be concluded that application of sulphur @ 20 kg per ha and boron @ 0.5 kg per ha were found beneficial for enhancing soybean productivity in Vertisols under rainfed conditions of Madhya Pradesh.

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Effect of Organic and Inorganic Farming Systems on Physico-chemical Properties of Vertisols under Soybean - Wheat Cropping System

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ABSTRACT

Physico-chemical properties of Vertisols were studied under organic and inorganic farming systems during 2008-09 and 2009-10 at farmers' fields of Indore district. Experiment was carried out in randomized block design with four treatments and five replications. Treatments comprised of organic farming ≥ 3 years, organic farming (< 3 years), RDF and farmers' practice of nutrient application. Each farmer was taken as one replication. Significantly higher values for soil organic carbon content, available zinc content along with soil porosity and soil aggregation were recorded with organic farming systems. The soil N, P and K status were maximum in inorganic farming system followed by organic farming systems and farmers' practice of nutrient application. The contrasting results were found in crop productivities of the two crops. Soybean productivity was higher in organic farming system (≥ 3 years) by 3.69 per cent over RDF (2088 kg/ha), while wheat productivity was higher in later one by 16.92 per cent over formers' practice of nutrient application (3417 kg/ha). Non-significant differences were observed among the treatments for pH, EC and for available Cu, Fe and Mn.

Key words: Physico-chemical properties, organic and inorganic farming systems

'Green Revolution' has shown path to the country for self-sufficiency in food grain production, but the indigenous knowledge and local wisdom was ignored in adopting scientific approach, particularly in applying fertilizers. Most of the agro- ecological regions now showing reduction in soil organic carbon contents consequent upon adoption of intensive cropping and improper crop management practices (Srinivasarao e*t al.*, 2006). As a result, soils are encountering

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diversity of constraints broadly on account of physical, chemical and biological health and ultimately leading to poor soil quality. This shows signs of reversing trend in production at several places, in spite of increased inputs (Srinivasarao, 2011).

Several scientists and activists believe that agriculture in general and organic farming in particular is more specific with respect to local than global level due to vide variations in soil, climate and captive water resources. Since it is site specific farmer's knowledge and identification of local practices are important to create new approaches to achieve sustainability (Shroff, 1994 and Deshpande, 2009). To evaluate the influence of organic and inorganic management, the present study is planned with soybean [*Glycine max* (L.) Merrill] - wheat (*Triticum aestivum* L.) cropping system on Vertisols of Central India.

MATERIAL AND METHODS

The experiment was laid out at the farmers' field located at different sites of Indore district (Madhya Pradesh) using randomized block design with four treatments, namely organic farming (≥ 3 years), organic farming (< 3 years), inorganic farming with recommended dose of fertilizers and farmers' practice of nutrient application, replicated 5 times (each farmer was taken as one replication). The study was carried out during *rabi* and *kharif* seasons of 2008-09 and 2009-10 in five villages namely, Semliyachau, Asrawad Khurd, Badiya Khema, Ralamandel and Morod Haat of Indore district. These bio-villages were adopted by the Department of Farmers' Welfare and Agriculture Development (Government of Madhya Pradesh), where in farmers have been practicing organic farming for last 2-7 years.

The two organic farming treatments received NADEP compost @ 7.5 t per ha, vermicompost @ 2.5 t per ha, bio-gas slurry @ 2.0 t per ha and biofertilizers *Rhizobium japonicum* + PSB (for soybean) and azotobacter + PSB (for wheat) as seed inoculants @10 g per kg seed each and soil application @ 2 kg per ha. Inorganic farming treatment involved application of recommended levels of $NP_2O_5K_2O$ (120:60:30 kg/ ha) to wheat and $NP_2O_5K_2O$ (20:60:20 kg/ha) to soybean through chemical fertilizers. The above three treatments were evaluated over farmers' practice of application of $NP_2O_5K_2O$ (150:50:0 kg/ ha) to wheat and $NP_2O_5K_2O$ (40:40:0 kg/ha) to soybean through chemical fertilizers. The popular variety Lok-1 of wheat and JS-335 of soybean were grown in the experiment following standard package and practices. The data on various parameter recorded in both the years were pooled, statistically analysed and presented in the manuscript.

Soil samples (0-15 cm and 15-30 cm) were collected from the four systems evaluated and analysed. The soils of the study area was medium black (Sarol series), belonging to fine, Montmorillonitic, hyperthermic family of Vertic Haplusterts. Standard methods as described by (Jackson, 1973) were used for soil analysis. Available micronutrients were extracted by using DTPA extractant (Lindsay and Norvell, 1978) and measured by using AAS (Perkin-Elmer model). The Soil bulk density was estimated by core sampler method given by Bodman (1942), soil porosity was computed by putting values in the formulae, soil aggregate analysis- Mean Weight Diameter (MWD) was estimated by wet sieving method using Yoder's apparatus (Yoder, 1936).

RESULTS AND DISCUSSION

Effect of different farming systems on chemical properties of soil

The pH and electrical conductivity were unaltered by various treatments under the study. The values of pH and EC for different treatments were ranged from 7.4 to 7.6 and from 0.19 to 0.21, respectively. This could be due to high buffering capacity of the soil, as reported by Palojarvi *et al.* (2002). Significant higher organic carbon content was noted in the organic farming system (5.58 to 6.32 g/kg soil) as compared to inorganic (4.86 g/kg soil) and farmers' practice of nutrient application (4.31 g/kg soil) (Table 1). This appeared feasible due to the direct and continuous addition of organic matter through organic sources. Bhandari *et al.* (1992) and Hapse (1993) reported similar increase in soil organic carbon content of soil due to continuous addition of organic manures. The available nitrogen, phosphorus and potassium contents also revealed significant differences. The content of these major nutrients were maximum in inorganic system followed by organic systems and farmers' practice of nutrient application. The direct application of nitrogen through fertilizers leading to immediate availability could be accounted for higher nitrogen contents in inorganic systems. Comparatively lower nitrogen contents in organic system could be due to shift in biological activity (Petersen *et al.,* 1999). Significantly lower phosphorus content in organic farming systems due to slow mineralization from native pool (Khan *et al.,* 1984) and of potassium due to its release consequent upon interaction of organic matter with clay (Miller and Donahue, 1995) could be the possible explanations. The justifications also explain the higher content of these nutrients in organic systems over farmers' practice receiving unbalanced and skewed nutrition. As far as micronutrients are concerned, there were non-significant differences for the content of Cu, Fe, and Mn between different management systems. Zinc content was significantly higher (1.29 kg/ha) in the organic farming (≥ 3 years) as compared to rest of the treatments (Table 1). Organic manures are known to naturally provide micronutrient as they store them in both stable and usable forms (Tisdale *et al.,* 1993). The significant higher soil zinc content was also observed by Ramesh *et al*. (2010) in organic farming system.

Effect of different farming systems on physical properties of soil

A soil with good structure and stable aggregates will exhibit desirable values of bulk density and porosity for a given soil type that promotes adequate soil aeration and available water. These characteristics define the physical environment of the soil ecosystem and are critical for a healthy soil and sustainable agriculture. Enhanced soil structural properties are linked with increased soil organic matter (Tisdall and Oades, 1982) and the literature contains considerable evidence that a range of recycled organic amendments (composts or bio-solids) increases the organic matter of soil (Albiach *et al.*, 2001).

The values for bulk density, porosity and mean weight diameter (MWD) for 0-15 cm and 15-30 cm, which are indicator of desirable soil structure and stable aggregates, were favourable in organic farming system (> 3 years) followed by organic farming system (< 3 years), inorganic system and farmers' practice of nutrient application (Table 2). The decrease in bulk density and increased aggregations on account of dilution effect of denser mineral fraction (Shiralipour *et al.*, 1992) and increase in aggregation on account of binding effect of humic acid (Khaleel *et al.*, 1981), particularly in organic systems is feasible. Enhanced soil structural properties are linked to increased soil organic matter has been brought forth in the present study.

Effect of different farming systems on crop productivity

The grain yield is the manifestation of various growth and yield attributing characters. In case of soybean, the higher productivity was obtained under organic farming (≥ 3 years) treatment, followed by inorganic farming with RDF (Table 2). On the contrary, in case of wheat, being cereal, the inorganic farming with RDF gave highest productivity as compared to rest of the treatments. Higher soybean productivity under organic systems as compared to farmers' practice of nutrient application, might be due to regulated availability of nutrients, throughout the crop growth as soybean gets majority of its nitrogen requirement through symbiotic N-fixation. Further, the addition of manure and bio-fertilizers causes increased activity of beneficial microorganisms which mediated biological process like N- fixation and P-solubilzation (Shwetha, 2007). Lower productivity of wheat under organic farming systems may be argued on the basis of slow mineralization of organic manure and non-availability of required nutrients, which resulted in a setback in crop growth at early stage of wheat and thus affected the crop yield (Prasad, 1994). The lower wheat productivity under organic farming system due to inadequate supply of nutrients during entire crop growth period through lower readily available nutrients has earlier been reported (Halberg and Kristensen, 1997).

Table 1. Soil chemical properties as influenced by organic and inorganic farming systems

Treatment	pH	EC (dS/m)	Organic carbon (g/kg soil)	Available						
				N (kg/ha)	P_2O_5 (kg/ ha)	K_2O (kg/ha)	Zn (mg/kg soil)	Fe (mg/kg soil)	Cu (mg/kg soil)	Mn (mg/kg soil)
Initial status	7.5	0.20	4.50	195	12.50	480	1.10	6.10	1.92	5.43
Organic farming (≥ 3 years)	7.4	0.19	6.32	208.4	12.97	501.4	1.29	6.14	1.96	5.48
Organic farming (<3years)	7.5	0.20	5.58	197.8	12.64	471.7	1.17	6.10	1.93	5.46
Inorganic farming with RDF	7.5	0.20	4.86	219.1	13.34	507.4	1.09	6.09	1.92	5.43
Farmers' practice of nutrient application	7.6	0.21	4.31	187.2	11.64	446.0	1.01	6.02	1.91	5.40
SEm (±)	0.03	0.0036	0.17	0.64	0.03	5.63	0.01	0.03	0.01	0.02
CD at 5%	**NS**	**NS**	**0.52**	**1.98**	**0.09**	**17.36**	0.03	**NS**	**NS**	**NS**

RDF- Recommended dose of fertilizers

Table 2. Soil physical properties and crop productivity as influenced by organic and inorganic farming systems

Treatment	Bulk density (Mg/m)		Porosity (%)		MWD (mm)		Seed yield (kg/ha)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	Soybean	Wheat
Organic farming (≥ 3 years)	1.22	1.44	53.8	44.9	1.222	0.807	2165	3698
Organic farming (<3years)	1.28	1.53	50.5	42.1	1.118	0.660	1849	3376
Inorganic farming with RDF	1.31	1.56	48.1	41.4	0.969	0.597	2088	3995
Farmers' practice of nutrient application	1.37	1.58	46.8	40.1	0.934	0.566	1576	3417
SEm (±)	0.01	0.01	0.21	0.40	0.030	0.010	0.16	0.29
CD at 5%	**0.02**	**0.02**	**0.63**	**1.24**	**0.090**	**0.020**	**49**	**89**

RDF- Recommended dose of fertilizers

The present study indicated that continuous practising organic farming for extended period promoted favourable soil environment for the growing crops by improving soil organic carbon and soil physical properties leading to better seed yield of soybean than inorganic farming system with RDF. However, the later one recorded better wheat yield along with higher residual major soil nutrients than the organic farming (≥ 3 years). The farmers' practices of nutrient application do not compete over other systems and needs to be revamped.

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Effect of Gypsum as a Source of Sulphur on Soybean [*Glycine max* (L.) Merrill] at Farmers Field on *Malwa* Region of Madhya Pradesh

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ABSTRACT

*Demonstrations were conducted for three consecutive years (*kharif *2006 to 2008) at 5 farmers' fields during each year, to observe the effect of graded levels of gypsum on production potential and economic benefits of soybean cultivation. The average plant height, number of pods per plant and number of seeds per pod of soybean increased significantly with the increase in gypsum application rates beyond 0.2 t per ha over control. The mean seed index (g/100 seeds) also increased with the increasing levels of gypsum. The maximum plant height (55.48 cm) and number of pods per plant (44.26) were recorded on application of gypsum @ 0.2 t per ha, however, maximum number of seeds per pod (2.75) and seed index (14.12 g/100 seeds) was noticed when gypsum was applied @ 0.3 t per ha. The highest seed (2 591 kg/ha) and stover (2 784 kg/ha) yields were recorded on application of gypsum @ 0.3 t per ha, which was statistically at par with @ 0.2 t per ha. The content of N, P, K and S in seed increased significantly with the increased level of gypsum application as compared to control. The highest content of N (6.53 %), P (0.51 %), K (2.39 %) and S (0.33 %) was recorded with application of gypsum @ 0.2 per t ha. The computed value cost ratio (VCR) indicated that the increased rate of gypsum application was invariably beneficial to the farmers. Soybean crop gave highest return (*INR *26.30) on single rupee invested on gypsum when applied @ 0.2 t per ha.*

Key words: Economics, gypsum, soybean, yield

During past four decades of its commercial venture, soybean has established itself as a major *kharif* season oilseed crop in India, particularly in central part of the country. Madhya Pradesh has its major share in area of 5.51 million hectare (59.3 %) with production of soybean of 6.10 mt (60.2 %) in India (www.sopa.org). Although, the soybean research and development system in the

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country has generated viable production technology to raise the productivity to more than 80% from the present level of around 1.0 tons per hectare, it appears that there are impediments in reaching to end users creating a technological gap (Bhatnagar, 2009). To convince the soybean growers on effectiveness of technology and to motivate them for adoption, conduct of demonstrations is one of the proven methods. The low productivity of soybean may be due to nutritional deficiencies and also imbalanced fertilization amongst the nutrients, sulphur is one of them whose response is observed in soybean (Prasad, 2006). Non-judicious use of chemical fertilizers, intensive cultivation of crops, higher cropping intensity and limited use of organic matter are the most possible causes for sulphur deficiency limiting soybean yield.

MATERIAL AND METHODS

Front line demonstrations were conducted for three consecutive years (2006-08) on farmers fields (5 farmers every year) covering eight adopted villages (Dakachya and Barlai of Sanwer tehsil, Panod and Balyakheda of Indore tehsil and Agra, Hatod, Sagwal and Budania of Depalpur tehsil) of Indore district of Madhya Pradesh under rainfed condition. The soil of the demonstration sites was medium black soil with low to medium fertility status (pH-7.80, EC-0.67 dSm^{-1}, available N 191.8 kg/ha, available P_2O_5 12.65 kg/ha, available K_2O 585 kg/ha and available S 10.53 kg/ ha). Each demonstration was conducted on an area of 0.4 hectare and the same area adjacent to the demonstration plot was kept as farmers practice. The experiment consisted of four levels of gypsum as fertilizer 0, 0.1, 0.2 and 0.3 t per ha. Package of improved technologies included high yielding, short duration variety (JS 93-05), recommended level of fertilizer application (25:60:30, N: P_2O_5: K_2O kg/ha) and hand weeding at 25 DAS. The soybean crop was sown between June 29th and 2nd July in 2006, June, 20th and 22nd in 2007 and June 15th and 28th in 2008 with seed rate 80 kg per ha at row to row spacing of 45 cm. Entire dose of N and P through DAP and K through MOP was applied as basal dose before sowing. Gypsum of agriculture grade (12.6% S) was used as a source of sulphur and applied before sowing of the crop. The seeds were treated with *Bradyrhizobium japonicum* and phosphate –solubilizing bacteria, each @ 10 g per kg seed. The crop was harvested in between October 7th and 10th in 2006, September 25th and 28th in 2007 and September 16th and 27th in 2008. The observations pertaining to yield attributing characters on five randomly selected plants, seed and stover yield of soybean were recorded and subjected to statistical analysis (Panse and Sukhatme, 1985) in randomized block design considering location (farmers) as replicate. The seed samples collected at harvest were analyzed for nitrogen (Kjeldhal, 1983) phosphorus by vanadomolybdo phosphoric yellow colour method in nitric acid system (Jackson, 1973), potassium (Black, 1965), sulphur by method given by Chesnin and

Yien (1950) and oil content as per AOAC (1984).

