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Genetic Variability in Black Soybean Genotypes for Agro-morphological and Seed Quality Traits under Rainfed Condition of Uttarakhand Hills

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ABSTRACT

Black soybean [Glycine max *(L.) Merrill*] *is an important grain legume in Uttarakhand hills and contributes significantly in the nutritional security of local inhabitants of this region. In the present study, genetic variability among 24 black soybean genotypes was assessed using multivariate analysis. According to principal component analysis first four principal components (PC) accounted for 86.50 per cent of total variance. PCI, PCII, PCIII and PC IV accounted for 39.86 per cent, 23.06 per cent 13.27 per cent and 10.31 per cent of total variation, respectively. Cluster analysis exhibited significant differences in mean values for various traits in all the three clusters. Cluster I had minimum mean value for days to 50 per cent flowering (43) and maximum mean values for protein (35.40 %) and oil (18.87 %) contents. Cluster II showed maximum mean value for plant height (67.54 cm) and number of nodes per plant (18) with minimum mean value for seed yield per plant (7.63 g) and major yield components viz., 100 seed weight (8.33 g), dry matter weight per plant (17.77 g) and seed quality traits viz., oil (14.73 %) and protein content (34.95 %). From yield and its major component traits cluster III was found promising as it had maximum mean value for seed yield (14.60 g), number of pods per plant (53), 100 seed weight (15.80 g), dry matter weight per plant (30.36 g) together with minimum mean value for basal pod height (9.81 cm) and days to maturity (93).Three genotypes namely VS 2011-117, VS 2011-104 and VS 2011-102 from cluster III were found superior in yield and multiple yield contributing traits. So, genotypes from cluster I and III can produce early maturing, nutritionally superior and high yielding transgressive segregants on hybridization and genotypes of cluster II can be improved by utilization of superior genotypes from both cluster I and III to develop high yielding and protein rich small grain size genotypes for Uttarakhand hills.*

Key words: Black soybean [*Glycine max* (L.) Merrill], Cluster analysis, principal component analysis

Black soybean [*Glycine max* (L.) Merrill] is a traditional food crop in Uttarakhand hills. It is locally known as *Bhat/Bhatmash* and grown in Kumaon region and in its bordering states and countries in the Himalayas (Shah, 2006). Both yellow and black seeded soybean are widely grown but in terms of food value

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small seeded black soybean is well accepted and preferred among local inhabitants in Uttarakhand hills. It is part of traditional cuisine and used in preparation of various local recipes like roasted black soybean (*Bhuti bhat*), chutney (*Bhat ke chutney*) and gravies (*Dubka*, *Chutkani*, *Ras*, *Ginjada*, *Joula/Bhatia* and *Churkwani/ bhatwari*) (Mehta *et al.,* 2010; Bungla *et al.,* 2012). Black soybean is more treated as pulse rather than an oilseed crop and plays an important role in nutritional security of rural populace in hills. It occupies an integral part in hill agriculture as well as food habits of local communities of this region. However, potential of black soybean as pulse crop all over the country is yet to receive due attention and popularization as it has the potential to eradicate protein malnutrition. In Uttarakhand hills, black soybean is third most important pulse crop after black gram and horse gram and cultivated in 5.55 thousand hectare area with the production of 4.98 thousand tons. It is entirely cultivated as rainfed crop and its productivity 897 kg per ha lags well behind the productivity of yellow soybean (1,479 kg/ha) in the state (Department of Agriculture Uttarakhand, 2010-11). The production of black soybean (*Bhat*) in hills is dwindling very rapidly as traditional cultivars yield are much lower than normal soybean. Poor yield potential of traditional black soybean, necessitates the development of the genetically improved cultivars for this region. Development of potential cultivars through conventional breeding depends primarily on hybridization and subsequent selection. In order to benefit transgressive segregation, genetic variability between parents is necessary (Joshi *et al*., 2004). Therefore, the present investigation was carried out to assess the variability in black soybean genotypes for different agro-morphological and seed quality traits and selection of promising lines for further utilization is black soybean improvement programme for Uttarakhand hills.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* 2012 at Experimental Farm, VPKAS, Almora (29^{0}35'N and 79^{0}39'E at an elevation of 1,250 msl). The experimental material comprised 22 advanced breeding lines of black soybean with two checks (VL *Bhat* 65 and Local *Bhat*). The experiment was conducted in randomized complete block design with two replications. Each genotype was grown in 4-row plots, 3 m long, with 45 cm × 10 cm spacing. Observations on principal phenological stages were recorded at 50 per cent of flowering and 80 per cent maturity, respectively on whole plot basis. The remaining quantitative traits *viz*., plant height, number of primary branches, basal pod height, number of nodes per plant, number of pods per plant, dry matter weight per plant and seed yield per plant were recorded on three randomly selected plants in each genotype per replication following standard procedures while seed weight was recorded in hundred randomly selected seeds. Oil content in the seeds of black soybean genotypes was estimated using petroleum ether in a semi-automatic Soxhlet apparatus (Pelican, socsplus, 2AS, Chennai) (AOAC, 1990). Protein content was estimated by dye-binding method (Bradford, 1976).The data of all quantitative traits was subjected to principal component analysis (Rao, 1984) and non-hierarchical euclidean cluster analysis (Spark, 1973) by computer software SPAR1 and correlation coefficients and between Principal Component Axes scores and original mean values of the traits were computed by SYSTAT software.

RESULT AND DISCUSSION

In the present investigation, moderate to high variability was observed for majority of quantitative traits *viz.*, plant height (34.17-81.34 cm), number of pods per plant (24-77), dry matter weight (10.24-35.25 g), 100 seed weight (4.46- 17.07 g), seed yield per plant (3.66-16.53 g), basal pod height (7.17-15.17 cm) and number of nodes per plant (12-20) (Table 1). Genetic variability has great significance to the plant breeder as it plays a crucial role in framing a triumphant breeding programme. Morphological characterization is an important step in description and classification of genotypes because a breeding programme mainly depends upon the magnitude of genetic variability (Zubair *et al.,* 2007). Presence of sufficient amount of variability for

Table 1. Estimates of Mean, Range, Standard Deviation (SD), Eigen root and Variation (%) explained by each Eigen root for 12 quantitative traits in black soybean

Characters	Mean	Range	Eigen root	Variation (%) explained by each root
Days to 50 % flowering	44.27	41 - 47	4.78	39.86
Plant height (cm)	52.00	34.17 - 81.34	2.77	23.06
Primary branches (No/plant)	5.10	4 - 7	1.59	13.27
Basal pod height (cm)	11.10	7.17 - 15.17	1.24	10.31
Nodes (No/plant)	15.00	12 – 20	0.66	5.46
Pods (No/plant)	46.63	24– 77	0.49	4.12
Dry matter (g/plant)	22.42	10.24 -35.25	0.19	1.57
Days to maturity	95.73	92 -99	0.13	1.11
100 seed weight (g)	12.28	4.46 -17.07	0.09	0.72
Seed yield per plant (g)	10.42	3.66 -16.53	0.03	0.24
Oil content (%)	16.46	12.36 -21.89	0.03	0.21
Protein Content (%)	35.21	30.23 -40.28	0.01	0.08

different agro-morphological traits suggests improvement of these traits through selection. Seed quality traits *viz.,* oil content (12.36-21.89 %) and protein content (30.23-40.28 %) also exhibited a higher range of variation which was observed within the range 10.8–19.6 per cent for oil and 32.1–39.8 per cent for protein contents as reported by Saha *et al.* (2008) in black soybean lines of Himalayan region.