RESULTS AND DISCUSSION

Effect of gypsum (sulphur) on yield attributes

Application of gypsum contributed significantly in enhancing the growth attributes and yield during all the three years of demonstrations (Table 1). In general, there has been an increasing trend in values of mean plant height, number of pods per plant and number of seeds per pod of soybean with increasing levels of gypsum up to 0.2 t per ha. The values for plant height (55.48 cm) and pods per plant (44.26) were maximum at this level and were significantly higher than control (49.06 cm and 39.85, respectively). Mean seeds per plant and seed index (g/100 seeds) showed a regular increase with increasing levels of gypsum. These highest values for two yield attributing–characters were associated with application of gypsum @ 0.3 t per ha. The seed index values differed significantly over control and other levels of application of gypsum. The observed improvement of growth attributing traits of soybean by application of gypsum can be explained on account of sulphur in gypsum, which plays a pivotal role in promoting the growth of crops, particularly oilseeds and pulses. The above results are in conformity with the findings of Joshi and Billore (1998), who reported a gradual increase in these yield attributes of soybean with increasing levels of sulphur applied through gypsum. Some other workers (Hemantrajan and Trivedi, 1997) also reported an increase the pod length (Hemantrajan and Trivedi, 1997), number of pods and seed index (Saxena and Nainwal, 2010) of soybean consequent upon application of sulphur.

Effect on yield

The effect of increased levels of gypsum for sulphur nutrition on soybean seed and stover yield was found to be statistically significant (Table 1). Application of gypsum @ 0.2 t per ha gave significantly higher seed as well as stover yield as compared to control and 0.1 t per ha gypsum addition. The highest seed (2591 kg/ha) and stover (2784 kg/ha) yields were recorded when gypsum was applied@ 0.3 t per ha, which was statistically at par with 0.2 t per ha level. The consistent increments in seed yield of soybean observed in the present study with increasing levels of sulphur through gypsum could be the consequence of cumulative improvement in yield attributes like number of pods per plant, seeds per pod and the seed index. The balanced nutrition provided by recommended fertilizers including sulphur through gypsum must have been the cause of improved seed and strover yield. Increased supply of sulphur is known to promote the process of tissue differentiation from somatic to reproductive, meristematic activity, which might have increased the number and size of leaves (Mengal and Kirkby, 1987). Since, sink lies in leaves, when supply of sulphur is optimum, greater translocation of

Table 1. Effect of different levels of gypsum application on yield attributes and yield (seed and stover) of soybean (averaged over of five demonstrations)

Gypsum levels (t/ha)	Year				Year			
	2006	**2007**	**2008**	**Mean**	**2006**	**2007**	**2008**	**Mean**
	Plant height (cm)				*Pods/plant (No)*			
0.0	45.40	47.04	58.40	49.06	29.50	45.20	44.88	39.85
0.1	47.40	49.62	55.90	50.95	27.30	48.10	48.18	41.18
0.2	51.60	52.38	58.20	55.48	32.20	50.00	50.64	44.26
0.3	48.20	52.34	58.56	53.03	31.00	50.42	50.64	44.19
SEm (+/-)	0.55	0.50	0.30	0.58	2.10	1.66	0.52	0.75
CD (5 %)	**1.70**	**1.55**	**0.92**	**2.01**	**6.46**	**5.11**	**1.60**	**2.58**
	Seeds/pod (No)				*Seed index (g/100 seeds)*			
0.0	2.9	2.47	2.45	2.61	14.02	13.11	13.41	13.50
0.1	2.9	2.56	2.51	2.62	14.26	13.37	13.51	13.71
0.2	3.0	2.57	2.67	2.71	14.73	13.56	13.66	13.97
0.3	3.0	2.60	2.67	2.75	15.12	13.61	13.64	14.12
SEm (+/-)	**0.06**	**0.03**	**0.03**	**0.02**	**0.09**	**0.03**	**0.04**	**0.04**
CD (5 %)	**0.19**	**0.10**	**0.09**	**0.08**	**0.27**	**0.10**	**0.11**	**0.13**
	Seed yield (kg/ha)				*Stover yield (kg/ha)*			
0.0	1701	2196	2456	2118	1817	2808	2641	2311
0.1	1959	2379	2621	2329	2087	2770	2775	2544
0.2	2163	2691	2829	2585	2286	3073	2955	2771
0.3	2189	2689	2881	2591	2284	3077	2992	2784
SEm (+/-)	32.21	44.94	25.97	24.94	44.90	49.91	23.34	27.67
CD (5 %)	**99.20**	**138.42**	**80.00**	**86.30**	**138.3**	**153.73**	**71.90**	**95.75**

photosynthates might have occurred from leaves to seed (Mengal and Kirkby, 1987) leading to higher yield. Such yield enhancements due to sulphur supply have been recorded by other workers (Kumar *et al.,* 1992; Sarker *et al.,* 2002; Meena *et al.,* 2011).

Effect on nutrient and oil contents

The content of N, P, K and S in seed in seed increased significantly with the increased level of gypsum application up to 0.2 t per ha as compared to control and remained at par with 0.3 t per ha (Table 2). The highest content of nitrogen (6.53 %), phosphorus (0.51 %), potassium (2.39 %) and sulphur (0.33 %) was recorded with application of 0.2 t gypsum per ha, whereas, minimum values recorded were under control (6.19 %, 0.41 %, 2.10 % and 0.26 %, respectively). This effect may be attributed to the fact that the increased supply of sulphur facilitated higher uptake of N, P, K and S from soil.

Increased sulphur content in soybean seed on application of sulphur to soybean has been recorded by Ganeshamurty (1996).

Oil content in soybean seed increased significantly with increasing doses of gypsum application up to 0.2 t per ha (Table 3) due to the fact that sulphur in gypsum might have played a key role in biosynthesis of oil in oilseeds. Mean values of oil contents in treatments supplied with 0.2 and 0.3 t of gypsum per ha recorded 21.02 per cent followed by 0.1 t gypsum per ha (20.34 %) and control (19.74 %). Raghuwanshi *et al.* (2009) also reported increased oil content in soybean seed by 4.37 per cent when sulphur was applied @ 50 kg per ha.

Effect on economical aspects

The economics in term of investment on cost of gypsum and returns through increased seed yield worked out on the basis of current market price revealed that the value cost ratio (VCR) gradually increased with sulphur application through gypsum up to 0.2 t per ha (Table 4). The VCR value for 0.2 t gypsum per ha worked out to 26.30. Beyond 0.2 t per ha application of gypsum, the benefit decreased (VCR 17.73) indicating lowering in per rupee investment. The computed VCRs value clearly indicated that the increased rate of gypsum application was always beneficial to the farmers as compared to

Table 2. Effect of different doses of gypsum application on nutrients and oil content (%) of soybean seed (averaged over of five demonstrations)

Gypsum levels (t/ha)	Year				Year			
	2006	2007	2008	Mean	2006	2007	2008	Mean
	N content (%)				*P content (%)*			
0.0	6.69	6.01	5.88	6.19	0.48	0.41	0.36	0.41
0.1	7.08	6.18	6.03	6.24	0.53	0.41	0.41	0.44
0.2	7.37	6.24	6.02	6.53	0.61	0.51	0.41	0.51
0.3	7.21	6.21	6.20	6.53	0.58	0.46	0.46	0.50
SEm (+/-)	0.08	0.14	0.09	0.05	0.01	0.03	0.02	0.01
CD (5 %)	**0.25**	**0.43**	**NS**	**0.18**	**0.03**	**0.10**	**0.06**	**0.03**
	K content (%)				*S content (%)*			
0.0	1.92	2.16	2.21	2.10	0.21	0.30	0.29	0.26
0.1	2.28	2.19	2.23	2.23	0.23	0.34	0.31	0.29
0.2	2.49	2.28	2.41	2.39	0.27	0.37	0.36	0.33
0.3	2.36	2.27	2.53	2.38	0.25	0.37	0.37	0.33
SEm (+/-)	0.06	0.10	0.06	0.04	0.003	0.006	0.008	0.003
CD (5 %)	**0.17**	**0.32**	**0.20**	**0.14**	**0.008**	**0.020**	**0.024**	**0.012**

Table 3. Effect of different doses of gypsum application on oil content (%) of soybean seed (averaged over of five demonstrations)

Gypsum levels (t/ha)	Year			
	2006	2007	2008	Mean
	Oil content (%)			
0.0	19.98	19.28	19.97	19.74
0.1	20.76	19.78	20.50	20.34
0.2	21.83	20.44	20.79	21.02
0.3	21.86	20.44	20.76	21.02
SEm(+/-)	0.06	0.19	0.09	0.06
CD (5 %)	**0.19**	**0.58**	**0.27**	**0.22**

Table 4. The average value cost ratio (VCR) of applied gypsum

	Gypsum levels (t/ha)			
	0.0	0.1	0.2	0.3
Yield (kg/ha)	2118	2329	2585	2591
Increase over control (kg/ha)	-	211	467	473
Profit (INR)	-	3787	8416	8517
Gypsum application cost (INR)	-	160	320	480
VCR	-	23.67	26.30	17.73

control. Saxena and Nainwal (2010) also reported that sulphur application @ 30 kg per ha recorded significantly higher B:C ratio than other levels of sulphur nutrition.

The demonstrations conducted for three consecutive years under real farm conditions on effect of application of sulphur through gypsum enhances growth, major nutrient contents in seed and yield (seed and straw) of soybean. The application of sulphur through gypsum @ 0.2 t per ha is optimum to enhance yield and is economically viable in medium black soils of Malwa plateau of Madhya Pradesh.

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Impact of New Water Management Practices on Productivity and Sustainability of Soybean Grown in the Chambal Command Area of South-Eastern Rajasthan

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ABSTRACT

On farm demonstrations in soybean was carried out during 2004 to 2008 at farmer's field under ORP of Agricultural Research Station, Kota. The main objective was evaluation of the productivity and sustainability of soybean in Chambal command. Treatments were comprised of irrigation scheduling at flowering and pod development stages by border strip (6 x 50 m) method using 80 per cent cut off ratio (improved water management technology) which was compared with farmer's practice i.e. wild flooding. Results revealed that improved water management technology gave higher and sustainable seed yield of soybean over the years. The mean yield recorded (2 008 kg/ha) was being 7.47 per cent higher as compared to the yield (1 870 kg/ha) observed under farmer's practice. Sustainability of soybean yield was reflected by the higher sustainability yield index (0.897) and value index (0.849). Improved water management technology possessed higher water expanse efficiency (163.21 kg/ha/cm) and incremental benefit cost ratio (3.2) over farmer's practice.

Key word: Soybean, sustainability yield index, value index and water management technology

Soybean (*Glycine max* (L.) Merrill), commonly known as golden bean, is most important *kharif* oilseed crop of south eastern Rajasthan. The productivity of soybean in the state is very low. Therefore, concentrated efforts are required to enhance its productivity. It is, generally, grown with the onset of monsoon in the month of July. Method of irrigation and time of application of water plays an important role in enhancing the water productivity of soybean. Declining

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availability of irrigation water, need of sustainability in crop production and increasing demand of food/oil; can be achieved through adoption of improved water management and crop production technologies, and efficient water management. Keeping this in view, demonstrations were conducted at farmer's field under Operational Research Programme (ORP) with the aim to improve water expanse efficiency at field level and to show the benefits of demonstrated water management technology in terms of enhanced yield and saving of irrigation water.

MATERIAL AND METHODS

The study area is in Chambal command, which lies between 25° and 26° North latitude and 75°-30' and 76°-6' East longitude in the south-eastern part of Rajasthan comprising part of Kota, Bundi and Baran Districts. It comes under agro-climatic zone V, which is also known as humid south-eastern plain of Rajasthan. Kota Barrage, situated in Kota city serves the main canal system of Chambal command, from here the two main canals – right and left takes off. In absence of canal water, irrigation was given by the tube well, etc.

The soils of the Chambal command area belong to the order Vertisols and Inceptisols, mainly comprised of Chambal series (62 %) and Kota variant (23 %). The bulk density, pH and cation exchange capacity of these soils varies between 1.30 - 1.60 Mg/m^3, and 7.75-8.50 and 30-40 Cmol/kg, respectively. The soils have a very low water intake rate (approximately 0.25 cm/h) on surface, but are almost impermeable at 1.2 to 1.5 m depth. The potential moisture retention capacity is almost 120 mm of water in 1 m profile depth. The soils of the region are poor in organic carbon (0.50 ± 0.08 %) and available nitrogen (275 ± 10 kg/ha), but are low to medium in available P_2O_5 (24.2 ± 1.0 kg/ha) and medium to high in available K_2O (290 ± 12 kg/ha).

The field demonstrations were carried out for five years from 2004 to 2008 during *kharif* season, at farmer's field under ORP of AICRP on Water Management to show economic feasibility and sustainability of improved water management technology in soybean crop. Each year eighteen demonstration were conducted, three each at head, middle and tail reach of Left main canal and Right main canal system of Chambal command, respectively.

Improved water management technology (two irrigation, one each at flowering and pod development stage, if needed, with 6 cm depth, by border strip method 6 m x 50 m at 80 % cut off ratio) with recommended package of practices *viz.*, high yielding varieties, seed treatment, recommended dose of fertilizer (20:40:40:30 kg/ha, NPKS), weed management, crop geometry (30 x 10 cm) and seed rate (80 kg/ha) were used in test block during each year. Each demonstration was laid out in an area of 0.1 ha. For assessing impact of improved water management technology, the adjoining field with similar area cultivated to soybean crop by the farmer himself was considered which served as check plot (Farmer's practice). Improved water management technology was compared with farmer's practice i.e. flooding method of irrigation with no control over the depth of irrigation (usually about 10 cm). For test plots measurement of water was done by velocity-area method at field level. The demonstration plots were sown with improved water management technology during first fortnight of July every year except 2008 where the sowing was done in fourth week of July due to delayed commencement of monsoon. The rainfall received during growing period of soybean were 478 mm, 430 mm, 645 mm, 736 mm and 585 mm, for the years of 2004, 2005, 2006, 2007 and 2008, respectively. Data were recorded from demonstration blocks and farmer's practice blocks. These recorded data were analyzed for different parameters, using following formulae, suggested by Prasad *et al*. (1993).

Extension Gap = Demonstration yield (Di) - Farmer's practice yield (Fi)

Technology Gap = Potential yield (Pi) - Demonstration yield (Di)

Technology Index = (Pi - Di)/Pi x 100

Data were also analyzed for parameters like standard deviation, coefficient of variation as per standard procedure (Panse and Sukhatme, 1961). Sustainability indices (Sustainability yield index and sustainability value index) were work out using formula (Singh *et al*., 1990).

$$SYI/\ SVI = Y\text{-}O/Y_{max}$$

Where:

Y = Estimated average yield/net return of practices over the year

O = Standard deviation

Y_{max} = Maximum yield/maximum net return.

RESULTS AND DISCUSSION

Seed yield

Five year average seed yield of demonstrations of soybean was 2 008 kg per ha which was 7.47 per cent higher than the five year average yield (1 870 kg/ha) obtained under farmer's practices (Table 2). Year-wise per cent increase in seed yield of demonstrations over farmer's practices ranged from 5.1 to 9.3. The higher seed yield under demonstrations could be attributed to adoption of improved water management technology under the supervision of scientists. Year-wise observed variation in seed yield might be due to the variation in the environmental conditions prevailed during that particular year. This fact has been reported by Joshi *et al.* (2004) stating that improved package of practices along with water management has shown positive effect on yield potentials of different crops. Average water expanse efficiency (163.2 kg/ha/cm) calculated was also higher in test block as compared to farmer's practice. This is due to lesser depth of irrigation water applied and more seed yield obtained. Same thing was also observed by Dhar *et al.,* (2011). During five years of study, two years, *i.e.* 2004 and 2005, only irrigation at pod development stage was applied, as the irrigation at flowering stage was supplied through effective rainfall. Early withdrawal of monsoon is a big problem of the area in the absence of canal water during the month of September, only those farmers who have irrigation facilities could harvest good crop; this phenomena is evident by the yield of year 2008.

Gap analysis

Yield gap analysis for all the five years as reflected by extension gap, technology gap and technological index revealed wide gaps in all the three parameters. Extension gap is a parameter to know the yield difference between the demonstrated technology and farmer's practice; for the present study, it ranged from 106 to 165 kg per ha with an average of 138 kg per ha. This indicated a wide gap between the demonstrated improved technology and its adoption by the farmers (Table 1). Technology gap is a measure of difference between potential yield and yield obtained under improved technology demonstration. This is of greater significance than other parameters as it indicated the constraints in implementation and drawbacks in our package of practices and could be environmental or varietal. This also reflects the poor extension activities, which resulted in lesser adoption of improved water management technology and package of practices by the farmers. This gap can be lowered down by strengthening the extension activities and further research to improve the package of practices. Technology index is dependent on technology gap and is a function expressed in per cent. For the five years of study it varied from 27.2 to 41.7 per cent, with an average of 34.0 per cent. The very low technology index (27.2) during the year 2004 could be due to introduction of improved water management technology, favourable climatic conditions, crop free from insect pest and disease incidence. High technology index shows a poor performance of package of practices and demonstrated technology. For example during the year 2008 the technology index was 41.7 per cent, this was mainly due to early withdrawal of monsoon and unfavourable climatic conditions with incidence of pest and diseases. Such higher technology indices have been reported in front line demonstrations on chickpea by Siag *et al.* (2002).

Economic analysis

Grain yield, cost of inputs and sale price of produce determine the economic

Table 1. Grain yield, gap analysis and water expanse efficiency of soybean demonstrations

Year	Yield (kg/ha)		% increase over FP	Depth of water applied (cm)		Water expense efficiency (kg/ha/cm)		Potential yield (kg/ha)	Extension gap (kg/ha)	Technology gap (kg/ha)	Technology index (%)
	IT	FP		IT	FP	IT	FP				
2004	2183	2077	5.10	13	17	167.92	122.18	3000	106	817	27.2
2005	2008	1892	6.13	12.5	16.5	160.64	114.67	3000	116	992	34.0
2006	2040	1875	8.80	12	20	170.00	93.75	3000	165	960	32.0
2007	2062	1908	8.07	12	20	171.83	95.40	3000	154	938	31.3
2008	1748	1600	9.25	12	20	145.66	80.00	3000	148	1252	41.7
Average	**2008**	**1870**	**7.47**	**12.3**	**18.7**	**163.21**	**101.20**	**3000**	**138**	**992**	**34.0**

IT= Improved technology; FP = Farmers practice

Table 2. Variability of seed yield and net returns of soybean demonstrations

Particulars		Years											
		2004		2005		2006		2007		2008		Average	
		IT	FP	IT	FP	IT	FP	IT	FP	IT	FP	IT	FP
Seed yield	H	2258	2137	2130	2010	2250	2180	2230	2130	1901	1767	2145	2045
(kg/ha) range	T	2128	2029	1930	1780	1900	1710	1910	1760	1595	1355	1905	1777
Mean seed yield (kg/ha)		2183	2077	2008	1892	2040	1875	2062	1908	1748	1600	2008	1870
S D		0.437	0.454	0.685	0.865	1.26	1.61	1.24	1.44	1.23	1.53	0.819	0.966
CV (%)		2.00	2.18	3.41	4.57	6.22	8.60	6.02	7.55	7.09	9.61	4.08	5.16
Net returns	H	18996	18044	19450	18432	22038	21675	23085	22285	20166	18742	20646	19835
range (₹./ha)	T	17436	16748	16820	16328	17225	15213	18445	16630	15362	12274	17218	15989
S D		567.3	545.2	901.2	1138.6	1745.8	2218.4	1800.4	2090.0	1945.6	2414.3	1161.5	1368.8
CV (%)		3.14	3.15	5.05	6.75	9.12	12.69	8.72	10.96	10.96	14.98	6.21	7.88
SYI		0.972	0.950	0.910	0.898	0.850	0.786	0.868	0.828	0.854	0.818	0.897	0.867
SVI		0.948	0.930	0.871	0.854	0.790	0.704	0.816	0.762	0.784	0.731	0.849	0.807

H = Maximum yield at head reach of canal; T = Minimum yield at tail reach of canal; IT= Improved technology; FP = Farmers practice; S D = Standard deviation returns and these vary from year to year as the cost of input, labour and sale price of produce changes from time to time. The year-wise additional returns from improved technology demonstrations over farmer's practice varied from INR 1 272 to INR 2 324 (Table 3). The mean additional cost of input of all the demonstrations for five years was INR 598 (Table 3). This additional investment along with non-monitory management factors gave an additional mean returns of INR 1 925. The higher sale price of produce, in spite of low production and higher additional cost of input during 2008 gave highest additional returns under improved technology demonstrations over farmer's practice. The incremental benefit cost ratio (IBCR) on overall average basis was 3.2. The highest IBCR during five years was observed in 2006 (3.8), which can be ascribed to comparatively higher grain yield, less cost of input and a good sale price.

Sustainability

Higher standard deviation in seed yield was observed under farmer's practice over improved water management technology demonstrations for all the five years (Table 2). Similar was the case with coefficient of variation. This may be due to more variation in the yield from farmer to farmer under farmer's practice and lesser in improved technology demonstrations. However, the sustainability yield index (SYI) and Sustainability value index (SVI) was more under improved technology than farmer's practices (Table 2). The mean SYI and SVI over these 5 years under improved technology of water management, ranged from 0.850 to 0.972 and 0.784 to 0.948 with an average of 0.897 and 0.849, while the corresponding values under farmer's practice were 0.786 to 0.950 and 0.704 to 0.930 with an average of 0.867 and 0.807, respectively. This shows that the improved technology is more sustainable as compared to farmer's practice. Similar results have been reported by Billore *et al.* (2009).

Table 3. Economic analyses of demonstrations on soybean during *kharif* season

Year	Cost of inputs (INR/ha)		Additional cost in IT	Sale price (INR /t)	Total returns (INR /ha)		Additional returns in IT (INR /ha)	Effective gain (INR /ha)	IBCR
	IT	FP			IT	FP			
2004	8100	7600	500	12000	26196	24924	1272	772	2.5
2005	8560	8000	560	13150	26405	24880	1525	965	2.7
2006	8900	8300	600	13750	28050	25781	2269	1669	3.8
2007	9250	8600	650	14500	29899	27666	2233	1583	3.4
2008	9680	9000	680	15700	27444	25120	2324	1644	3.4
Average	**8898**	**8300**	**598**	**13820**	**27599**	**25674**	**1925**	**1327**	**3.2**

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Productivity, Sustainability and Stability of Soybean Based Cropping Systems under Different Tillage Systems

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ABSTRACT

Field experiments were conducted during 1995 to 2006 to study the impact of tillage systems on yield trend, stability, relative stability, sustainability, energy budgeting and economics of soybean–wheat and soybean–chickpea cropping systems. Soybean yields remained uninfluenced by the tillage systems. Soybean grown prior to wheat did not show appreciable higher yield than that of chickpea. Seed yield of soybean grown prior to wheat was more sustainable than that of chickpea. Trend analysis revealed that yield of all the three crops, i.e. soybean (9.9 %/annum), wheat (1.71 %/ annum) and chickpea (11.9 %/ annum) increased linearly over the years under all the three tillage systems, which were equally stable. However, minimum tillage was more stable than conventional and no-till with regards to soybean. In rabi *crops; no-till was more stable than remaining two tillage systems. Total crop productivity in terms of soybean equivalent yield (SEY) remained unaffected due to tillage systems. Soybean –wheat system was more productive, stable and profitable compared to soybean-chickpea. Trend analysis revealed that the rate of yield increment was more than double in soybean – chickpea than soybean-wheat. Under no-till system both the cropping systems performed well under unfavourable environments. Energy budgeting revealed that the soybean–wheat system was associated with higher energy input and output than soybean-chickpea system, while soybean-chickpea was most energy efficient in terms energy use efficiency, energy productivity and energy intensiveness. Minimum and no-till systems were most economically viable and energy efficient than conventional tillage.*

Key words: Chickpea, relative stability, soybean, stability, sustainability, tillage, trend analysis, wheat

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It has become imperative for India to become globally competent in production of various crops in view of the challenges put-forth subsequent to become signatory to WTO in 1995. This necessitated resorting to making all out efforts to optimize production from a unit area in unit time at minimum cost. The efforts which are being made to contain the production cost of crops through reducing the extent of tillage, enhancement of cropping system efficiency, utilization of integrated approaches in management of nutrients, water and weeds, and increase the farm mechanization keeping sustainability in mind. Among these measures, manipulation of tillage system by changing land configuration for planting and curtailing the extent of tillage operations works out to be important ones. The conservation and no-till systems not only contain soil erosion and restore organic carbon content in soil (Madari *et al.*, 2005; Write *et al.*, 2005), but also reduces cost of production. Moreover, the later is instrumental in providing sustainability to crop production. Although, the commercial cultivation of soybean in India is slightly more than four decades old, the crop has made a special niche in cropping systems of Central India, particularly in the area covered under Vertisols and associated soils. The major cropping systems in Central India are soybean-wheat (irrigated) and soybean-chickpea (rainfed). There is dearth of information on performance and sustainability of soybean-wheat and soybean-chickpea system under different tillage systems. Therefore, performance and sustainability of these two cropping systems with different tillage systems on Vertisols of Central India have been studied in present investigation.

MATERIAL AND METHODS

Two field experiments involving tillage and cropping systems (1995-2001) and tillage, fertility levels and cropping systems (2001-2006), each at a fixed site were conducted at research farm of Directorate of Soybean Research, Indore. For drawing conclusions on the effect of different tillage systems on the performance of soybean-wheat and soybean-chickpea, the data generated in said two experiments and to work out the trend analysis, stability and sustainability over the years was clubbed and presented in the text. The experimental soil belonged Haplusterts. It was analyzed for pH 7.86, EC 0.14 dS per m, organic carbon 0.30 per cent, available P_2O_5 4.80 kg/ha and available K_2O 298 kg/ha. The clubbed data for 10 years for three tillage systems *viz.*, zero, minimum (2 cross harrowing) and conventional (deep ploughing, 2 harrowing and planking) and two cropping systems i.e. soybean (JS 71 05) – followed by wheat (Sujata) and soybean (JS 71 05)- chickpea (JG 218) taking three replications was analyzed in strip plot design. All these crops were raised with respective recommended package of practices. The *rabi* crops received pre-sowing irrigation and two additional irrigations during crop growing period.

Sustainability index, stability and relative stability were estimated as per the procedure suggested by Singh *et al*. (1990), Finley and Wilkinson (1963) and Raun *et al.* (1993). Type of stability was decided on regression coefficient (b) and mean values. If 'b' is equal to unity, the treatment was considered to have average stability (same performance in all the environments). If 'b' more than unity, it was suggested to have less than average stability (good performance under favourable environments) and if 'b' was less than unity, it was reported to have more than average stability (good performance under poor environment). The trend analysis of yield over years was worked out as suggested by Dobermann *et al.*, (2000).

The economics of each treatment was calculated as per the prevailing prices of inputs and outputs. The energy budget of the treatments was determined by using the conversion factors for each inputs, outputs and cultural operations as suggested by Mittal and Dhawan (1988). Energy intensiveness (EI) and energy productivity (EP) were worked out as per Burnett (1982) and Fluck (1979).

RESULTS AND DISCUSSION

Soybean yield

Cumulative data over ten years (Table 1) on soybean-wheat and soybean-chick pea adapted to different intensities of tillage revealed that soybean cropped prior to wheat yielded marginally higher (2.3 %) than that cropped before chickpea. Soybean yields in case of soybean-wheat was maximum (1594 kg/ha) in minimum tillage, which was 0.6 per cent and 2.8 per cent higher than no-till and conventional tillage, respectively. In case of soybean-chickpea, maximum seed yield of soybean was in no-till (1562 kg/ha), which was 3.6 per cent and 0.8 per cent higher than minimum tillage and conventional tillage, respectively. This indicated that there were no perceptible differences between tillage systems implying that reducing the extent of tillage will be a potent shift to reduce the expenses on these cropping systems. The year to year variability in performance of soybean crop could be accounted for the variability in monsoon, its pattern and distribution. Higher sustainable yield index (SYI) values for soybean indicated that the soybean yields were more sustainable when grown before wheat rather than chickpea. Legume in rotation following cereal crops is considered to be of great help owing to their soil ameliorating benefits and attaining the sustainability (Gangwar and Prasad, 2005). In terms of SYI for tillage systems, the minimum tillage had an edge over no-till and conventional tillage with reference to sustainability (Table 5).