Transformation of quantitative traits into principal components yielded twelve eigen roots. First eigen roots having highest eigen value 4.78 and only first four of the twelve principal component axes (PCA) had given eigen value more than one. Only principal component with eigen value more than one were considered in determining the agro-morphological variability (Kaiser, 1960). The first four principal component axes (PCA) together accounted for 86.50 per cent of total variance and PCI, PCII, PCIII and PCIV accounted for 39.86 per cent, 23.06 per cent, 13.27 per cent and 10.31 per cent of total variation, respectively. PCA I exhibited highly significant positive correlation with traits namely plant height (0.88), days to maturity (0.79), number of nodes per plant (0.75) and basal pod height (0.65). PCA II mainly defined by number of pods per plant (0.83), number of primary branches per plant (0.75), number of nodes per plant (0.55) and dry matter weight per plant (0.54). PCA III was determined by days to 50 per cent flowering (0.59) and protein content (0.57) while PCA IV was found positively correlated with days to 50 per cent flowering (0.48) (Table 2). Principal component analysis is useful as it gives information about the groups where certain traits are more important allowing the breeders to conduct specific breeding programs (Salimi *et al.,* 2012).

Non-hierarchical euclidean cluster analysis was found useful in estimating the genetic variability on the basis of agro-morphological and seed quality traits in 24 black soybean genotypes. Cluster analysis is another commonly used multivariate analysis method in identifying genetic variability which can analyze several factors simultaneously and provides different classes based upon similarity values (Aydm *et al.,* 2007). On the basis of F test 3 clusters were found to be more suited for this study. Cluster I and II consisted of maximum (9) genotypes each followed by Cluster III which consisted 6 genotypes. Average distances of clusters from cluster centrioids ranged from 1.87 to 2.74. It was found minimum in cluster I and maximum in cluster II. It suggested that genotypes in cluster II were relatively more diverse among themselves however, in most of the cases, the inter cluster distances were greater than intra cluster distances implying greater degree of genetic diversity between the genotypes of the two clusters than the genotypes present within the cluster (Tyagi and Sethi, 2011). So far as inter cluster distance is concerned, cluster III and II centriod were the farthest (4.96) from each other, *i.e.* these two clusters are genetically more diverse followed by cluster I and II (4.27) and cluster I and III (3.38). Greater the variability between two clusters wider the genetic variability between genotypes (Mian and Bahl, 1989). Hence, selection of genotype should be done from the two clusters with wider inter cluster distance to

Table 2. Correlation coefficients between the first four principal components (PCI, PCII PC III & PCIV) and 12 quantitative traits of 24 black soybean genotypes

Characters	PC I	PC II	PC III	PC IV
Days to 50 % flowering	0.23	0.50*	0.59**	0.48*
Plant height (cm)	0.88**	0.34	0.12	-0.23
Primary branches (No/plant)	0.15	0.75**	-0.42*	-0.18
Basal pod height (cm)	0.65**	-0.07	0.26	-0.54**
Nodes (No/plant)	0.75**	0.55**	0.07	-0.14
Pods (No/plant)	-0.31	0.83**	-0.30	0.01
Dry matter (g/plant)	-0.72**	0.54**	0.19	-0.34
Days to maturity	0.79**	-0.22	-0.30	-0.34
100 seed weight (g)	-0.89**	-0.10	0.32	-0.23
Seed yield per plant (g)	-0.77**	0.44*	0.25	-0.36
Oil content (%)	-0.54**	-0.40	-0.48*	-0.31
Protein Content (%)	0.25	-0.10	0.57**	-0.31

**, **: Significant at 5% and 1% probability levels, respectively.*

get more variability and heterotic effect (Pradhan and Roy, 1990.) The genotypes belongs to distant clusters with desirable agro morphological traits can be used to make multiple crosses and genes for desirable traits can be transferred to a common genetic background.

Cluster means for various characteristics exhibited significant differences (Table 3). Cluster I had minimum mean value for days to 50 per cent flowering (43) and maximum mean values for protein (35.40 %) and oil (18.87 %) content. Cluster II showed maximum mean value for plant height (67.54 cm) and number of nodes per plant (18) with minimum mean values for seed yield per plant (7.63 g) and major yield components *viz.*, 100 seed weight (8.33 g), dry matter weight per plant (17.77 g) and seed quality traits, namely oil (14.73 %) and protein content (34.95 %). Suneja *et al.* (2010) also reported that black seeds of soybean have more protein and less in oil content with small sized black seeds with low average hundred seed weight (7.62 g) in comparison to creamish white colored seeds in local collection of soybean. Cluster III had maximum mean values for seed yield (14.60 g) and important yield contributing traits *viz.*, number of pods per plant (53), 100 seed weight (15.80g) dry matter weight per plant (30.36g) together with minimum mean values for basal pod height (9.81cm) days to maturity (93). Three genotypes namely VS 2011-117, VS 2011-104 and VS 2011-102 from cluster III found superior in yield and multiple yield contributing traits and Local *Bhat* from cluster II found promising in traits namely number of primary branches, number of pods per plant and low oil content (Table

Table 3. Cluster means for 12 quantitative traits in 24 black soybean genotypes

Characters	Cluster I	Cluster II	Cluster III
Days to 50 % flowering	43	45	46
Plant height (cm)	41.57	67.54	44.33
Primary branches (No/plant)	4.87	5.35	5.06
Basal pod height (cm)	10.44	12.63	9.81
Nodes (No/plant)	13	18	14
Pods (No/plant)	43.28	45.52	53.33
Dry matter (g/plant)	21.77	17.77	30.36
Days to maturity	96	98	93
100 seed weight (g)	13.87	8.33	15.80
Seed yield per plant (g)	10.43	7.63	14.60
Oil content (%)	18.87	14.73	15.41
Protein Content (%)	35.40	34.95	35.33

4). Therefore, through the utilization of superior lines from cluster III and II high yielding genotypes with small grain size can be developed which is normally preferred for the preparation of traditional recipes in Uttarakhand hills. From yield point of view, superior genotypes from clusters III can be used to develop high yielding as well as high grain weight genotypes. Cluster I was found promising for seed quality traits along with desirable phenological trait. So, the genotypes from cluster I and III can produce early maturing, nutritionally superior and high yielding transgressive segregants on hybridization and further to improved genotypes. These improved genotypes can be helpful to ensure the nutritional security in Uttarakhand hills.

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Table 4. Promising lines from clusters I, II & III for yield and component traits in black soybean

Trait	Superior lines	Cluster
Primary branches (No/plant) (>7)	Local *Bhat*	II
Basal pod height (< 8cm)	VS 2011-116	I
	VS 2011-117	III
	VS 2011-119	I
Nodes (No/plant) (>18)	VS 2011-112	II
	VS 2011-113	II
	VS 2011-118	II
	VS 2011-120	II
Pods (No/plant) (>60)	VS 2011-104	III
	Local *Bhat*	II
	VS 2011-117	III
Dry matter (g/plant) (>30g)	VS 2011-104	III
	VS 2011-117	III
100 seed weight (>15.5 g)	VS 2011-102	III
	VS 2011-104	III
	VS 2011-110	III
	VL *Bhat* 65	III
	VS 2011-117	III
Seed yield per plant (>15g)	VS 2011-102	III
	VS 2011-104	III
	VS 2011-117	III
Oil content (>20 %)	VS 2011-107	I
	VS 2011-111	I
Oil content (<14 %)	VS 2011-103	II
	Local *Bhat*	II
	VS 2011-121	II
Protein content (>40 %)	VS 2011-112	II

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Genotype x Environment Interaction in Soybean [*Glycine max* (L.) Merr.] Genotypes

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ABSTRACT

*Fifteen diverse soybean [*Glycine max *(L.) Merr.] genotypes, derived from nine different crosses, were evaluated along with four checks namely, Bragg, Him Soya, Hara Soya and Shivalik under three different locations for stability parameters in five traits,* viz.*, days to maturity, plant height, branches per plant, pods per plant and seed yield using Eberhart and Russell (1966) model. Variance due to G × E interaction was significant for all the traits revealing thereby the differential response of the genotypes to different environments. G x E (linear) component was found to be non-significant for all the traits except plant height when tested against pooled deviations indicating the equal importance of both linear and non-linear interactions. Individual parameters of stability revealed that genotypes, P12-1-1-1 (SL 284 x Pb 1), P1-1 (Pusa 20 x PK 1029), NRC-95-03-01, P2-2 (VLS 2 x Lee) and P13-4 (DSD 74-22 x Himso 308) were found to be stable as regression coefficient (bi) was equivalent to unity and deviation from regression (S^2di) was non-significant. Among these stable genotypes, P1-1 was observed to be higher yielder than over all mean and can be recommended for general cultivation. Genotype P69-8-4-4 (Himso 330 x Hardee) was stable for days to maturity over locations. In contrast, most of the genotypes showed regression coefficients greater than unity indicating their sensitivity to environmental changes for seed yield. Under favourable environments, genotype P100-1-4 (Ankur x P4-2) was suitable for general cultivation, whereas genotype P1-4 (SL 284 x Bragg) was suitable for poor/unfavourable environmental conditions.*

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

Soybean the world's leading source of oil and protein crop is grown over wider agro-ecologies especially in low to mid-altitude areas (300 to 1700 masl) that have moderate annual rainfall (500-1500 mm) and, hence it is exposed to the influence of genotype environment interaction (G x E). Sprague (1966) indicated that G x E interaction constitutes an important limiting factor in the estimation of variance components and in the efficiency of selection programmes.

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The presence of a significant G x E interaction for quantitative traits such as seed yield can reduce the usefulness of subsequent analysis, restrict the significance of inferences that would otherwise be valid, and seriously limit the feasibility of selecting superior genotypes (Flores *et al.,* 1998). Stability of yield of a cultivar across a range of production environments is very important for varietal recommendation. The cultivars must have the genetic potential for superior performance under ideal growing conditions, and must also produce acceptable yields under less favorable environments. Therefore, a stable genotype can be referred to as the one that is capable of utilizing the resources available in high yielding environments and has a mean performance that is above average in all environments (Eberhart and Russell, 1966; Allard and Bradshaw, 1964). Thus, the present study was intended to study the stability of soybean genotypes under different environmental conditions of the State.

MATERIAL AND METHODS

During *kharif* 2009, fifteen soybean strains derived from nine different crosses were evaluated with four checks (Bragg, Him Soya, Hara Soya and Shivalik) at three diverse locations of Himachal Pradesh comprising mid as well as low hills *viz.*, Palampur, Kangra and Dhaulakuan for five traits, *viz.*, days to maturity, plant height (cm), branches per plant, pods per plant and seed yield (q/ha). The genotypes were planted at each location in a randomized complete block design with three replications. For raising the crop recommended package of practices were followed. The observation on yield and yield attributes were recorded on 5 competitive plants at the time of harvest from each plot. The stability analysis was carried out as per procedure outlined by Eberhart and Russell (1966).

The data were subjected to analysis of variance separately for each environment and combined over environments. The statistical model used for ANOVA is:

$Yijk = \mu + Gi + Ej + GEij + Bk(j) + eijk$, where, $Yijk$ = observed value of i^{th} genotype in k^{th} block of environment/location j, μ = grand mean, Gi = effect of i^{th} genotype, Ej= effect of j^{th} environment/location, $GEij$ = the interaction effect of i^{th} genotype with j^{th} environment, $Bk(j)$ = the effect of k^{th} block in j^{th} location/environment and $eijk$= error/residual effect of genotype i in block k of environment j.

Mean separation was conducted using least significant difference (LSD) test to discriminate the genotypes and identify superior ones based on the trait of interest. ANOVA is important in detecting the presence of G x E interaction but it does not indicate which genotypes possess more contribution to the interaction and which of the genotype(s) is (are) stable across environments.

RESULTS AND DISCUSSION

The pooled analysis of variance for yield and yield contributing traits (Table 1) indicated that the genotypes significantly differed for days to maturity, plant height and seed yield and, the G x E interaction was significant for all traits. Significant G × E interaction revealed the differential response of the genotypes to different environments. The response of genotypes to changing environment was measured by the environmental linear effect. G x E (linear) component was found to be non-significant for all the traits except plant height when tested against pooled deviations indicating the equal importance of both linear and non-linear interactions. Significant pooled deviation for days to maturity, branches per plant, pods per plant and seed yield indicated non-linear response of the genotypes due to environmental changes and role of unpredictable components of G x E interaction towards differences in stability of genotypes. Singh *et al.* (1991), Mebrahtu and Elmi (1997) and Pan *et al.* (2007) have also reported significant environmental variations over years in soybean genotypes.

Table 1. Analysis of variance combined over environments (Mean Sum of Squares)

Source	df	Days to maturity	Plant height (cm)	Branches (No/plant)	Pods (No/plant)	Seed yield (kg/ha)
Environment	2	907.46*	2974.01*	7.55*	472.13	10685460.00*
Genotype	18	240.46*	1630.67*	2.83	2593.74	613646.00*
Geno. x Env.	36	63.74*	200.89*	1.74*	1692.50*	320393.80*
Env. + (E x G)	38	67.88*	219.97*	0.95*	559.34*	663570.30*
Env. (linear)	1	1814.88	5948.04	15.09	944.26	21370890.00
G x E (linear)	18	25.52	103.81*	0.51	691.42	67157.48
Pooled deviations	19	16.07*	28.54	0.61*	413.96*	138734.10*
Pooled error	108	1.09	30.86	0.19	58.73	13198.07

** Significant against pooled error ms at P≤0.05; significant against pooled deviation ms at P≤0.05*

The stability parameters viz., mean, regression coefficient (bi) and deviation from regression (S2di) for all characters of each genotype were computed (Table 2). The substantial magnitudes of deviation from linearity for all the characters were observed suggesting large fluctuation in the expression of all the characters over environments. Mean sum of squares due to pooled deviation were found significant for most of the characters except plant height. Stability worked out for all the 15 genotypes for yield and its component traits showed that the genotypes, namely P12-1-1-1 (SL 284 x Pb 1), P1-1 (Pusa 20 x PK 1029), NRC-95-03-01, P2-2 (VLS 2 x Lee) and P13-4 (DSD74-22 x Himso 308) were found to be stable. Among these stable genotypes, P1-1 (Pusa 20 x PK 1029) was observed to be higher yielder than over all mean and can be recommended for general cultivation. Genotype P69-8-4-4 (Himso 330 x Hardee) was stable for days to maturity over locations. In contrast, most of the genotypes showed regression coefficients greater than unity indicating their sensitivity to environmental changes for seed yield. Under favourable environments, genotype P100-1-4 (Ankur x P4-2) was suitable for general cultivation, whereas genotype P1-4 (SL 284 x Bragg) was suitable for poor/unfavourable environmental conditions. Earlier workers (Sood *et al.,* 1999, Jai Dev *et al.,* 2009, Jai Dev *et al.,* 2009) have also identified stable soybean strains for cultivation under mid-hills of Himachal Pradesh.

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Table 2. Stability parameters for yield and component characters in soybean

Genotypes	Days to maturity			Plant height (cm)			Branches (No/plant)			Pods (No/plant)			Seed yield (kg/ha)		
	Mean	bi	s^2di	Mean	bi	s^2di	Mean	bi	s^2di	Mean	bi	s^2di	Mean	bi	s^2di
P69-8-4-4 (Himso330 x Hardee)	127.11	0.97	0.09	92.93	2.39*	32.44	4.07	2.52*	0.38	58.02	-0.45	42.42	961	1.09	75397.00*
P12-1-1-1 (SL284 x Pb1)	115.22	1.03	8.15*	88.38	1.02	0.13	4.09	1.19	0.73	60.27	-1.81	752.31*	1240	0.75	18983.00
P1-1 (Pusa-20 x PK1029)	113.93	1.28	11.56*	64.60	0.79*	2.60	3.60	1.81	0.15	68.33	0.02	596.03*	1318	1.03	13430.50
P9-2-2 (JS79-295 x Pb1)	111.96	0.48*	0.27	42.87	-0.19*	6.55	3.58	1.43	0.24	50.07	-3.23*	15.60	1149	1.11*	543.13
P46-2-2 (Ankur x P4-2)	118.52	1.96	30.75*	82.13	1.03	8.06	4.51	2.51	0.37	82.16	1.10	201.69	1081	0.83*	52.31
P100-1-4 (Ankur x P4-2)	122.89	0.58*	2.89	95.07	1.08	51.19	3.82	0.95	0.46	72.07	4.03*	78.55	1324	1.29*	874.00
P69-8-1-1-1 (Himso 330 x Hardee)	121.63	1.64	27.07*	85.44	0.96	51.21	3.02	0.33	0.13	48.16	-2.74	177.48	1014	1.39	220196.80*
P7-2-4-1 (SL284 x Pb1)	116.70	1.48	20.63*	76.22	0.81	30.39	4.96	2.14	2.35*	105.51	7.74	1294.20*	1409	0.94	576784.90*
NRC-95-03-01	115.00	1.72	18.37*	94.38	1.29	150.41*	4.00	1.14	0.15	65.82	-0.46*	1.13	1110	0.81	22256.94
P12-3-3 (SL284 x Bragg)	117.48	1.20	32.32*	84.84	1.32	46.53	3.84	-0.62	0.22	78.80	6.51	365.94*	1633	0.62	1094737.00*
P2-2 (VLS2 x Lee)	108.00	0.40	8.43*	61.04	1.06	16.70	3.56	0.43	0.37	41.96	0.39*	123.89	1153	1.01	457.63
P13-4 (DSD74-22 x Himso 308)	107.30	-0.18*	1.06	65.18	1.50	19.59	2.96	0.67	0.55	43.76	-1.23	164.85	925	1.02	946.00