Trend analysis (Table 4) revealed that soybean yield increased linearly over the years under all the three tillage

Table 1. Influence of tillage systems on yield of soybean prior to wheat and chickpea (pooled data)

Year	Tillage system									Mean	
	No- till			Minimum			Conventional				
	S-W*	**S-C****	**Mean**	**S-W**	**S-C**	**Mean**	**S-W**	**S-C**	**Mean**	**S-W**	**S-C**
1995-96	2073	2000	2037	1404	1409	1407	1323	1706	1515	1600	1705
1996-97	393	170	282	366	299	333	514	451	483	424	307
1997-98	1752	1952	1852	1905	1886	1896	1871	1871	1871	1843	1903
1998-99	875	878	877	1071	963	1017	935	887	911	960	909
1999-00	1705	1364	1535	1738	1225	1483	1549	1387	1468	1664	1325
2000-01	637	553	595	818	726	772	580	529	555	678	603
2001-02	2371	2284	2328	2471	2327	2399	2458	2432	2445	2433	2348
2002-03	1584	2113	1849	1793	1711	1752	1808	1592	1700	1728	1805
2003-04	2557	2566	2562	2504	2765	2635	2580	2788	2684	2547	2706
2004-05	1893	1743	1818	1872	1770	1821	1885	1858	1872	1883	1790
Mean	**1584**	**1562**	**1574**	**1594**	**1508**	**1552**	**1550**	**1550**	**1550**	**1576**	**1540**

	SEm (±)	**CD (P = 0.05)**
Year	166.83	472.79
Tillage	91.76	258.96
Cropping system	74.60	220.09
Tillage x cropping system	129.22	369.32

** Soybean – wheat, ** Soybean - chickpea*

Table 2. Influence of tillage systems on yield of wheat and chickpea after soybean (Pooled data)

Year	Tillage system									Mean	
	No- till			Minimum			Conventional				
	S-W*	S-C**	Mean	S-W	S-C	Mean	S-W	S-C	Mean	S-W	S-C
1995-96	2685	1017	1851	2371	874	1623	2359	784	1572	2472	892
1996-97	2327	391	1359	2677	793	1735	2447	593	1520	2484	592
1997-98	1292	609	951	2165	804	1485	2035	884	1460	1831	766
1998-99	3421	468	1945	3717	942	2330	3534	619	2077	3557	676
1999-00	2925	1039	1982	3103	1208	2156	3249	1093	2171	3092	1113
2000-01	1628	569	1099	1998	718	1358	2000	719	1360	1875	669
2001-02	1537	825	1181	1807	925	1366	1486	922	1204	1610	891
2002-03	1147	926	1037	1204	951	1078	1227	936	1082	1193	938
2003-04	4105	2796	3451	4228	3025	3627	4264	2679	3472	4199	2833
2004-05	3185	1537	2361	4115	2041	3078	4488	2418	3453	3929	1999
Mean	**2425**	**1018**	**1722**	**2739**	**1228**	**1984**	**2709**	**1165**	**1937**	**2624**	**1137**

	SEm (±)	CD (P = 0.05)
Year	271.66	769.89
Tillage	148.79	421.69
Cropping system	121.49	358.40
Tillage x cropping system	210.43	601.41

** Soybean – wheat, ** Soybean – chickpea*

Table 3. Influence of tillage systems on system productivity (Soybean equivalent yield- pooled data)

Year	Tillage system									Mean	
	No- till			Minimum			Conventional				
	S-W*	S-C**	Mean	S-W	S-C	Mean	S-W	S-C	Mean	S-W	S-C
1995-96	4026	3248	3637	3128	2482	2805	3039	2668	2854	3398	2799
1996-97	2085	650	1368	2313	1272	1793	2294	1179	1137	2231	1034
1997-98	2692	2699	2696	3450	2873	3162	3351	2956	3154	3164	2843
1998-99	3363	1452	2408	3774	2119	2947	3505	1647	2576	3547	1739
1999-00	3832	2639	3236	3995	2708	3352	3912	2728	3320	3913	2692
2000-01	1821	1251	1536	2271	1607	1939	2034	1411	1723	2042	1423
2001-02	3489	3297	3393	3785	3462	3624	3539	3564	3552	3604	3441
2002-03	2418	3249	2834	2669	2878	2774	2700	2741	2721	2596	2956
2003-04	5542	5997	5770	5579	6478	6029	5681	6076	5879	5601	6184
2004-05	4209	3629	3919	4865	4275	4570	5149	4826	4988	4741	4243
Mean	**3348**	**2811**	**3080**	**3583**	**3015**	**3300**	**3520**	**2980**	**3190**	**3484**	**2935**

	SEm (±)	**CD (P = 0.05)**
Year	307.49	871.43
Tillage	168.42	477.30
Cropping system	137.51	405.67
Tillage x cropping system	238.18	680.72

***** *Soybean – wheat, ** Soybean – chickpea* systems. Irrespective of cropping system, the highest annual increment was recorded under minimum tillage (11.1 %) followed by conventional tillage (9.38 %) and no-till (6.80 %). Soybean yields under different cropping systems indicated that highest annual yield increment (10.60 %) seed yield was associated with minimum tillage in soybean–wheat system followed by no-till (8.36 %) and conventional tillage (6.79 %). In case of soybean–chickpea, it was maximum under no-till (12.20 %) followed by minimum tillage (9.90 %) and conventional tillage (9.83 %). The trend analysis flays the myth that continuous cropping of soybean over years reduces the performance of crops including soybean. On the contrary, placing legumes like soybean in cropping systems either under irrigated or rainfed regimes is beneficial.

Stability analysis (Table 5) indicated that the tillage systems provided more or less equal stability under favourable as well unfavourable environments, indicating that no-till ('b' = 0.990) and minimum till ('b' = 995) had an edge over conventional tillage ('b' = 981) for the cropping systems. The analysis also suggested that under no-till ('b' = 0.901) and conventional tillage ('b' = 0.912) soybean cropped prior to wheat cropping system performed well as compared to minimum tillage ('b' = 1.06) under unfavourable environment. Relative stability (Table 6) showed that productivity of soybean cropped prior to either wheat or chickpea was found relatively more stable in minimum ('b' = 0.059 and 0.069) and conventional tillage ('b' = 0.017 and 0.040) than no-till.

Table 4. Trend analysis of cropping systems under variable tillage systems

Treatment	No- till			Minimum tillage			Conventional		
	a	b	R^2	a	b	R^2	a	b	R^2
Soybean prior to wheat	6.768	0.084	0.167	6.668	0.106	0.299	6.868	0.068	0.169
Soybean prior to chickpea	6.462	0.122	0.189	6.660	0.099	0.281	6.681	0.098	0.277
Soybean	6.838	0.068	0.109	6.600	0.111	0.298	6.696	0.094	0.232
Wheat	7.645	0.012	0.006	7.759	0.016	0.015	7.687	0.025	0.030
Chickpea	6.067	0.125	0.421	6.389	0.102	0.401	6.194	0.132	0.584
Soybean equivalent yield (soybean-wheat)	7.861	0.037	0.103	7.878	0.049	0.247	7.806	0.057	0.283
Soybean equivalent yield (soybean-chickpea)	7.143	0.116	0.302	7.337	0.105	0.465	7.278	0.110	0.408

Table 5. Influence of tillage systems on sustainability of soybean-wheat and soybean-chickpea cropping systems (soybean, wheat and chickpea)

Year	Tillage system									Mean	
	No- till			Minimum			Conventional				
	S-W*	S-C*	Mean	S-W	S-C	Mean	S-W	S-C	Mean	S-W	S-C
Kharif (Soybean)											
Mean	1584	1562	1574	1594	1508	1552	1550	1550	1550	1576	1540
SD	690	782	736	652	705	679	679	725	702	674	737
CV (%)	43.56	50.69	47.13	40.90	46.72	43.81	43.80	46.74	45.27	42.75	47.56
SYI	0.35	0.30	0.33	0.38	0.29	0.34	0.34	0.30	0.32	0.36	0.30
b (Tillage)	0.901	1.079	0.990	1.067	0.923	0.995	0.912	1.049	0.981	0.982	1.167
Rabi(Wheat and chickpea)											
Mean	2425	1018	1722	2739	1228	1984	2709	1165	1937	2624	1137
SD	952	674	813	972	670	821	1067	709	888	997	684
CV (%)	39.25	66.22	52.74	35.48	56.97	46.23	39.41	60.88	50.15	36.05	61.36
SYI	0.36	0.12	024	0.42	0.18	0.30	0.37	0.17	0.27	0.38	0.16
b (Tillage)	0.448	0.710	0.579	1.314	1.208	1.261	1.194	1.051	1.12	1.000	0.999
Soybean equivalent yield (SEY)											
Mean	3348	2811	3080	3583	3015	3300	3520	2980	3190	3484	2935
SD	1072	1429	1198	1013	1415	1181	1101	1450	1330	1040	1412
CV (%)	32.02	50.85	38.89	28.28	46.92	35.80	31.27	48.67	41.69	29.84	48.10
SYI	0.41	0.23	0.33	0.46	0.25	0.35	0.43	0.25	0.32	0.44	0.25
b	0.999	1.000	0.757	1.181	1.099	1.171	1.003	0.999	1.001	0.999	1.000

****Soybean – wheat, ** Soybean – chickpea***

Wheat and chickpea yields

Both the *rabi* crops performed better under minimum tillage followed by conventional and no-till. As compared to no-till (wheat 2425 kg/ha; chick pea 1018 kg/ha), the conventional tillage and minimum tillage recorded 11.7 and 12.9 per cent higher yield of wheat and 14.4 and 20.6 per cent higher yield of chickpea, respectively (Table 2). The variation in productivity over years was higher in chick pea (CV = 61 %) than in wheat (CV = 38 %) irrespective of the tillage systems. SYI values also indicated that the wheat (0.38) was found more sustainable than chickpea (0.16). The maximum values were associated with minimum tillage (0.30) followed by conventional (0.27) and no-till (0.24) (Table 5). The above results are in conformity of findings of Billore *et al* (2005).

The trend analysis (Table 4) revealed a linear increase over experimental period with an average increment of 1.71 per cent irrespective of degree of tillage. The average yearly increment in yield was maximum with conventional (2.46 %) followed by minimum tillage (1.59 %) and no till (1.17 %), respectively. The fluctuation in yield data of wheat over years revealed that there has been steady increase in yield under minimum tillage (CV = 36 %) as compared to conventional (39 %/year) and no-till (39 %/year), thereby showing highest average yield of wheat under minimum tillage over years. Chickpea also a linear increase in yield over years (average yearly rate of increment – 12 %). Maximum rate of increase was under conventional tillage (13.2 %) followed by no-till (12.5 %) and minimum tillage (10.2 %).

Stability analysis (Table 5) revealed that both the *rabi* crops (wheat and chickpea) fared well under favourable conditions under minimum ('b' = 1.314 for wheat and 1.208 for chickpea) and conventional tillage ('b' = 1.194 and 1.051) systems where as it was just reverse under no-till system ('b' = 0.448 for wheat and 0.710 for chick pea). Relative stability values (Table 6) showed that no-till was relatively more stable than conservation and conventional tillage, respectively in wheat as well as in chickpea. Comparing wheat with chickpea irrespective of the tillage systems, the later was found relatively more stable in yield.

System productivity

Evaluation of cropping system productivity in terms of soybean equivalent yield (SEY) established the numerical superiority of minimum tillage (3300 kg/ha) over conventional (3190 kg/ha) and no-till (3080 kg/ha). For soybean-wheat and soybean-chickpea systems, the SEY of minimum and conventional tillage was higher (between 3 and 7%) than no-till (Table 3). Though increase in yield in both the cropping systems is marginal which probably, could be compensated by reduced cost on tillage operation leading to almost similar

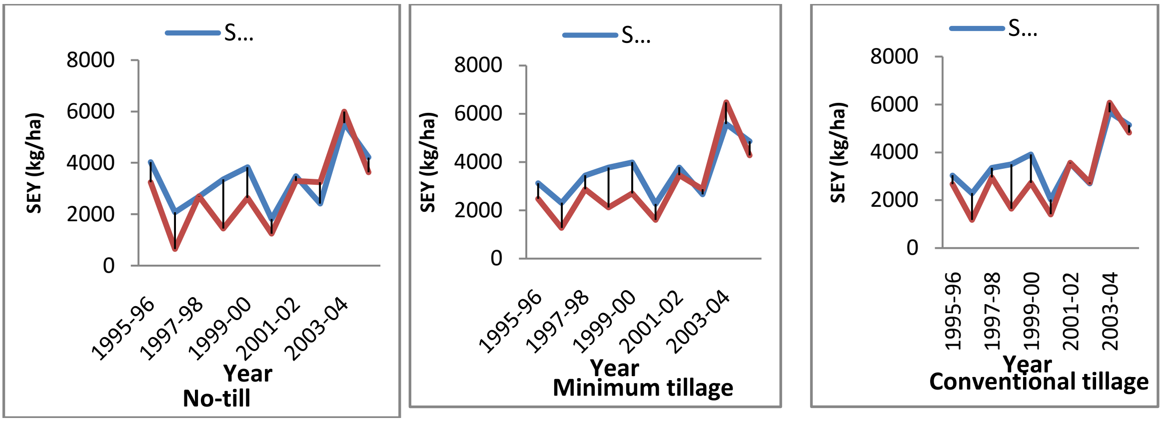

Fig.1. Effect of different tillage systems on total system productivity over years

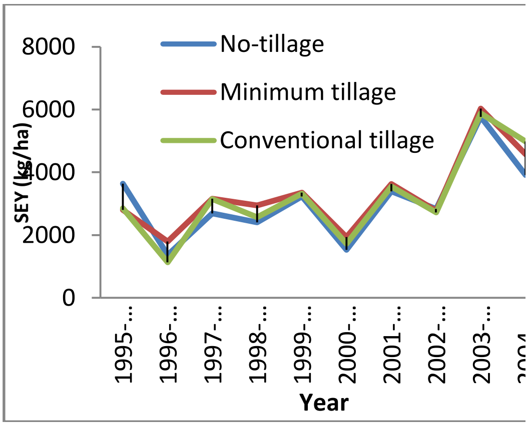

Fig. 2. Mean productivity of the system under different tillage systems

net profit. The productivity (SEY) of the two cropping systems soybean-wheat and soybean-chickpea followed the same trend under three tillage systems (Fig. 1 and 2). To start with the minimum tillage, it showed slight advantage in SEY. However, after five years the effect was not visible, but again in the tenth year the conventional tillage recorded slightly higher productivity as compared to no-tillage. The advantage appeared to be marginal that could be compensated by the cost incurred on tillage operations. The yearly variations in the productivity could be explained by the amount of intensity and the duration of precipitation received in that particular period/ year.

The variation under the tillage systems is not pronounced. This might be and on account of vertic (self ploughed) nature of experimental swell-shrink soils.

The trend in the productivity of soybean-wheat and soybean-chickpea was almost similar over the years; however, productivity of soybean-wheat remained marginally higher up to eight years, whereas soybean-chickpea system was found to be more productive in later two year. This could be because of the price variation of the commodity in the market. But it could be compensated by reduction in the cost of tillage operations.

Rating in terms of SYI brought out

that soybean-wheat (0.44) was comparatively more sustainable than soybean-chickpea (0.25) irrespective tillage systems. Minimum tillage (0.35) had an edge over conventional tillage (0.32) and no-till (0.33) as indicated by SYI values (Table 5). These results are in agreement with the findings of Billore *et al* (2005).

The trend analysis (Table 4) over years established the superiority of soybean-checkpea over soybean-wheat as the average annual increment in yield was more than double (10.0 %) in former than later (4.7 %). The maximum rate of annual increment of soybean–chickpea system was under no-till (11.6 %) followed by conventional (11.0 %) and minimum tillage (10.5 %). While in case of soybean–wheat, the rate of increment increased linearly with the increase in the frequency of tillage (from 3.7 to 5.7 %). Contrary to these observations, Singh *et al*. (2004), while working with rice-wheat rotation reported a declining trend in yield of rice and no change in trend in wheat over a period of time.

Stability analysis (Table 5) indicated that under no-till ('b'= 0.757), both the cropping systems performed better than minimum ('b' = 1.171) and conventional tillage ('b' = 1.001) under unfavourable conditions. No differentiation with respect to performance under variable environment could be discerned with respect to cropping systems. Relative stability analysis (Table 6) indicated that the no-till worked out to be more stable than minimum and conventional tillage and minimum tillage had better stability than conventional tillage. This indicated that the reduction in extent of tillage enhances the stability of the cropping systems. Soybean – wheat system in all the 3 tillage systems was found more stable than soybean- chickpea. It has been documented that no-till system has established itself as cost saving, yield boosting and environment friendly management option (Gangwar and Prasad, 2005).

Energy budgeting and economic evaluation

Cropping systems over tillage systems significantly influenced the energy budgeting (Table 7). Soybean-wheat cropping system required higher energy input as compared to soybean-chickpea. The resultant higher gross and net energy outputs were as well associated with the soybean-wheat as compared to soybean-chickpea. The calculated energy use efficiency (3.11), energy productivity (212 g/MJ) and energy intensivity (0.43 MJ/₹) was higher in soybean-chick pea than soybean-wheat on account of variations in energy input, productivity and sell price of output. Since, Gangwar *et al.,* (2003) have already reported that the soybean based cropping systems were distinctly better than other cropping systems, only soybean-based cropping systems have been compared here.

As regards energy requirement, the perceptible differences in tillage

Table 6. Relative stability of different treatments under various tillage systems

Treatment	b	R^2	Treatment	b	R^2
Soybean			***Soybean equivalent yield***		
S-W v/s S-C under No- till	-0.090	0.078	S-W v/s S-C under No till tillage	-0.153	0.209
S-W v/s S-C under Minimum tillage	-0.079	0.087	S-W v/s S-C under Minimum tillage	-0.334	0.337
S-W v/s S-C under Conventional tillage	-0.066	0.077	S-W v/s S-C under Conventional tillage	-0.271	0.317
S-W v/s S-C (Total)	-0.084	0.181	S-W – No till v/s Minimum tillage	0.069	0.053
Soybean after wheat			S-W – No till v/s Conventional tillage	-0.028	0.004
No till v/s Minimum tillage	0.059	0.025	S-W –Minimum v/s Conventional tillage	-0.095	0.188
No till v/s Conventional tillage	0.017	0.002	S-C – No till v/s Minimum tillage	0.0183	0.006
Minimum v/s Conventional tillage	-0.041	0.058	S-C – No till v/s Conventional tillage	-0.015	0.002
Soybean after chickpea			S-C –Minimum v/s Conventional tillage	-0.020	0.009
No till v/s Minimum tillage	0.069	0.040	No till v/s Minimum tillage	-0.0008	0.0000
No till v/s Conventional tillage	0.040	0.016	No till v/s Conventional tillage	-0.108	0.089
Minimum v/s Conventional tillage	-0.028	0.021	Minimum v/s Conventional tillage	-0.105	0.193
Wheat after soybean			***Chickpea after soybean***		
No till v/s Minimum tillage	-0.021	0.003	No till v/s Minimum tillage	-0.038	0.018
No till v/s Conventional tillage	-0.120	0.075	No till v/s Conventional tillage	-0.034	0.006
Minimum v/s Conventional tillage	-0.095	0.257	Minimum v/s Conventional tillage	0.005	0.0003

Table 7. Energy budgeting of cropping systems under different tillage systems

Energy indices	No-till			Minimum tillage			Conventional tillage			Mean		
	S-W	S-C	Mean	S-W	S-C	Mean	S-W	S-C	Mean	S-W	S-C	Mean
Energy input (MJ/ha)	18314	13135	15725	18897	13717	16307	23618	14770	19194	20276	13874	47202
Gross energy output (MJ/ha)	49216	41322	45276	52670	44321	48510	51744	43806	47775	51259	43145	47202
Net energy output (MJ/ha)	30902	28187	29551	33773	30604	32203	28126	29036	28581	30983	29271	30127
Energy Use Efficiency	2.69	3.15	2.88	2.79	3.23	2.97	2.19	3.19	2.49	2.53	3.11	2.82
Energy productivity (g/MJ)	182.81	214.01	195.87	189.60	219.80	202.36	149.04	201.76	169.32	171.98	211.55	191.77
Energy intensiveness (₹/MJ)	0.497	0.425	0.464	0.479	0.414	0.449	0.610	0.451	0.537	0.529	0.429	0.479

	Gross energy		Net energy		Energy use efficiency		Energy productivity		Energy intensiveness	
	SEm (±)	**CD** (P = 0.05)	**SEm (±)**	**CD** (P = 0.05)	**SEm (±)**	**CD** (P = 0.05)	**SEm (±)**	**CD** (P = 0.05)	**SEm (±)**	**CD** (P = 0.05)
Year	4532	12844	4440	12583	0.31	0.87	20.32	57.60	0.07	0.19
Tillage	2482	7035	2432	6892	0.17	0.48	11.13	31.55	0.04	0.10
Cropping system	2027	5979	1986	5858	0.14	0.40	9.09	26.81	0.03	0.09
Tillage x cropping system	3511	10033	3439	9829	0.24	0.68	15.74	44.99	0.05	0.15

Table 8. Economics of cropping systems under different tillage systems

Treatment	Gross returns (₹/ha)			Net returns (₹/ha)			Benefit cost ratio		
	S-W	S-C	Mean	S-W	S-C	Mean	S-W	S-C	Mean
No-till	36828	30921	33875	23267	17774	20521	2.72	2.35	2.54
Minimum tillage	39413	33165	36289	24852	19018	21935	2.71	2.34	2.53
Conven-tional tillage	38720	32780	35750	21159	15633	18396	2.20	1.91	2.06
Mean	38357	32285	35321	23129	17471	20300	2.52	2.18	2.35
		SEm (±)	**CD (P=0.05)**		**SEm (±)**	**CD (P=0.05)**		**SEm (±)**	**CD (P=0.05)**
Year		3382	9585		0.23	0.66		3381	9582
Tillage		1853	5250		0.13	0.36		1852	5248
Cropping system		1513	4462		0.10	0.31		1512	4461
Tillage x cropping system		2620	7488		0.18	0.52		2619	7485

systems over cropping sequences are concerned, logically conventional tillage required maximum energy input followed by minimum tillage and no-till. On the contrary, the gross and net energy output, energy use efficiency, energy productivity and energy intensiveness were with minimum tillage as compared to no-till and conventional tillage. Billore *et al.* (2005) have earlier documented that the conventional tillage is most energy intensive. The economic evaluation (Table 8) revealed that the values for gross and net returns (₹ 38357 and 23129/ha), and benefit: cost (B: C) ratio (2.52) were higher in soybean-wheat as compared to soybean-chickpea system. The gross returns from tillage systems over cropping systems showed that minimum tillage yielded marginally higher gross returns (₹ 36289/ha) than conventional tillage (₹ 35750/ha), whereas no-till (₹ 33875/ha) had the lowest value. Minimum tillage maintained its superiority in terms of net return (₹ 21935/ha) over no till (₹ 20521/ha) and conventional tillage (₹ 18396/ha). Benefit: cost ratio showed more or less same value for no till (2.54) and minimum tillage (2.53) and both were superior to conventional tillage (2.06).

Thus, soybean-wheat and soybean-chickpea systems are sustainable in Vertisols. To bring down the cost of cultivation, the farmers of the region can conveniently adopt minimum tillage to earn higher net profit by way of higher returns for each rupee invested.

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A Study on Farmers' Seed Replacement Rate of Soybean and Related Problems in Major Soybean Growing States

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ABSTRACT

The average national productivity of soybean has been hovering around 1.1 tons per ha during last few years. Unavailability of quality seed and poor seed replacement rate in major soybean growing states have been perceived to be a major constraint to achieve increased productivity levels. A study was, therefore, conducted in order to study the different issues associated with soybean seed and its replacement rate at farmers' level. The data was collected using structured interview schedule from 300 respondents belonging to major soybean growing states, namely Madhya Pradesh, Maharashtra and Rajasthan on proportionate basis. It was observed that among the 17 odd varieties grown by the farmers, soybean variety JS 335 is popular among majority of the farmers followed by newly released ones like JS 93-05, JS 95-60, and NRC 7, which are steadily making inroads in the farmers' field. It was interesting to note that because of unavailability of seed of new varieties and lack of knowledge about them, some old cultivars are still grown by the farmers of Madhya Pradesh. The efforts of State Seed Corporation of Maharashtra in fulfilling the certified seed to its farmers is worth welcome compared to rest of the states. The study revealed that more than 86 per cent of the Maharashtra farmers used certified seed for planting each year as compared to only 8 per cent in Madhya Pradesh and none in Rajasthan. Further, sources other than the primary extension agencies like input suppliers and fellow farmers are found to be major source of information related to arrival of new variety/seed availability. Unavailability of quality seed of required varieties is further documented to be a major problem for soybean growers of Madhya Pradesh and Rajasthan whereas farmers from Maharashtra are more concerned on other biotic aspects as State Seed Corporation is able to meet their seed requirement.

Keywords: Farmers, problems, seed, seed replacement, soybean, varieties

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Soybean is an important and premier oilseed crop of the country which was cultivated on all time high area of 10.29 million hectare during the year 2011-12 and is estimated to be producing nearly 12.57 million tons with an average productivity of 1221 kg per ha (DAC, 2011). The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh, of which first three states almost contribute about 90 per cent area (about 9.0 of total 10.13 M ha). The introduction of soybean during the late seventies and its commercial cultivation thereafter by the farmers of major soybean growing states have not only contributed enormously in order to meet out edible oil demand of the country, but also brought out desirable socio-economic changes in the farmers' lifestyle (Dupare *et al.*, 2008 and 2009).

Seed constitutes the most basic, important and expensive input for productive agriculture in case of all the crops. Seed system uses the appropriate combination of formal, informal, market and non-market channels to efficiently meet farmer's demand for quality seed. Farmers use different sources to meet his seed requirement (Ravinder Reddy *et al.*, 2007). In an agrarian based economy like India, majority of farmers have continued the practice of using their own produce as seed (farm saved seed) for the next season. The seed collected from produce is normally not of desired quality, and has telling effect on productivity of crops, particularly in soybean seed, which itself is a poor germinating entity. The use of poor quality of seed is considered to be one of the major constraints in enhancing the soybean productivity in the country which is showing an upward trend after hovering around one ton per ha during last few years. In view of above the present study was conducted to study in detail the seed related problems of farmers belonging to major soybean growing states.

MATERIAL AND METHODS

The present study was conducted in three leading soybean growing states of the country, namely Madhya Pradesh, Maharashtra and Rajasthan. The data for the study were gathered from the farmers belonging to major soybean growing districts representing different agro-ecological zones of the concerned state. A semi-structured interview schedule consisting on questions seeking information on seed related aspects was formulated initially and was utilized after pre-testing on a limited scale with the farmers of Madhya Pradesh. The same was used to collect data from the farmers. In all, 300 respondents were included in the study with the proportionate sample of 160 farmers from Madhya Pradesh (Indore, Ujjain, Dhar, Dewas, Khargone, Badwani, Shajapur, Hoshangabad, Betul, Chhindwara), 110 farmers from Maharashta (Nagpur, Wardha, Amaravti, Akola, Buldhana, Aurangabad, Parbhani, Beed, Nanded, Latur, Satara, Sangli, Kolhapur and Pune) and 30 farmers from

Rajasthan (Kota, Jhalawad and Bundi). The information so collected was coded, collated, scored and analyzed using simple statistical tools like frequency and percentages after undertaking content analysis.

RESULTS AND DISCUSSION

Soybean varieties grown by the farmers

Although released as early as in 1994, JS 335 still continued to be a most popular variety among farmers belonging to the three states. The variety JS 93-05, followed the suit, but more popular in Madhya Pradesh as compared to other two states. A recently released (2006), extra-early maturing variety, JS 95-60 is gaining popularity in the state of Madhya Pradesh followed by Rajasthan. The exhibited wider adoptability, good germinability, and consistency in performance of JS 335 places this variety as preferred choice for the farmers of Maharashtra and cent percent farmers grow it. In addition, varieties like JS 93-05, is being grown by sizeable number of farmers. On probe, it was observed that this variety is sold by the input dealers in the name of Surabhi too. Some of the varieties released by Marathwada Agricultural University (MAUS 71 and 81), and Agharkar Research Institute (MACS 450 and 124) are in cultivation to a limited extent, particularly in the neighboring villages. It is worth mentioning here that there is a very strong network of seed outlets (both public and private), which are producing seeds of the popular varieties in plenty and making it available to the farmers.

In the soya-state of Madhya Pradesh, comparatively larger number of varieties is being cultivated by the farmers. Although, the variety JS 335 still preferred by 40 per cent farmers of the state, the later short maturity duration introductions like NRC 7, JS 93-05 and JS 95-60 have made inroads in sizable area. The variety JS 97-52, although of longer maturity duration, was preferred for cultivation by the farmers due to its suitability in high rainfall or high soil moisture conditions. However, it is quite interesting to see the presence of very old varieties like JS 71-05, PK 1044, Ankur and JS 72-44 in farmers' fields in spite of not being present in the seed chain. It is worth mentioning that in the absence of harmony between the PPV and FR Act 2001, Bidiversity Act 2002 and the existing Seed Act, 1966, a good number of varieties (Anamika, BS 2, Gold 301, Star 111, Delta, Surabhi) not released by the formal system, are grown by the farmers in sizable area. Since these varieties are not in seed chain, are being multiplied by farmers at their own level and utilized for next sowing or making it available to other farmers. In the absence of knowledge to maintain purity and retain quality during production and storage, the seed of these varieties is of poor quality limiting yield levels. Almost similar is the tendency of soybean farmers in Rajasthan (Table 1).

Table 1. Soybean varieties grown by the farmers

State	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
Anamika*	-	21 (13.12)	-	21 (7.00)
JS 335	110 (100.00)	65 (40.62)	17 (56.66)	192 (64.00)
Sonia*	-	11 (6.87)	-	11 (3.66)
DS 228	2 (1.81)	-	-	2 (0.66)
BS2*	-	5 (3.12)	-	5 (1.66)
NRC7	-	21 (13.12)	-	2 (0.66)
PK 1044	-	11 (6.87)	-	11 (3.66)
JS 71-05	-	9 (5.62)	-	9 (3.00)
JS 93 05	14 (12.72)	58 (36.25)	8 (26.66)	80 (26.66)
JS 95 60	-	10 (6.25)	5 (16.66)	15 (5.00)
Gold 301*, Star 111*, Delta*, Ankur	-	4 (0.62)	-	4 (1.33)
Surabhi*	4 (3.63)	-	-	4 (1.33)
JS 72 44	-	12 (7.50)	-	12 (4.00)
JS 97 52	-	9 (5.62)	-	9 (3.00)
KHB441, MACS 450, MACS 124	3 (2.72)	-	-	3 (1.00)
MAUS 71	6 (5.45)	-	-	6 (2.00)
MAUS 81	3 (02.72)	-	-	3 (1.00)

**Varieties of common knowledge which are not released by the formal system; Figures in parentheses indicate percentages*

Source/availability of seed

The multiple choice responses of the respondents on sources of seed (Table 2) brings out that Maharashtra is the leading state to use certified seed by the farmers as about 76 per cent of the requirement is met by Mahabeej (Maharashtra State Seed Corporation), 5 per cent by Cooperative Societies and 4 per cent by University/Research Stations. Remaining 15 per cent of seed requirement is met from farm saved seed (10 %) and from progressive farmers (5 %). On the contrary in Madhya Pradesh, only 22 per cent farmers obtain certified seed (Seed Corporations – 9 %, Cooperative societies – 11 % and University/Research Station- 2 %). The major source of seed is being farm saved (54 %), followed by purchase from neighbour (18 %) and from progressive farmers (7.5 %). Only 5 per cent farmers meet their seed requirement

Table 2. Sources of seed available to the farmers

Source	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
Farm saved seed	12 (10.90)	86 (53.75)	30 (100.0)	128 (42.66)
Progressive farmer	6 (5.45)	12 (7.50)	11 (36.66)	29 (9.66)
Relative	0 (0.00)	2 (1.25)	3 (10.00)	5 (1.66)
Neighbor	0 (0.00)	29 (18.12)	2 (6.66)	31 (10.33)
Seed corporations	84 (76.36)	14 (8.75)	8 (26.66)	106 (35.33)
Private seed companies	26 (23.63)	8 (5.00)	0 (0.00)	34 (11.33)
Cooperative societies	6 (5.45)	17 (10.62)	0 (0.00)	23 (7.66)
SAUs/Research stations	4 (3.63)	3 (1.87)	5 (16.66)	12 (4.00)

Figures in parentheses indicate percentages

Table 3. Seed replacement rate of soybean farmers

Frequency of seed replacement	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
Every year	95 (86.36)	8 (5.00)	0 (0.00)	103 (34.33)
After 2 year	8 (7.27)	32 (20.00)	8 (26.66)	48 (16.00)
After 3 yrs	5 (4.54)	48 (30.00)	7 (23.33)	60 (20.00)
After 4 years	2 (1.81)	28 (17.50)	12 (40.00)	42 (14.00)
After 5 years	0 (0.00)	44 (27.50)	3 (10.00)	47 (15.67)

Figures in parentheses indicate percentages

from private seed companies. Logically, the higher use of certified seed in Maharashtra keeps the average state productivity higher as compared to other two major states Moreover, although substantial quantity of soybean seed is produced by the seed companies located at Indore and around, it is sold in Maharashtra or other states. The status of Rajasthan in this respect is still not encouraging as 100 per cent farmers use their own farm saved seed and the other sources utilized for quality seed are limited (Seed corporations – 27 % and University/Research farms – 17 %). The average yield performance of these three states is in line with the proportion of certified/quality seed utilized.