P21-2 (Ankur x Pusa-20)	122.56	0.50*	0.47	85.04	1.43*	2.96	3.73	0.61	0.22	68.76	2.07	82.52	1463	0.96	101588.40*
P1-4 (SL284 x Bragg)	116.48	1.24	42.94*	79.53	1.66*	4.88	4.04	0.76	3.07*	91.42	10.66	2288.58*	1759	0.57*	112.13
P2-11-1-1 (PK472 x H330)	125.22	1.03	8.15*	74.84	0.83	56.09	4.07	0.43	0.82*	57.07	-0.94	900.97*	1707	1.20	444612.90*
Hara Soya (c)	117.52	0.75	17.95*	82.51	1.00	0.09	2.89	0.71	1.01*	45.96	-2.24	135.60	1050	1.17	40763.63
Him Soya (c)	118.52	1.16	50.99*	62.20	0.06	4.66	3.16	1.09	0.02	53.09	-1.43*	15.78	907	1.10	12548.13
Shivalik (c)	119.37	0.87	17.95*	70.56	0.40	57.70	3.69	0.52	0.01	65.24	0.31	83.85	1473	0.68*	2100.97
Bragg (c)	118.67	0.90	5.32*	75.47	0.56	0.08	2.86	0.38	0.41	50.96	0.70	543.82*	1385	1.43*	9562.75
Over all mean	**117.58**			**77.02**			**3.73**			**63.56**			**1266**		

** Significant at P≤0.05*

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Soybean (*Glycine max* L.) Genotypes for Water Logging Tolerance

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ABSTRACT

A screening technique known as 'cup method' was standardized and used for screening of soybean genotypes for tolerance to water logging conditions. Per cent increase in plant height and per cent reduction in dry weight were taken as criteria for screening genotypes with comparatively better performances. Fifty soybean genotypes including popular varieties, germplasm lines and breeding lines were screened with this method for the assessment of their response to artificially created water logging conditions. Based on these values, few genotypes viz., JS 95-60, JS 97-52, Bhatt, Cat 3299 and JS 93-05 showed relatively better tolerance among the genotypes under study, which can be used in breeding programme for the development of water logging tolerant varieties.

Key words: Cup method, screening, soybean, water logging

Soybean is an important oilseed crop cultivated under varying agro-climatic conditions across India. Growing health consciousness on nutrition and export value of de-oiled cake from soybean has made crop potential for further expansion both horizontally and vertically. The crop is also visualized as future energy crop for the production of bio-diesel, an eco-friendly usage to meet the fuel energy requirements in several countries. Rapid growth of soybean in terms of area and production has resulted in crop exposed to many biotic and abiotic stresses. Along with drought, salinity and nutrient deficiency, prolonged flooding due to heavy rains and low infiltration rate of the soils in which crop is grown (Vertisols), severely reduces the productivity of soybean in some of the major crop growing regions of India. The National Commission on Agriculture assessed in 1976 that an area of about 6.0 million hectare was waterlogged in the country. Out of this, an area of 3.4 million hectare was estimated to be suffering from surface water stagnation and 2.6 million

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hectare through rise in water table. The Ministry of Agriculture estimated in 1984-85 that an area of 8.53 m ha was suffering from the problem of waterlogging including both irrigated and unirrigated areas. At present, as much as 40 per cent of irrigated area suffers from excess soil moisture conditions in India (Rangley, 1987).

Crop plants require a free exchange of atmospheric gases for photosynthesis and respiration. In water logged conditions the diffusion of gases is hampered thus restricting the roots to absorb available oxygen (Armstrong, 1978). Turbid flood water becomes anaerobic especially during night (Setter *et al.,* 1987). Thus the plant growth is inhibited due to hypoxia or anoxia, finally leading to plant death. Soybean yields can reduce drastically due to water logging. About 17-43 per cent of yield loss occurs at vegetative growth stage and 50-56 per cent at reproductive stage because of water logging (Oosterhuis *et al.,* 1990). Moreover, flooding during early vegetative (V2) and early reproductive (R1 to R3) stages is more damaging to seed yield than during other stages (Linkemer *et al.,* 1998). Plants adapted to water logged conditions, have mechanism to cope with this stress, such as aerenchyma formation, increased availability of soluble sugars, greater activity of glycolytic pathway and fermentation enzymes and involvement of antioxidant defence mechanism to cope with the post hypoxia/anoxia oxidative stress. Water logging tolerance is a complex trait conferred by many physiological mechanisms and complicated by confounding factors such as temperature, plant developmental stage, nutrient availability, severity of water logging stress, soil physical properties, *etc* (Setter and Waters, 2003). Therefore, to overcome the losses on account of water logging, it is imperative to evaluate and identify genetic sources possessing relative tolerance/resistance to such conditions. Field trials conducted for screening genotypes for flooding tolerance are very difficult to manage, but they can be screened under simulated conditions. . Thus, we have developed an easy method for this purpose, which was standardized so that a number of lines could be screened anytime depending upon need of the hour.

MATERIAL AND METHOD

The aim of this study was to standardize the protocol for screening genotypes for their response to water logging stress over a period of time, as well as to evaluate the available soybean genotypes for their response to artificially induced flooding conditions. Thus, fifty soybean accessions including varieties and germplasm lines were evaluated using 'cup method' (Table 1). In this method plants were grown in 10 cm x 10 cm pots with one plant per pot. Each genotype was replicated four times. Flooding treatment was imposed at R1 growth stage for two weeks by placing individual pots in a trough and the trough was filled with water in such a way that the plants were immersed in water up to 10 cm above the soil surface. Plants in the control treatment were watered normally to maintain stress free normal growth. At the end of the flooding treatment, pots were drained and

Table 1. List of genotypes used for waterlogging screening (cup method)

S. No.	Genotype	S. No.	Genotype	S. No.	Genotype	S. No.	Genotype
1.	JS 90-41	14.	MAUS 199	27.	JS 93-05	40	PS 564
2.	JS 97-52	15.	MAUS 423	28.	JS 2	41.	MAUS 2
3.	JS 335	16.	MAUS 449	29.	JS 76-205	42.	MAUS 32
4.	JS 95-60	17.	MAUS 608	30.	JS 80-21	43.	MAUS 61-2
5.	JS 20-29	18.	MAUS 704	31.	JS 79-81	44.	MAUS 61
6.	JS 20-36	19.	Cat 198	32.	PUSA 40	45.	MAUS 81
7.	JS 20-38	20.	Cat 2718	33.	PUSA 16	46.	NRC 2
8.	JS 20-69	21.	Cat 3299	34.	PUSA 97-12	47.	NRC 12
9.	JS 20-77	22.	Ankur	35.	PUSA 98-14	48.	MACS 450
10.	MAUS 17	23.	Bhatt	36.	PK 262	49.	MACS 58
11.	MAUS 26-1	24.	NRC 7	37.	PK 472	50.	RKS 18
12.	MAUS 47	25.	NRC 37	38.	PS 1024		
13.	MAUS 59-1-1	26.	JS 71-05	39.	PS 1042		

plants were allowed to continue normal growth and recovery up to maturity. Data was recorded for days to flower initiation, days to maturity, plant height and dry matter weight.