Seed replacement pattern

The information gathered on frequency of seed replacement with certified/foundation seed by the respondent farmers in the three targeted states (Table 3) presents an eye opening picture. The survey revealed that more than 86 per cent of the Maharashtra farmers used certified seed for planting each year as compared to 8 per cent in Madhya Pradesh and none in Rajasthan. Based on their past experience, the farmers of Maharashtra believe that their farm saved seed is poor in germination leading to sub-optimal plant population, it is unhealthy and under size to fight against biotic and abiotic stresses, and prefer to replace seed each year as it is easy and convenient and adequate availability of certified seed at their doorsteps by the Seed Corporations/Cooperatives and Sugar factories in the localities. The last agency is said to supply the seed free of cost. Rest of the farmers who were identified to be seed producer for State Seed Cooperative/Seed Companies are technically sound to manage seed vigour but still replace their seed within 2-3 years. No such efforts and awareness exists in other two states. Overall seed replacement of 34 per cent annually on an average is misleading as do not reflect the skewed seed replacement rate in different states.

On the contrary, majority of soybean growers from Madhya Pradesh and Rajasthan which contribute nearly 62 per cent area, do not replace their seed with certified seed on annual basis. A sizable number of farmers in these two states are not able to replace their seed even after 4-5 years. Although awareness on quality seed exists and there is willingness to purchase at higher prices, the certified seed of desired variety in required quantity is not available to them. The altered weather conditions coupled with early withdrawal of monsoon during past one decade on account of global climatic change, farmers are inclined to grow early maturing varieties. The State Seeds Corporation, Madhya Pradesh is making certified seed of JS 335 available in bulk, whereas the demand for short

Table 4. Source of information about new varieties

Information source	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
Krishi Vigyan Kendra	11 (10.00)	2 (1.25)	5 (16.66)	18 (16.00)
Department of Agrilculture	18 (16.36)	15 (9.37)	8 (26.66)	41 (13.66)
Input supplying agency	86 (78.18)	15 (9.37)	7 (23.33)	108 (36.00)
Progressive farmer	3 (2.72)	2 (1.25)	4 (13.33)	9 (3.00)
Agricultural Assistant/ Gram Sewak	5 (4.54)	9 (5.62)	3 (10.00)	17 (5.66)
Agricultural Research Station	39 (35.45)	4 (2.50)	2 (6.66)	45 (15.00)
TV/Newspaper	4 (3.63)	0 (0.00)	2 (6.66)	6 (2.00)
Interaction among farmers	15 (13.63)	58 (52.72)	6 (20.00)	79 (26.33)
Seed Corporation	0 (0.00)	4 (2.50)	0 (0.00)	4 (1.33)
Neighbor/Relative	0 (0.00)	30 (18.75)	4 (13.33)	34 (11.33)

Figures in parentheses indicate percentages duration varieties like JS 93-05, JS 95-60 and NRC 7 is more among farmers. As far as the seed sector is concerned, there appears to be missing harmony between public-private-growers leading to lower seed replacement rate in other states than Maharashtra, thereby affecting national productivity.

Information Sources utilized by the farmers

The respondent farmers attempts to get information about new varieties from multiple sources. It is unpleasant to learn that in Maharashtra, farmers have better contacts with input supplying agencies rather than State Department of Agriculture/ Agricultural Assistant / Gram Sewak, which should have been the primary agency to provide information. More faith to seek information is disposed on the Agricultural Research Stations followed by interaction among farmers. In Madhya Pradesh, the interaction among farmers turned out to be the major information source followed by flow of information from neighbour/relative, State Department of Agriculture/ Agricultural Assistant/Gram Sewak and input supplying agencies in that order. In Rajasthan, the formal system, State Department of Agriculture/ Agricultural Assistant/Gram Sewak constitute main source for providing information followed by input supplying agency, interaction among farmers, Krishi Vigyan

Table 5. Seed related problems

Problem	Maharashtra (n=110)	Madhya Pradesh (n=160)	Rajasthan (n=30)	Total (N= 300)
Unavailability of seed	7 (6.36)	92 (57.50)	12 (40.00)	111 (37.00)
Unavailability of new variety	5 (4.54)	27 (16.87)	7 (23.33)	39 (13.00)
Poor quality/undersize seed	0 (0.00)	34 (21.25)	8 (26.66)	42 (14.00)
Lack of information on new varieties	0 (0.00)	13 (8.12)	14 (46.66)	27 (9.00)
Poor germination	0 (0.00)	30 (18.75)	0 (0.00)	30 (10.00)
Other Problems				
Management of *Spodoptera litura*	33 (30.00)	0 (0.00)	15 (50.00)	48 (16.00)
Weed management	26 (23.63)	39 (24.37)	3 (10.00)	68 (22.66)
Insect attack (semilooper, girdle beetle, tobacco caterpillar)	0 (0.00)	57 (35.62)	12 (40.00)	69 (23.00)
Disease (YMV)	0 (0.00)	26 (16.25)	18 (60.00)	44 (14.66)
Lack of knowledge about package of practices	0 (0.00)	48 (30.00)	6 (20.00)	54 (18.00)

Figures in parentheses indicate percentages

Kendras and progressive farmers. This brings out that there is an urgent need to look into the functioning of State Department of Agriculture functionaries, which should be largely responsible for dissemination of information. There is need to look into proper functioning of Krishi Vigyan Kendras also, which are supposed to play the role of information centres.

Seed related and other constraints

The data related to seed related problems faced by the farmers of major soybean growing states (Table 5) revealed that farmers of Maharashtra do not face the issue of non-availability of quality seed as the Maharashtra State Seed Corporation is capable of supplying the required quantity of soybean seed to meet their needs. Instead, farmers of Maharashtra were more worried on yield erosion due to weeds and management of insect-pests, particularly that of *Spodoptera litura*. On the contrary, seed related constraints (unavailability of required quantity of seed, unavailability of seed of new varieties, poor quality/undersize seed and lack of information on newer varieties) along with management of insect-pests (semilooper, girdle beetle, tobacco caterpillar), disease (YMV) and lack of knowledge on production package constitute major flaws in Madhya Pradesh and Rajasthan.

From the aspects discussed above, it is imperative to promote varietal diversification in the soybean growing states for increasing the productivity of soybean in major soybean growing states of India,. Further, the constraints related to availability of quality seed in some of the states needs to be addressed by the appropriate institutions through popular seed outlets. The low seed replacement rate at farmers' level in the soy-state of Madhya Pradesh and Rajasthan is needed to be increased in order to harness the production potential of this golden bean. The state extension machinery should also take necessary steps to impart necessary skills to farmers in order to produce soybean crop for the quality seed purpose.

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Yield Performance of Soybean in Vindhyan Plateau of Madhya Pradesh

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ABSTRACT

Demonstrations on improved production technology for soybean were organized on the farmers' field of Sehore districts under Vindhyan plateau agro-climatic zone of Madhya Pradesh for consecutive four years (2007-08 to 2010-11). Results showed that by adoption of improved production technology by the farmers led to increase in average yield by 18.2 per cent and net returns by 31.6 per cent over farmers' practice (1,320 kg/ha and ₹11,358/ha). The cost benefit ratio for improved practice worked out between 1:1.9 and 1:2.0 in case of adoption of improved module as compared to 1:1.7 and 1.8 in farmers' practice.

Key words: B: C ratio, relative spread index, technology gap, technology index, yield

Soybean is a predominant *kharif* crop of Madhya Pradesh. Sehore is one of the key district devoting 3, 25, 421 hectares (Districts Statistics Book, 2010) area under the crop of 55, 00, 193 ha under soybean cultivation in Madhya Pradesh (Agrawal *et al*., 2010). Current productivity of the crop in the district is 1, 360 kg per ha as against national productivity of 1, 089 kg per ha, which is low as compared to its potential yield in the experimental station (Kumar, 1997). Some of the crucial factors for realized low productivity are inadequate and imbalanced nutrient management devoid of integrated approach, and poor management of weeds and insect-pests. Although research emanated production technology has already been developed, yet could not effectively reach to the farmers. Organization of demonstration is one of the most effective extension techniques to persuade the farmers on adoption of improved technology. The present investigation deals with demonstration of a module with key production practices to convince the farmers of its advantages and popularize among them.

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MATERIAL AND METHODS

A total of 52 demonstrations (13 each year covering 5 ha) were organized in the adopted villages, namely Dhablamata, Amlaramjipura, Bheelkhedi and Rola of Sehore district of Madhya Pradesh during *kharif* seasons of consecutive four years (2007-08 to 2010-11) in the selected farmer's fields. For the selection of farmers to conduct the demonstrations, a farmers' group meeting was convened each year and the receptive and innovative farmers were selected. The module of improved practices demonstrated included use of balanced dose of fertilizers (20:60:20 N: P205:K2O kg/ha) after adjustment with soil test values, use of disease resistant variety and seed treatment with fungicide (carbendazime and thiaram @ 2 + 1 g/kg seed) and seed inoculation with *Bradyrhizobium japonicum* and phosphorus solubilizing bacteria (PSB) @ 5 g per kg seeds each and one spray of carbendazime (0.1 %) and endosulphon (0.07 %) at pod initiation stage. The performance of the crop under module was compared with the farmers' practice in the same location. The farmers practice included use of 50 kg diammonium phosphate per ha, use of higher seed rate (125 kg/ha) and seed sown without seed treatment with fungicides and inoculation with *Bradyrhizobium japonicum and PSB*. The soil of demonstrations fields belonged to Vertisols.

The soybean crop was sown between second and last week of June and harvested in last week of September to first week of October The seed rate for variety JS 95-60 and JS 93-05 used was 87 kg and 75 kg per ha. Soil test based tailored NPK fertilization was done as basal. The crop was protected from insect-pests and diseases as per recommendations. The observations on incidence of Rhizoctonia blight and unfilled pods by stem-fly infestation were taken at five places by randomly placing a quadrate in each demonstration and on selected five plants from each quadrate at pod initiation stage. The per cent damage by Rhizoctonia blight (No. of damaged plants/No. of plants observed × 100) and damaged pods (No. of damage pod per plant/Total No. of pods per plant observed × 100) was worked out. The yield data from each demonstration and farmer's crop was collected after harvesting the crop. Five plants were randomly selected from each quadrate, thus from each demonstration 25 plants were drawn for recording the observations on yield parameter such as pods per plant. A sample of 100 seeds was drawn and weighed to record the seed index.

For economic evaluation in term of grass and net returns and cost benefit ratio, the prevailing rates for input, labour and produce was utilized.

The technology gap, extension gap and technology index (Samui *et al.*, 2000) and relative spreading indexes (Lanka, 1999) were worked..

A comprehensive questionaire was developed for the collection of data through rural agricultural extension officers (RAEO) regarding horizontal spread of both varieties in the study area. The questionnaire was pre-tested before actually conducting the interviews of the beneficiaries.

Extension gap	=	Demonstration yield - Farmers yield
Technology gap	=	Potential yield – Demonstration yield
Technology index	=	(Potential yield – Demonstration yield)/ Potential yield × 100
Relative spread index	=	Area of soybean crop expressed as per cent of total cultivated area of the district/Area of the crop expressed as per cent of total cultivated crop area in districts × 100

RESULTS AND DISCUSSION

Yield

Adoption of module of improved technology remarkably increased (16.8 to 20.7 %) the seeds yield of soybean over farmers' practice during the span of four years of demonstrations. On an average basis, irrespective of variety and seasonal variations, the average yield achieved under module was 1, 560 kg per ha as compared to that of 1, 320 kg per hectare under farmer's practice, which was 18.38 per cent higher. Although the potential yield of the two varieties (JS 93-05 and JS 95-60) is higher than the productivity achieved under real field conditions using the module (Table 1). This is in agreement with the suggestion of Cassman (1999), who reported that even cereals under best production systems can perform to the maximum extent of 80 per cent of potential productivity under real field conditions. The very reason for improved productivity through the tested module appears to be soil test based balanced and integrated approach involving fertilizers and bio- fertilizers which play a vital role in making available N, P and K as per plant needs (Gautam and Pant, 2002 and Pauline *et al.,* 2010). The results clearly indicated the impact of FLDs over the existing practices towards enhancing the yield of soybean in Sehore district (Madhya Pradesh) as an cumulative effect of yield attributes namely number of pods per plant (19.9) and seed index (11.3 g/100 seeds) under recommended practices as compared to farmers' practices (16.3 and 11.2 g/100 seeds, respectively). The year-

Table 1. Effect of module on improved production technology on yield and yield attributes in 52 demonstrations (thirteen each year)

Year	Variety	Yield Potential (kg/ha)	Plant population(No/m²)		Pods (No/plant)		Seed index (g/100 seeds)		Yield (kg/ha)	
			RM	FP	RM	FP	RM	FP	RM	FP
2007-08	JS 9305	2000-2300	36.5	39.0	19.0	15.0	10.9	10.8	1460	1250
2008-09	JS 9305	2000-2300	38.0	39.0	19.0	15.5	10.9	10.8	1520	1280
2009-10	JS 9560	1800-2000	38.0	36.0	18.5	16.5	11.7	11.5	1480	1260
2010-11	JS 9560	1800-2000	38.0	39.5	23.0	18.0	11.7	11.6	1810	1500
Average			**37.6**	**38.4**	**19.9**	**16.3**	**113**	**11.2**	**1560**	**1320**

RM – Recommended module; FP – Farmer's practice

to-year fluctuations in yield can be explained on the basis of variations in microclimatic condition of that particular village. The yield increase with the module under the farming situation of demonstration area is likely to be effective in area with similar microclimate. Mukherjee (2003) has also opined that depending on identification and use of farming situation, specific interventions may have greater implications in enhancing systems productivity. Yield enhancement in different crops in front line demonstration has amply been documented by Tiwari *et al.* (2003) and Tomer *et al*. (2003).

Economic evaluation

The cost of cultivation in demonstrations was comparatively higher (INR 14, 000 to 15, 500) as compared to farmer's practice (INR 12, 500 to 14, 600) on account of additional input provided in the demonstration. The gross returns (INR 26, 000 to 34, 295) and net returns (INR 12, 000 to 18, 795) were derived from demonstrations as compared to farmer's practices (INR 22, 500 to 28, 300) and net returns (INR 10, 000 to 13, 700). On average basis, the increase in net returns from adaptation of improved production module was 31.56 per cent over farmer's practice (Table 2). The benefit cost ratio was accordingly reflected for demonstrations (1:1.9 to 1:2.0) and farmer's practice (1:1.7 to 1:1.8). Year to year variations in cost of cultivation was on account of variability in cost of inputs and that of produce. The result suggests economic viability and agronomic feasibility of demonstrated module in soybean cultivation. The observed results are in conformity of findings reported by Siddique *et al*. (2004), Deshmukh *et al.* (2005) and Jain and Trivedi (2006).

Extension and technology gap and technology index

The variability technology gap (190 to 1, 040 kg/ha; average 683 kg/ha), which indicated lower exploitation of varietal potential, which might not have been feasible on account of variable and less favourable climate and deficit in crop management (Table 3). The extension gap varied between 210 to 310 kg per ha

Table 2. Economic evaluation of adaptation of module on improved production technology

Year	Cost of cultivation (INR /ha)		Grass returns (INR /ha)		Net returns (INR /ha)		B:C ratio	
	RM	FP	RM	FP	RM	FP	RM	FP
2007-08	14000	12500	26000	22500	12000	10000	1:1.9	1:1.8
2008-09	14500	13000	28880	24132	14380	11320	1:2.0	1:1.8
2009-10	15500	14600	30100	25200	14600	10600	1:1.9	1:1.7
2010-11	15500	14600	34295	28300	18795	13700	1:2.0	1:1.8
Average	14875	13675	29819	25033	14943	11358		

RM – Recommended module; FP – Farmer's practice

Table 3. Extension gap, technology gap and technology index

Year	Technology gap (kg/ha)	Extension gap (kg/ha)	Technology Index (%)
2007-08	1040	210	32.1
2008-09	980	240	29.3
2009-10	520	220	35.1
2010-11	190	310	9.5
Average	683	245	

(average 245 kg/ha) indicating the need for popularizing and adaptation of improved technology by the farmers. The technology index indicating the inverse relation with feasibility of technology varied between 9.5 and 35.1 per cent. Although, the fluctuation and uncertainty of prevailing climate regulates the feasibility, the reduction in technology index to 9.5 is good indicator of increased feasibility of suggested production module in these demonstrations and can be adopted by the farmers of the region. Similar results were reported by Sagar and Chandra (2004).

Disease incidence

The data recorded on plants infested with Rhizoctonia blight caused by (*Rhizoctonia soloni*) revealed lower infestation in crop under demonstrations as compared to farmer's practice. On an average basis only 5.1 plants per square meter showed wilting symptoms in demonstration as compared to 7.8 plants per square meter in farmers practice. Percentage of damaged plant was only 12.2 in demonstration *vis a vis* 16.1 in farmer's practice (Table 4). This indicated that seed treatment with fungicides (thiram and carbendazim) and spray of carbendazim must have been influential. This observation gets the support the work of other workers (Maunio *et al*., 2006 and Jatender *et al.,* 2006), who reported that thiram alone and in combination with carbendazim is highly effective inhibiting mycelia and fungal germ tube growth of

Table 4 Impact of imparted module on pest and diseases incidence

Year	Wilt affected plants (No/m²)		Damage (%)		Shading of premature pods (No/plant)		Damage (%)	
	RM	FP	RM	FP	RM	FP	RM	FP
2007-08	4.5	7.0	10.9	15.2	6	10	24.1	40.0
2008-09	6.0	9.0	14.3	15.2	5	9	20.8	36.7
2009-10	5.0	8.0	11.9	18.2	5	**8**	21.2	32.6
2010-11	5.0	7.5	11.6	15.9	4	6	15.1	18.2
Average	5.1	7.8	12.2	16.1	5	8.3	20.3	31.8

RM – Recommended module; FP – Farmer's practice

the pathogen and in reducing Rhizoctonia blight incidence and increased seed yield.

Insect pest infestation

Infestation of stem-fly (*Melanagrousmyza sajae*) in soybean leads premature shading of pods. Spraying of endosulfon @ 0.07 per cent at flowering and pod initiation stage reduced the premature shading by 33.8 per cent as compared to farmers practice (Table 4). Similar observations were reported by Bagle and Verma (1990), Parsai *et al.*, (1991) and Savajji (2006).

Horizontal spread of the demonstrated technology

During 2007- 08 to 2010-11, the total horizontal spread of the module increased seven times (from 4 500 to 28 700 ha) with lesser change in cropped area under soybean cultivation in Sehore district. There has been remarkable increase in coverage of the two varieties. It was noted that during 2007-08 to 2010-11 with the increasing area (10.1 %) under the two varieties, the relative spread index was also increased. These two varieties dominated from the point of view of adoption and productivity in the Sehore district. The adoption of soybean varieties namely, JS 95-60 and JS 93-05 along with suggested module by the farmers can improve their productivity with decreased cost.

Impact of technology

The mean yield of 52 FLDs conducted has exhibited 16.8 - 20.6 per cent increase seed yield of soybean at different locations against farmer's practice, which was primarily due to release of high yielding and disease resistant varieties and adoption of improved technology module. The assessment of horizontal spread of the technology amounted to its spread in 28, 700 ha over four years providing additional yield of 6, 888 tons. It was possibly a result of effective dissemination of evaluated module among practicing farmers and input by RAEOs in terms of field oriented activities involving training programmes, personal motivation and provision of literature on package and practices of soybean crop.

The demonstrations conducted for consistently four years pointed out that

Table 5. Horizontal spread of improved technology in farming community

Year	Horizontal spread of module (000 ha)	*Kharif* area (000 ha) of the districts	Soybean area in the districts (000ha)	Per cent area covered by soybean in the districts	Per cent area under variety	Relative spread index
2007-08	4.5	304.6	265.8	87.2	1.6	1.8
2008-09	14.5	311.0	284.5	91.4	5.0	5.4
2009-10	21.6	309.0	282.5	91.2	7.6	8.3
2010-11	28.7	314.8	284.5	90.3	10.1	11.2

these can serve as an effective tool for transfer of improved technology culminating in enhanced yield of soybean in the demonstration area and also area with similar microclimate. The module demonstrated is economically viable and agronomically feasible.

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Assessment of Improved Weeding Technology for Reducing Drudgery of Farm Women while Weeding Soybean Crop

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The contribution of women farmer to the Indian agriculture is unparallel as they are accomplishing arduous field operation using traditional tools and gadgets along with household chores. These implements are not only the source of drudgery but also a major cause of low efficiency and output. AICRP on Home Science (1996-2001) conducted a study to find out the drudgery prone activities performed by women in the areas of farm, allied and home and it was observed that transplanting, cutting/uprooting and weeding activities were performed primarily by women. The time spent and difficulties experienced were also found high in these farm activities involving maximum drudgery. Another study quoted by Sadangi and Pattanaik (2006) also reported that, farm operations like weeding, cutting and carrying harvested crop were the moderately heavy activities. For minimizing the drudgery involved in any of such activities, would require introduction and adoption of labour saving and drudgery reducing technologies enabling rural-women to participate more energetically with increased efficiency. According to Kulkarni and Gite (2009), the experimental studies of ergonomical characteristic gives information on capacity of person to work at different comfort levels and includes anthropometric data, muscular strength and maximum aerobic capacity. Hence, ergonomic study for minimizing the drudgery involved in the activities and to address adequately the realities of these rural women life and to assist them in obtaining equal access to resources and farm technologies is very much important. Keeping all these ergonomical views, the present comparative study was carried out to assess the perceived exertion and body discomfort of the working women for assessing the muscular stress involved in the activity and to assess the heart beat rate and energy expenditure of working farm women.

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For the present study, randomly 20 women were exclusively selected from adopted cluster area (villages Jalalkhedi and Akasoda) of District Ujjain (Madhya Pradesh).

For analysis of the comparative study between existing tool (*khurapi*) and improved tool (twin wheel hand hoe weeder) while performing the weeding activity in *kharif* crop- soybean and the following parameters were studied. General information about the respondent was collected and analysed.

***Rate of perceived exertion (RPE)*:** RPE was assessed by using the five point scale from very light to very heavy and at three periods, i.e. resting, working and recovery. The score of the scale was – very light (1), light (2), neutral (3), heavy (4), and very heavy (5).

***Muscular stress*:** Specially designed body map was used for assessing the body discomfort. The body map where all the body parts were denoted was shown to all the respondents and the assessed responses of the questions were recorded on five point scale basis with score of scale, very mild (1), mild (2), neutral (3), severe (4) and very Severe (5).

Heart beat rate: Heart beat rate per minute were counted down for resting (before) and recovery (after) period while performing the weeding activity in soybean. Digital apparatus (Acon, Acon Laboratories Inc.) automatic blood pressure monitor, REF OB 11-11 was used for collecting the data. On that equipment not only heart beat rate, but blood pressure (systolic and diastolic) in mm Hg was also recorded.

Energy expenditure: Based on heart beat rate, the energy expenditure was calculated using the formula given by Varghese *et al*. (1994).

EE (Kj/min) = 0.159 x Heart beat rate (beats/min) - 8.72

Constraints: Constraints of the improved tool was also studied in the form of feed back of the respondents.

Drudgery Index: Drudgery index was calculated by using the following formula given by (Anonymous, 1998-99)

X + Y + Z / 3 *100

Where X = co-efficient of time, Y = co-efficient of degree of difficulty, and Z= co-efficient of frequency of performance

All the respondents were married and were in the age group of 25 to 40 years, weighed between 37 and 45 kg and were 140-153 cm tall. None of the respondent was suffering from any chronic illness and all were physically fit.

Comparison between existing and improved method was studied in terms of body discomfort in terms of muscular stress. The percentages were drawn as per the response received from the respondents. The consequences of the two methods of weeding under study also brought out that various body parts were affected considerably by execution of weeding operation by *khurapi* rather than by two wheeled hoe (Table 1). Majority of respondents reported severe to very severe pain in body parts in former method and the trend was just reverse in later. Very severe impact on cervical point (80 %), knee (80 %), lumber point (75 %), thigh (75 %), neck (60 %) and feet (50 %) was noted in respondents while using *khurapi*. On the contrary, only 10 per cent experienced pain on cervical point and lumber point, 5 per cent on neck and no pain in thigh and knee when twin wheeled hoe was used. Discomfort in wrist was severe with *khurpi* (70 %), which was just 30 per cent in two wheeled hoe. Only 40 per cent of respondents experienced head-ache while weeding with *khurpi* (Table 1). All most all respondents were satisfied with two wheeled hoe which required less strain and body pain.

The drudgery index was found to be lower (73 %) for the improved method (twin wheel hoe) as compared to 92 per cent for existing method (*khurapi*) of weeding (Table 2) indicating reduction in extent of drudgery. Apart from considerable reduction in drudgery in weeding with twin wheeled hoe, the efficiency of weeding operation was remarkably improved (Table 2). The weeded area covered was nearly double (55.9 m^2/h/labour) in twin wheeled hoe as compared to performing the operation by *khurpi* (30.5 m^2/h/labour). Although the heart beat during resting period was almost equal (75 and 76 beats/minute, respectively), it was comparatively lower (92 beats/minute) in operation with *khurapi* than twin wheeled hoe (101 beats/minute) during recovery period. Since energy expenditure was dependent exclusively on heart beat rate and hence it showed concomitant increase with heart beat rate. The demand for energy was more in weeding with twin wheeled hoe as compared to *khurpi*. The rate of perceived exertion representing the end feeling by the respondents was noticed maximum in case of improved method. Posture, an important causative factors for increasing or decreasing the drudgery, showed a change from squatting (weeding by *khurpi*) to standing (weeding by twin wheeled hand hoe) indicating comfort to the operator. In many studies, it was quoted that squatting posture for continuous and for prolonged period was very harmful as compared to any other posture. According to the Saha (1994), the major health problems related to abnormal working posture are 'the problems of aches' of the muscular skeletal system. Working at abnormal posture such as bending, stooping, twisting etc., might be the likely cause of many health problems, particularly in the muscle skeletal system in the long-run. Posture related discomfort (muscilo-skeletal problems as measured by lumber and cervical point) to respondents was reported to be more in farm activity like weeding as compared to household and allied chores (Anonymous, 1998-99) .

Analysis of work out put revealed that one labour covered 30.5 m^2 per ha by using traditional *khurapi* amounting to 244 m^2 in a day of 8 hours working. This means 40 labours would be required to cover one hectare in a day costing INR 6 360 (@ INR 159/day/labour). In case of improved method, one labour covered 55.9 m^2 per ha amounting to 447.2 m^2 in a day. This would require only 22 labours for covering one hectare in day and the total cost on labour would be INR 3 498 (@ INR 159/day/labour) only. This brings out that switching weeding operation from *khurpi* to twin wheeled hand hoe will save INR 2 862 per hectare saving expenditure and energy of farm women coupled with reduction in drudgery.

Table 1. Assessment of body discomforts in existing and improved method (N = 20)

Body parts	Existing method (*Khurapi*)					Improved method (Twin wheel hand hoe)				
	Very mild	Mild	Neutral	Severe	Very severe	Very mild	Mild	Neutral	Severe	Very severe
Eye	2 (10)	4 (20)	5 (25)	7 (35)	2 (10)	8 (40)	7 (35)	1 (05)	3 (15)	1 (05)
Neck	-	1 (05)	4 (20)	3 (15)	12 (60)	6 (30)	11 (55)	1 (05)	1 (05)	1 (05)
Cervical point	-	-	1 (05)	3 (15)	16 (80)	1 (05)	4 (20)	7 (35)	7 (35)	1 (05)
Lumbar point	-	-	-	5 (25)	15 (75)	-	2 (10)	11 (55)	5 (25)	2 (10)
Fingers	-	-	8 (40)	8 (40)	4 (20)	1 (05)	10 (50)	7 (35)	1 (05)	1 (05)
Wrist	-	-	-	14 ((70)	6 (30)	1 (05)	5 (25)	5 (25)	6 (30)	3 (15)
Leg	-	-	5 (25)	7 (35)	8 (40)	-	4 (20)	16 (80)	-	-
Thigh	-	-	1 (05)	4 (20)	15 (75)	5 (25)	9 (45)	6 (30)	-	-
Knee	-	-	1 (05)	3 (15)	16 (80)	5 (25)	9 (45)	6 (30)	-	-
Feet	-	-	1 (05)	9 (45)	10 (50)	3 (15)	9 (45)	7 (35)	1 (05)	-
Head- ache	12 (60)	-	8 (40)	-	-	-	-	-	-	-

Figures in parenthesis are per cent values.