Percent increase in plant height in controlled and water logged treatment was calculated as: per cent increase in height = (height at R4 - height at V5)/ height at R4 x 100. Another dependent variable "percent reduction in dry weight" was calculated according to the formula: Reduction in dry weight = (control - flooding)/control x 100. These two traits were taken as criteria for screening genotypes with comparatively better performances.

RESULTS AND DISCUSSION

Effect on growth

A huge range of variation was seen among the genotypes in treatment plot for plant height which ranged from - 3.41 to 36.52 compared to the genotypes of control plot, in which value ranged from 1.05 to 26.51. It is clear that there were genotypes for which there was a reduction in plant height (Pusa 40 with per cent increase of - 3.41%), while there was also a significant increase of 36.52 per cent (Bhatt) and this has overcome the increase in height of genotypes from control plot (Fig. 1). The average per cent increase in height for control plot was 7.54 per cent, whereas it was 8.02 per cent for treatment plot (Table 2). It means that most of these genotypes under water logged conditions are capable of maintaining, even surpassing the plant height to that under controlled conditions. Reduced plant growth due to water logging was also observed in tomato (Ezin *et al.,* 2010), *Annona* species (Nunex-Elisea, 1999), *Panicum antidotale* (Ashraf, 2003), *Paspalum dilatatum* (Vasellati, 2001) and soybean (VanTotai *et al.,* 2010). All of these plant species showed growth reduction to varying extents in waterlogged conditions. According to Cox *et al.*, (2003), plant height can be increased due to promotion of shoot extension, which is a developmental effect of flooding and it supplements the aerenchyma system where it improves access to aerial or dissolved oxygen or to light for the generation of photosynthetic oxygen.

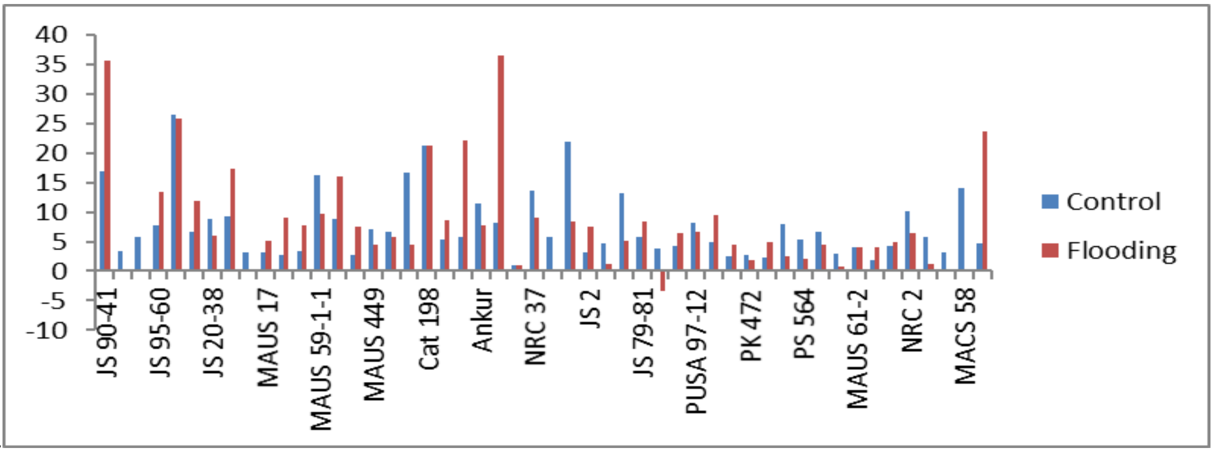

Fig. 1. Plant height for different genotypes under control and flooding conditions

Table 2. Average values for different characters under different treatments

Treatment	Plant height (% increase)	Days to maturity (No)	Dry weight (g)
Control	7.54	98	7.7
Flooding	8.02	97	5.35

Effect on yield and yield component

There was no significant difference for days to flowering initiation and days to maturity for the genotypes under controlled as well as flooding conditions. However, the average maturity for genotypes under flooding condition (97 days) was reduced than that of genotypes under controlled condition (98 days) (Table 2) (Fig. 2). Though the reduction is less, but it still reflects in the individual genotypes under both controlled and flooding conditions. The explanation behind this tendency is well given by Drew and Sisworo (1977). The nitrate uptake from soil is arrested due to microbial de-nitrification and damage to uptake mechanism (resulting from absence of oxygen), resulting the younger leaves takes nutrition from older leaves leading to premature senescence.

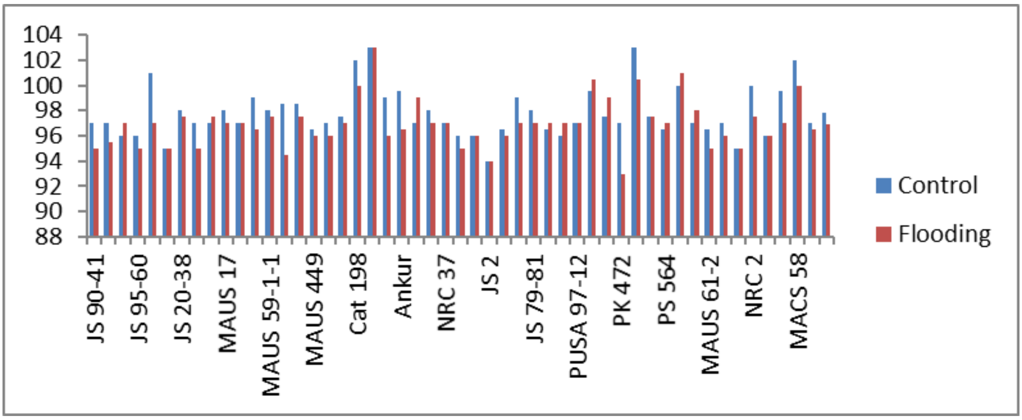

Fig. 2. Days to maturity for different genotypes under control and flooding conditions

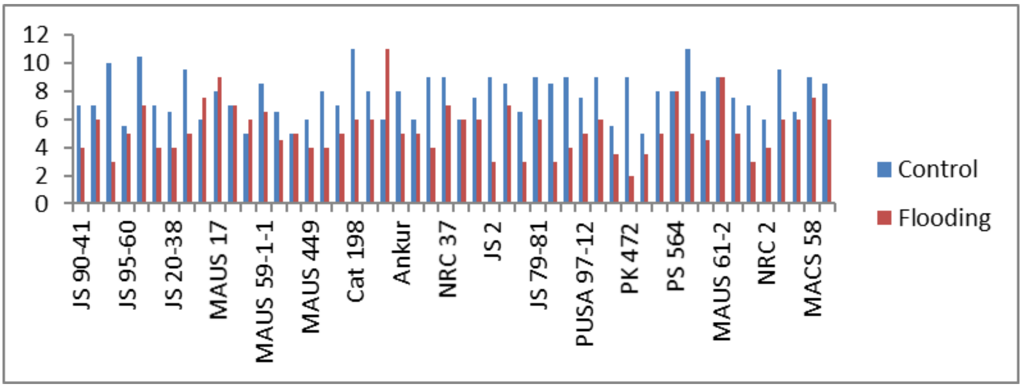

Fig. 3. Dry weight for different genotypes under control and flooding conditions

Dry matter weight was also considered as a criterion to distinguish genotypes for their response to flooding conditions. The average dry matter for control was 7.7 g, whereas for flooding treatment it was 5.35 g (Table 2). Therefore, the average dry matter reduction was found to be 30.5 per cent in flooding treatment. Overall reduction in dry weight was found to be in the range of 7.69 to 77.8 per cent, with lowest reduction in MACS 450 and highest reduction in PK 472 (Fig. 3). However, there were genotypes with no reduction in dry weight at all. Thus, the dry matter either reduced or remained unchanged, but never increased over control treatment. This shows that there was lot of variation among genotypes for their response to flooding treatment on dry matter. Bacanamwo and Purcell (1999) also observed reduction in biomass yield in flooded genotypes and suggested that this was all due to reduced level of N_2 accumulation during flooding conditions. Wilson (1988) suggested that for any limiting resource, availability within the plant decreases with distance from the site of uptake. This implies that under nutrition deficits, shoots are more starved than roots and decrease photosynthesis and overall dry matter accumulation, leading to reduction in dry weight.

The present study for standardizing screening protocol and evaluating soybean for water logging conditions demonstrated that the pot experiments under 'cup method' whether conducted on season or off-season can be used as a tool to screen a large number of genotypes with much ease as compared to under field trials. This method can save time as well as space while conducting screening trials. With the use of this procedure, the results obtained indicated that there was a significant variation for the tolerance of genotypes to flooding conditions. Out of fifty, few genotypes were showing better performance and these five genotypes *viz*., JS 95-60, JS 97-52, Bhatt, Cat 3299 and JS 93-05 were considered superior over the rest of genotypes for their performance under water logging conditions.

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Compatibility of Some Maize and Soybean Varieties for Intercropping Under Sandy Soil Conditions

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ABSTRACT

The spatial variation in plant species associated with intercropping is intended to reduce resource competition between species and increase yield potential. A two-year study was carried out at Ismailia Agricultural Experiments and Research Station, ARC, Ismailia Governorate, during 2011 and 2012 seasons to evaluate the compatibility of some maize and soybean varieties for intercropping under sandy soil conditions to determine the dual intercropping effects on yield of both crops. Alternating ridges (60 cm/ridge) between maize and soybean were used as 2:4, respectively; soybean was grown by two rows per ridge and thinned to two plants per hill (15 cm apart), while, maize was distributed in two plants per hill (40 cm apart), in addition to solid cultures of both crops. Three maize varieties (S.C. 122, S.C. 166 and S.C. 176) and three soybean varieties (Giza 22, Giza 35 and Giza 111) were used. A split-split plot distribution in randomized complete block design replicated thrice was used. Combined data (across the two seasons) indicated that all the studied soybean characters were affected significantly by shading of adjacent maize plants except numbers of branches and pods per plant. Maize + soybean intercropping decreased seed yields per plant and per ha by 5.48 and 23.94 per cent, respectively, as compared to solid culture of soybean. Maize varieties affected significantly soybean yield and its attributes except plant height, numbers of branches and pods per plant. Soybean plants produced the highest seed yields per plant and per ha by intercropping with maize variety S.C. 166. Soybean varieties differed significantly for all the studied soybean characters except numbers of branches and pods per plant. Soybean variety Giza 22 had the highest values for seed index, seed yields per plant and per ha, as well as, harvest index, while soybean variety Giza 111 recorded the highest values for biological yield and plant height. Seed yields per plant and per ha were affected significantly by the interaction between maize and soybean varieties. Soybean variety Giza 22 was more compatible with maize variety S.C. 166 which recorded 2.12 tonnes soybean seeds in addition to 3.65 tonnes maize grains per ha. Land equivalent ratio (LER) and relative crowding coefficient (RCC) were above 1.00 indicating intercrop advantages for all combinations. The value of aggressivity of soybean was negative for all combinations indicating that soybean is dominated component in the present study.

Key words: Competitive relationships, intercropping, maize varieties, soybean varieties, sandy soil

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Egypt is one of the countries facing great challenges due to its limited water resources represented mainly by its fixed share of the Nile water and its aridity as a general characteristic. The agriculture requirements exceed 80 per cent of the total demand for water (Abdel-Shafy and Aly, 2002). The per capita share of water has dropped dramatically to less than 1000 m^3, which is classified as "Water poverty limit". It is projected that the value decreases to 500 m^3 per capita in the year 2025 (Abdel-Wahaab, 2003). Currently, water is a primary limiting factor in Egyptian agriculture especially after building the Ethiopian Renaissance Dam which could be affected negatively Nile water of downstream countries, *i.e.* South Sudan, Sudan and Egypt and thus a significant deficiency in the amount of water allocated for irrigation and agriculture. Some Egyptian experts said that the Ethiopian dam could cause great harm to Egypt, as it may lead to a lack of Nile water, dry agricultural land and increase soil salinity in the Delta region. It is important to address our efforts to this fundamental issue by increasing crop production per unit area with reducing their water consumption especially on the reclaimed sandy soils.

This can be achieved through an effective use of modern cropping and irrigation techniques. Use of intercropping culture under sprinkler irrigation could be playing an important role for maximizing land equivalent ratio under low conditions of sandy soil. Component crops in intercropping may differ in their use of growth resources over time and space such that when grown together they make more efficient use of light, water and nutrients than when grown separately (Weil and McFadden, 1991). It can provide production advantages over sole crops in the absence of increased external inputs due to more efficient utilization of resources (Chowdhury and Rosario, 1992). It lead to increase in available water as a result of increasing field capacity which can be attributed to better soil structural development and stability related to higher organic matter and root activity. Also, it increases the total porosity and macro-porosity (Mapa, 1995), as well as, the size and stability of yields compared to monocropping, especially under low conditions (Hauggaard-Nielsen *et al*., 2006). Finally, it can be used as a tool to improve competitive ability of a canopy with good suppressive characteristics (Rezvani *et al*., 2011).

Corn – soybean intercrop system has been reported to use resources more efficiently and is able to remove more resources than monocrop systems (Marchiol *et al*., 1992). Compared with corresponding sole crops, yield advantages have been recorded in many intercropping systems; including corn and soybean (West and Griffith, 1992). Moreover, Ouda *et al*. (2007) concluded that to attain high water use efficiency from 1:2 soybean/maize intercropping pattern, irrigation should be applied using 1.0 pan evaporation coefficient, which could save up to 7 per cent of irrigation amounts. Finally, maize prolific hybrids intercropping with soybean, as legume crop, increased productivity of cropping system in favourable meteorological conditions (Dolijanovic *et al.,* 2013).

In Egypt, there is a decline in area under soybean (*Glycine max* L.) in the Nile

Valley and Delta, where it reached to about 8,785 ha in 2011 with an average yield of 3.23 tonnes per ha, while, under maize (*Zea mays* L.) to about 6,79,898 ha in 2011 with an average yield of 1.35 tonnes per ha (Egyptian Bulletin of Statistical Cost Production and Net Return, 2012). Consequently, there is a need to expand the scope of soybean cultivation outside the Nile Valley and Delta.

From earlier studies on different intercropping patterns, it was realized that the efficiency of this system can be enhanced by the proper choice of varieties of both the crops (Sayed Galal *et al.*, 1983). There were significant varietal differences among three maize varieties, distinguished by root length density and length/weight ratio distributions at depth and at varying soil moisture regimes under sandy loam soil (Aina and Fapohunda, 1986).

On the other hand, soybean varieties could be successfully grown under sandy soil. Soybean *cv*. Hodgson 78 showed a large decrease in total dry weight, whereas, soybean *cv*. Baegunkong showed smaller decreases as soil water potential was decreased (Jin and Lee, 1997). Increasing moisture deficit decreased significantly dry matter weight of all plant organs and shoot: root ratio at all growth stages of soybean. Continuous moisture stress reduced number of branches per plant (Ghosh *et al.*, 2000). Drought – stress treatment had its greatest effect on branch vegetative and reproductive development of soybean as compared with main stem development (Frederick *et al.*, 2001).

Also, Noureldin *et al*. (2002) revealed that Giza 111 genotype recorded higher values for seed yield per plant and per unit area, protein and oil yields per unit area under drip irrigation in sandy soil at Wadi El-Faregh region in West of Egypt. On the other hand, Giza 82 genotype recorded higher values for seed yield per plant and per unit area, harvest index "HI", protein and oil yields per unit area followed by Crawford genotype under surface irrigation in sandy soil at Domo region in Middle of Egypt.