Table 2. Comparative parameters of exiting and improved method (N = 20)

Parameters	Existing method (*Khurapi*)	Improved method (Twin wheel hand hoe)
***Drudgery index* (%)**	92	73
Heart Rate (beats/min)		
Resting period	75	76
Recovery period	92	101
Energy Expenditure (Kj/min)		
Resting period	3.24	3.38
Recovery period	5.91	7.33
Rate of perceived exertion		
Resting period	1	1
Working period	3	4
Recovery period	2	3
Posture	Squatting	Standing
Total area covered (m^2/h/labour)	30.5	55.9

The data generated on feedback from respondents on constraints of performing the weeding by twin wheeled hand hoe brought out that it requires practice for smooth functioning (70 %). About 80 and 90 per cent respondents expressed that sometimes during incessant rain and on wet land surface, respectively it becomes difficult to operate the hoe in the field. Responses from respondents also revealed that the improvement in twin wheeled hoe with respect to slight reduction in weight (65 %), adjustable height as per the height of worker (40 %), change in shape of handle making it straight rather than curved (70 %) can further make it convenient and increase in efficiency of weeding.

The study clearly brings out that switching from existing method (*khurapi*) to improved method (twin wheeled had hoe) is effective in reducing drudgery and body discomfort coupled with double output per unit time in half the expenditure on weeding operation. For the *kharif* crop like soybean, timely weeding operation within the narrow window of time is important and can save the crop from weed competition and yield loss. Hence, the use of twin wheeled hand hoe needs popularisation in the women workers in order to reduce drudgery.

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Effect of Sulphur on Seed Yield, Nutrient Content and Uptake by Soybean [G*lycine max* (L.) Merrill]

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Sulphur is one of the essential secondary plant nutrients. Its importance in Indian Agriculture is being increasingly emphasized. Its role in crop production particularly in oilseed and pulse crops has earlier been reported (Prasad, 2006). Sulphur deficiency causes 12-15 per cent reduction in seed yield of soybean (Kandpal and Chandel, 1993; Sharma, 2003). Since, adequate information on soybean responses to sulphur application on medium black clay soil of Madhya Pradesh is not available, the present study was undertaken to know the effect of sulphur levels on performance and nutrient acquisition by soybean.

A field experiment was conducted during the *kharif* seasons 2007 and 2008 at Krishi Vigyan Kendra farm, Shajapur. The soil was medium black, clayey in texture with pH 7.80. The available nitrogen, phosphorus, potassium and sulphur contents were 218 kg N , 13 kg P_2O_5, 580 kg K_20 and 9.75 S kg per ha, respectively. The experiment was laid out in randomized block design with four replications. The treatments consisted 6 levels of sulphur (0, 10, 20, 30, 40 and 50 kg/ha). Sulphur was applied through gypsum at the time of sowing with a recommended dose of fertilizers (20 kg N + 60 Kg P_2O_5 +20 kg K_2O). The seeds were treated with *Bradyrhizobium japonicum* and phosphate-solubilizing bacteria, each @ 10 g per kg seed. Soybean JS 93-05 was sown at 45 cm apart in rows using 80 kg seed per ha in last week of June during in both the years. Statistical analysis was carried out using standard analysis of variance (Panse and Sukhatme, 1985).The processed seed and straw samples were analyzed for total nitrogen (Kjeldhal, 1983), phosphorus by vanadomolybdo phosphoric yellow colour method in nitric acid system

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(Jackson, 1973), potassium (Black, 1965), sulphur by method given by Chesnin and Yien (1950). The uptake of these nutrients was worked out utilizing the data collected for seed and straw yield.

Increasing levels of sulphur up to 50 kg S per ha significantly and progressively enhanced seed and straw yield of soybean (Table 1). The contents of N, P, K and S in seed and straw and total uptake by soybean were also found to increase with the increasing levels of sulphur application (Table 2). However the N content in seed was not statistically significant. The crop response to sulphur application appears on account of deficient level (below soil critical level of 10 kg/ha) of sulphur in soil. Similar results have also reported by Sharma and Gupta (1992) and Sharma (2003). The increasing application of sulphur might have facilitated higher uptake of N, P, K and S from soil (Ganeshamurty, 1996). Increased sulphur content in soybean seed on application of sulphur to soybean has been recorded by Ganeshamurty (1996). Significant enhancement of seed and straw yield along with nutrient contents and total uptake by application of sulphur through gypsum might be due to readily available plant available SO_4 sulphur and concomitant addition of calcium. These results are in line with the findings of Kandpal and Chandel (1993) and Sharma (2003).

The economic evaluation revealed that net return and C: B ratios showed an increasing trend with increasing levels of sulphur (Table 1). The maximum net returns of ₹ 25, 560 per ha had accrued by the use of sulphur @ 50 kg S per ha with C: B ratio of 1:3.84. In comparison, the net return and C: B ratio in control treatment observed were ₹ 16, 110 per ha and 1:2.79, respectively. These findings confirm the findings of Ramamoorthy *et al.* (1996). The results of the study suggest that it will be economically viable to apply sulphur @ 50 kg per ha through gypsum in Vertisols to enhance the productivity of soybean.

Table 1. Effect of sulphur levels on seed and straw yield and economics of soybean (mean of two years)

Sulphur level (kg/ha)	Seed yield (kg/ha)	Straw Yield (kg/ha)	Net Returns (₹/ha)	C:B Ratio
0	1674	1858	16110	1:2.79
10	1786	2008	17790	1:2.97
20	1921	2170	19815	1:3.20
30	2075	2367	22125	1:3.45
40	2208	2556	24120	1:3.68
50	2304	2712	25560	1:3.84
SEm (±)	16.21	13.95	706.7	-
CD at 5%	**48.90**	**41.84**	**2120**	-

Table 2. Effect of sulphur levels on nutrient content and uptake by soybean (mean of two years)

Sulphur level (kg/ha)	Nutrient contents in seed (%)				Nutrient content in straw (%)				Total nutrient uptake (kg/ha)			
	N	**P**	**K**	**S**	**N**	**P**	**K**	**S**	**N**	**P**	**K**	**S**
0	5.64	0.09	0.876	0.263	0.965	0.072	0.766	0.108	112.34	2.90	28.89	6.41
10	6.20	0.117	0.938	0.375	0.982	0.073	0.784	0.112	130.45	3.56	32.49	8.95
20	6.24	0.119	0.943	0.379	1.022	0.075	0.791	0.117	142.05	3.92	35.28	9.82
30	6.25	0.120	0.953	0.384	1.032	0.077	0.797	0.133	154.12	4.31	38.63	11.12
40	6.28	0.122	0.990	0.389	1.052	0.078	0.801	0.142	165.55	4.68	42.33	12.22
50	6.30	0.123	1.011	0.393	1.064	0.082	0.807	0.150	174.01	5.05	45.18	13.12
SEm (±)	0.09	0.0003	0.004	0.0016	0.0013	0.0003	0.0016	0.003	1.78	0.16	0.66	0.12
CD at 5%	**NS**	**0.001**	**0.012**	**0.005**	**0.004**	**0.001**	**0.005**	**0.009**	**5.36**	**0.47**	**1.98**	**0.38**

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Pratap Raj 24 (RKS 24) – A High Yielding Variety of Soybean for Rajasthan

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Soybean [*Glycine max* (L.) Merrill] has emerged as a major oilseed crop grown during *kharif* season in India. It is termed as wonder bean or miracle bean as it contains 38-42 per cent good quality protein rich in lysine and 18-22 per cent oil high in essential fatty acids (omega-6 and omega-3). Soybean cultivation in India has shown an unparallel growth during past four decades. The limited area of 0.03 m ha under cultivation of soybean in 1970 is now estimated to be 10.18 million ha. Rajasthan, the third major soybean producing state in the country has 0.90 million ha under the crop producing 1.39 million tons with an average productivity of 1 544 kg per ha during 2011 (Anonymous, 2012). Although the productivity of the state is higher than national productivity of 1 207 kg per ha, it is much lower than the potentials of existing predominant varieties (JS 335, JS 93-05 and JS 95-60) in cultivation (> 2500 kg/ha). With passage of time, these varieties have become susceptible to major insect-pest (girdle beetle, semi-looper, and tobacco caterpillar) and diseases (yellow mosaic virus, charcoal rot, bacterial pustules and bacterial blight). Under the situation, a new variety named Pratap Raj 24 (RKS 24) was released and notified for Rajasthan with high yield potential of 3 000-3 500 kg per ha, a comparative higher oil content (21.25 %) and moderate resistance to various insect-pest and diseases. It will provide an option to farmers of the region to improve yield levels and to promote varietal diversification.

Pratap Raj 24 (RKS 24) was developed from two genetically diverse genotypes through single cross between PK 472 x PK 1024. Segregating generations

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of this cross were handled by pedigree selection programme at the experimental farm of Agricultural Research Station, Ummedganj, Kota. The F_8 progeny of this cross was evaluated in replicated trials for seven years (*kharif* 2002-2008) at Agricultural Research Station, Kota, for three years in multi-location trials (*kharif* 2006-2008), for three years under moisture stress condition (*kharif* 2006-2008) and for five years (*kharif* 2004-2008) in different coordinated trials with popular check varieties.

On the basis of average of seven years (2002-2008) testing, the variety RKS 24 yielded 2 360 kg per ha (Table 1) and was found 25.27 and 104.51 per cent superior over the national checks JS 335 (1 884 kg/ha) and Bragg (1 154 kg/ha), respectively, while 28.26 per cent superiority for seed yield was observed over the zonal check JS 93-05 (1 840 kg/ha). Under multi-location trials (Table 2) conducted at ten different coordinated centers, the variety RKS 24 gave an average yield of 1 632 kg per ha which was 23.7 and 35.2 per cent higher over the checks JS 335 (12.7 kg/ha) and JS 93-05 (1 319 kg/ha), respectively. Thus, the present variety showed better performance over both the most popular and best adopted varieties of the zone.

Since, soybean is predominantly cultivated under rainfed condition in *kharif* season in the country as well as in Rajasthan, the performance of the variety RKS 24 was also evaluated in moisture stress conditions by not providing any irrigation even if needed (Table 3), with national, zonal and local check varieties adapted to this zone. This variety yielded 1 333 kg per ha seed yield under moisture stress conditions, which is 51.95, 21.85, 12.68 and 7.86 per cent higher over JS 335, JS 93-05 and Pratap Soya 1, respectively.

Table 1. Performance of RKS 24 in state trials

Name of trial	Year	RKS 24	National check		Zonal check	CD (P = 0.05)
			JS 335	Bragg		
RST-I	*Kharif* 2002	2910	2536	2012	2195	**283.5**
RST-II	*Kharif* 2003	2825	2420	1850	2110	**262.2**
IVT	*Kharif* 2004	2429	2223	1070	1811	**270.1**
AVT -I	*Kharif* 2005	2743	2373	1840	1910	**234.8**
AVT-II	*Kharif* 2006	2060	1693	1318	1755	**207.9**
AVT-II*	*Kharif* 2007	2196	2429	1651	1887	**160.7**
AVT-II *	*Kharif* 2008	1357	0513	0347	1214	
	Mean	**2360**	**1884**	**1154**	**1840**	
% increase of RKS-24 over			**25.27**	**104.51**	**28.26**	

**Repeat*

Table 2. Performance of RKS-24 in multi-location trials

Location	Year	Released Variety (RKS 24)	Zonal Check (JS 93 05)	National Check (JS 335)	CD (P = 0.05)
ATC Nanta, Kota	*Kharif* 2006	1570	1215	1344	**150.7**
ATC, Bundi	*Kharif* 2007	1978	1890	1628	**169.3**
ATC, Chittorgarh	*Kharif* 2008	1250	1100	1150	**-**
ARS, Kota	*Kharif* 2008	1357	1214	0513	**174.1**
RCA, Udaipur	*Kharif* 2008	1685	1251	1008	**178.0**
KVK, Bundi	*Kharif* 2008	1744	1510	1337	**248.3**
KVK, Anta	*Kharif* 2008	1370	1190	0593	**-**
KVK, Chittorgarh	*Kharif* 2008	1878	1287	1607	**176.2**
ARSS, Aklera	*Kharif* 2008	1152	0965	0835	**152.2**
ARSS, Pratapgarh	*Kharif* 2008	2333	1567	2056	**383.1**
	Mean	**1632**	**1319**	**1207**	**-**
% increase of RKS-24 over			**23.7**	**35.2**	

ATC=Adaptive Trial Centre, ARS=Agricultural Research Station, RCA= Rajasthan College of Agriculture, KVK= Krishi Vigyan Kendra, ARSS= Agricultural Research Sub-Station

RKS 24 was found with high yield potential (2 145 kg/ha) having18.50, 7.84 and 18.66 per cent higher yield over national and zonal checks namely, Bragg, JS 335 and JS 93-05 respectively, under irrigated condition in 32 coordinated trials (Table 4) conducted at different centers of India in Central zone during the evaluation span of four years (*kharif* 2004-2007).

RKS 24 has high mean oil content (21.25 %) as compared to checks Bragg (19.15 %), JS 335 (19.42 %) and JS 93-05 (19.50 %); ensuring higher oil yield per unit area along with higher seed yield. Thus, the present variety RKS 24 is also likely be preferred by the oil industry.

RKS 24 is medium tall with determinate growth habit, medium maturity, white flower, high number of primary branches, dark, broad and thick leaf, tawny pubescence on stem, leaf and pod surface, cream yellow seed, round and medium bold in shape and size, pink hypocotyle and brown hylum (Fig. 1 and 2). It is non-lodging and non-shattering type. This variety possesses multiple moderate resistances to various diseases

Table 3. Performance of RKS 24 under moisture stress condition at ARS, Kota (Mean yield in kg/ha)

Name of trial	Year	RKS 24	National check (JS 335)	Zonal Check (JS 93-05)	Local Check (Pratap Soya 1)	CD (P = 0.05)
RST-I	*Kharif* 2006	1350	1010	1120	1200	**198.2**
RST-I	*Kharif* 2007	1560	1120	1250	1336	**180.6**
RST-I	*Kharif* 2008	1087	0500	0911	1012	**183.4**
	Mean	**1333**	**0877**	**1094**	**1183**	
% increase of RKS 24 over			**51.95**	**21.85**	**12.68**	

Table 4. Summary data of 32 coordinated varietal trials conducted in five different years and centers (Mean yield in kg/ha)

Year of testing	No. of trials	Released variety RKS 24	Checks		
			Bragg	JS 335	JS-93-05
2004	9	**2297**	1593	1674	1476
2005	9	**2202**	1945	2257	1966
2006	7	**2118**	1840	2013	1829
2007	7	**1963**	1862	2012	1960
2008	1	**1388**	347	513	1214
Mean	**32**	**2145**	**1810**	**1989**	**1808**
% increase of RKS-24 over			**18.5**	**7.84**	**18.66**

Fig 1. RKS 24, a high yielding variety for Rajasthan

Fig. 2. Medium bold cremish yellow seed with pink hypocotyle and brown hylum

like bacterial pustules, charcoal rot and yellow mosaic virus and major insect-pests like stem fly, lepidopterous defoliators, girdle beetle and tobacco caterpillar. The variety is released and notified (Notification number S.O. 283 (E) on 7th, February, 2011) by the Central Varietal Release Sub-Committee on Crop Standards, Notification and Release of Varieties 2011) for timely sown, high fertility, irrigated condition of Rajasthan and maintains good germination (80-90 %) under ambient condition of storage for the seven months with yield potential of 3000-3500 kg per ha.

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