The objective of this study was to evaluate the compatibility of some maize and soybean varieties for intercropping under sandy soil conditions to determine the dual intercropping effects on yield performance of both the crops.

MATERIAL AND METHODS

A two – year study was carried out at Ismailia Agricultural Experiments and Research Station, A.R.C., Ismailia governorate (Lat. 30° 35' 30" N, Long. 32° 14' 50" E, 10 m a.s.l.), Egypt during 2011 and 2012 summer seasons to evaluate the compatibility of some maize and soybean varieties for intercropping under sandy soil conditions to determine the dual intercropping effects on yield performance of both the crops. Three soybean (*Glycine max* L.) varieties (Giza 22, Giza 35 and Giza 111) and three maize (*Zea mays* L.) varieties (S.C. 122 'white', S.C. 166 and S.C. 176 'yellow') kindly provided by Legumes and Maize Research Departments, Field Crops Research Institute, ARC were used in the investigation (Table 1). The preceding winter crop was wheat in both seasons.

Mechanical and chemical analysis of the soil (0 – 60 cm) were done by Water, Soil and Environment Research Institute, ARC (Table 2). The experimental soil (0-60 cm) had 11.28 per cent sand, 2.00 per cent silt and 86.72 per cent silt, and loamy sand texture.

Sprinkler irrigation (water duty = 5873 m^3/ha) was the irrigation system in the area, the amount of water irrigation per hour was 69.9 m^3 per ha. Normal cultural practices for growing maize and soybean crops were used as recommended in the area. Soybean and maize crops were sown at the same date on 29 and 20th May at 2011 and 2012 seasons, respectively. Maize was thinned to two plants at 40 cm between hills under intercropping culture.

Soybean was thinned to two plants at 15 cm between hills under intercropping and solid cultures. The experiment included two cropping systems, three maize varieties and three soybean varieties (Fig. 1). Recommended solid cultures of both crops were used to estimate the competitive relationships. Cropping systems (intercropping and solid) were randomly assigned to the main plots, maize varieties were allotted in sub-plots and soybean varieties were devoted to sub-sub-plots. The area of sub-sub-plot was 14.4 m^2, it consisted of 6 ridges, and each ridge was 4.0 m in length and 0.6 m in width.

Yield and its attributes

Maize yield and its attributes: At harvest, the observations on important traits were recorded on ten guarded plants from each plot. Ear leaf area (cm^2) was determined as leaf length x leaf width x 0.75 according to Francis *et al.* (1969). Ear leaf area was taken from three leaves around the ear. Leaf angle per plant (^{0}) was determined physically using a protractor. Upper leaf angle was taken as the vertical distance between the stalk and leaf. Grain yield per plant (g) and grain yield per ha (ton) was recorded on the basis of experimental plot area by harvesting all maize plants of each plot and adjusted maize grains to 15.5 per cent moisture and estimated according to cropping system.

Soybean yield and its attributes: At harvest, the observations on traits, namely plant height (cm), numbers of branches and pods per plant, seed index (g), seed yield per plant were recorded on ten guarded plants from each plot. Biological and seed yields were recorded on the basis of experimental plot and expressed as tons per ha. The yield data was utilized to work out harvest index using formula: Harvest index = Economic yield/Biological yield * 100 (Clipson *et al.*, 1994).

Competitive relationships

Land equivalent ratio (LER): LER, defined as the ratio of area needed under solid cropping to one of intercropping at the same management level to produce an equivalent yield (Mead and Willey, 1980), was calculated as follows:

$$LER = (Y_{ab} / Y_{aa}) + (Y_{ba} / Y_{bb})$$

Where, Y_{aa} = Pure stand yield of crop a

Table 1. Pedigree and country of origin of maize and soybean varieties

Maize varieties*			Soybean varieties**			
Varieties	Pedigree	Country of origin	Varieties	Pedigree	Maturity group	Country of origin
S.C. 122	GZ 628 x 603	Egypt	Giza 22	Giza 21 x 186 k – 73	IV	Egypt
S.C. 166	GZ 639 x 656	Egypt	Giza 35	Crawford x Celeste (Early)	IV	Egypt
S.C. 176	Sakha 10 x Sakha 6026	Egypt	Giza 111	Crawford x Celeste (Late)	IV	Egypt

**Data from Maize Research Department, FCRI, ARC, Giza, Egypt; **Data from Food Legumes Res. Dept., FCRI, ARC, Giza, Egypt.*

Table 2. Chemical properties of soil (0-60 cm) from experimental site

Properties	Growing season		Properties	Growing season	
	2011	2012		2011	2012
pH	8.7	8.3	Cl^- (ml/l)	0.75	0.65
E.C. (mMohs/cm)	0.25	0.25	SO_4^{-2} (ml/l)	1.95	1.83
$CaCO_3$ (%)	0.6	0.3	N (ppm)	5.0	10.0
Ca^{+2} (ml/l)	2.0	1.4	P (ppm)	15.0	7.0
Mg^{+2} (ml/l)	0.4	1.2	K (ppm)	56.0	48.0
Na^+ (ml/l)	0.9	0.6	Fe (ppm)	1.00	1.60
K^+ (ml/l)	0.1	0.08	Cu (ppm)	0.02	0.06
CO_3^{-2} (ml/l)	--	--	Zn (ppm)	0.10	0.56
HCO_3^- (ml/l)	0.7	0.8	Mn (ppm)	1.16	2.74

(maize); Y_{bb} = Pure stand yield of crop b (soybean); Y_{ab} = Intercrop yield of crop a (maize); Y_{ba} = Intercrop yield of crop b (soybean)

Relative crowding coefficient (RCC): RCC, which estimates the relative dominance of one species over the other in the intercropping system (Banik *et al*., 2006) was calculated as follows:

$K = K_a \times K_b$

$K_a = Y_{ab} \times Z_{ba} / [(Y_{aa} - Y_{ab}) \times Z_{ab}]$; $K_b = Y_{ba} \times Z_{ab} / [(Y_{bb} - Y_{ba}) \times Z_{ba}]$

Where, Y_{aa} = Pure stand yield of crop a (maize); Y_{bb} = Pure stand yield of crop b (soybean); Y_{ab} = Intercrop yield of crop a (maize); Y_{ba} = Intercrop yield of crop b (soybean); Z_{ab} = The respective proportion of crop a in the intercropping system (maize); Z_{ba} = The respective proportion of crop b in the intercropping system (soybean).

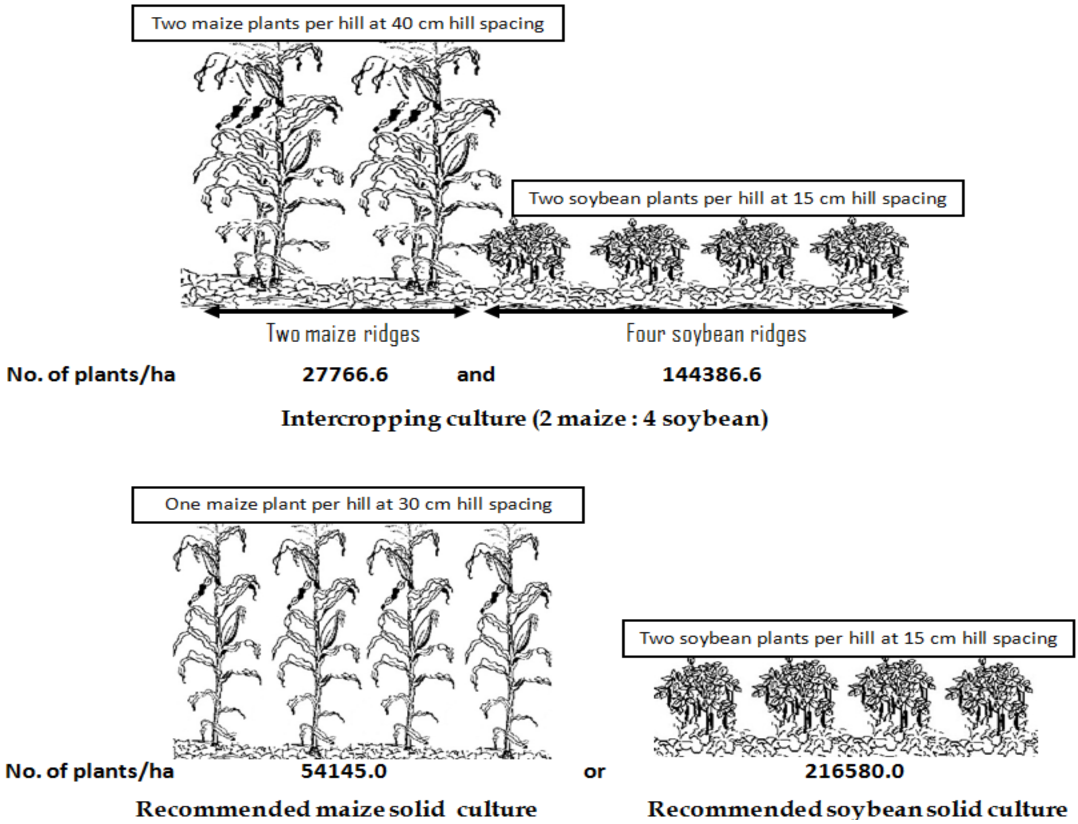

Fig.1. Intercropping maize with soybean and solid cultures of both crops

Aggressivity: Aggressivity, which represents a simple measure of how much the relative yield increase in one crop is greater than the other in an intercropping system (Willey, 1979), was calculated as follows:

$A_{ab} = [Y_{ab} / (Y_{aa} \times Z_{ab})] - [Y_{ba} / (Y_{bb} \times Z_{ba})]$;
$A_{ba} = [Y_{ba} / (Y_{bb} \times Z_{ba})] - [Y_{ab} / (Y_{aa} \times Z_{ab})]$

Where, Y_{aa} = Pure stand yield of crop a (maize); Y_{bb} = Pure stand yield of crop b (soybean); Y_{ab} = Intercrop yield of crop a (maize); Y_{ba} = Intercrop yield of crop b (soybean); Z_{ab} = The respective proportion of crop a in the intercropping system (maize); Z_{ba} = The respective proportion of crop b in the intercropping system (soybean)

Statistical manipulation

Analysis of variance of the obtained results of each season was performed. The homogeneity test was conducted of error mean squares and accordingly, the combined analysis of the two experimental seasons was carried out. The measured variables were analyzed by ANOVA using MSTATC statistical package (Freed, 1991). Mean comparisons were done using least significant differences (L.S.D) method at 5 per cent level of probability to compare differences between the means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Maize yield and its attributes

Cropping systems: Intercropping maize with soybean increased significantly ear leaf area, grain yields per plant and per ha, whereas, leaf angle was not affected in comparison with maize solid culture (Table 3). These results suggested that alternating ridges of intercropping pattern (2:4) possessed growth advantages than those grown under solid planting pattern, where maize plants benefited greatly from environmental resources which led to decrease in intra-specific competition between maize plants. It is clear that intercropping pattern (2:4) encouraged maize canopy to occupy more space and utilizing solar radiation and converting it to higher plant dry weight through photosynthesis process as compared with maize solid culture. These results are in harmony with those obtained by Metwally *et al.* (2009 a and b), who showed that solid planting of maize recorded the highest grain yield per unit area as compared with intercropping maize with soybean but it gave lower values for total leaf area and grain yield per plant.

Maize varieties: Maize variety S.C. 166 had the highest values of ear leaf area, grain yields per plant and per ha, while the lowest values of ear leaf area, grain yields per plant and per ha were recorded by maize variety S.C. 122 (Table 3). It is evident that leaf angle affected the amount of light transmitted in a maize crop. Several studies have shown that radiation interception is influenced by several architectural attributes, including leaf orientation. Light interception by canopy increases as the leaf orientation to horizontal increases thus decreasing the maximum potential photosynthesis by self-shading. Therefore, breeding for more erect oriented leaves may increase the net photosynthesis and ultimately the yield of the plant. Furthermore, erect oriented leaves will allow more transmission of light to the understory crop and thus can lead to transgressive yielding. These results are similar with those obtained by Muraya *et al.* (2006), who observed that there were significant differences among the synthetic maize varieties, commercial hybrid and KSTP for all traits under study. Also, Alom *et al.* (2010) showed that Pacific-11 variety of hybrid maize was higher yielder in monoculture and its respective intercrops because of more number of cobs per plant and higher 1000-grain weight or cumulative effect of yield attributes as compared with the other maize hybrids.

Soybean varieties: All the studied traits of maize varieties were not affected by soybean varieties (Table 3). Obviously, genetic variation of soybean varieties is still not sufficient to do significant impact

Table 3. Effect of cropping systems, maize and soybean varieties, and their interactions on ear leaf area, leaf angle, grain yields per plant and per ha of maize plants (combined data across 2011 and 2012 seasons)

Characters	Soybean varieties	Ear leaf area (cm^2)				Leaf angle (^{0})				Grain yield/plant (g)				Grain yield/ha (ton)			
		Maize varieties			Mean	Maize varieties			Mean	Maize varieties			Mean	Maize varieties			Mean
Cropping systems		S.C. 122	S.C. 166	S.C. 176		S.C. 122	S.C. 166	S.C. 176		S.C. 122	S.C. 166	S.C. 176		S.C. 122	S.C. 166	S.C. 176	
Intercropping culture	Giza 22	701	873	765	**779**	20.6	32.2	28.8	**27.2**	112.36	129.74	120.93	**121.01**	3.11	3.65	3.35	**3.37**
	Giza 35	741	956	835	**844**	20.4	31.9	29.3	**27.2**	110.64	130.02	116.24	**118.96**	2.98	3.53	3.23	**3.24**
	Giza 111	813	915	787	**838**	20.5	32.0	29.1	**27.2**	110.12	129.19	113.97	**117.76**	2.98	3.58	3.26	**3.27**
Average of intercropping		**751**	**914**	**795**	**820**	**20.5**	**32.0**	**29.0**	**27.1**	**111.04**	**129.65**	**117.04**	**119.24**	**3.02**	**3.58**	**3.28**	**3.29**
Recommended solid culture		672	808	723	**734**	20.4	32.1	29.0	**27.1**	91.20	101.38	99.17	**97.25**	4.69	5.11	4.98	**4.92**
General mean of maize varieties		**711**	**861**	**759**	**777**	**20.4**	**32.0**	**29.0**	**27.1**	**101.12**	**115.51**	**108.10**	**108.24**	**3.85**	**4.34**	**4.13**	**4.10**
L.S.D. at 5% of Cropping systems (C)					78.1				N.S.				19.87				0.36
L.S.D. at 5% of Maize varieties (M)					73.2				2.82				13.64				0.12
L.S.D. at 5% of Soybean varieties (S)					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of C x M					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of C x S					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of M x S					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of C x M x S					N.S.				N.S.				N.S.				N.S.

in high yielding ability of maize varieties. The results are in accordance with those obtained by Metwally *et al.* (2009a), who demonstrated that total leaf area, grain yields per plant and per unit area were not affected by soybean varieties.

Interactions among cropping systems, maize and soybean varieties: With respect to response of maize varieties to cropping systems, ear leaf area, grain yields per plant and per ha did not reach the 5 per cent level of significance (Table 3). These data show that each of these two factors act independently on all the studied traits of maize meaning that maize varieties responded similarly *($P > 0.05$)* to cropping systems. These results are in harmony with those obtained by Muraya *et al.* (2006) who investigated that the studied characters were not affected by the interaction between maize genotypes and cropping systems. Also, Metwally *et al.* (2009b) indicated that grain yields per plant and per unit area were not affected by the interaction between cropping systems and maize varieties.

With respect to response of soybean varieties to cropping systems, ear leaf area, grain yields per plant and per ha did not reach the 5 per cent level of significance (Table 3). These data show that each of these two factors act independently on all the studied traits of maize meaning that soybean varieties responded similarly *($P > 0.05$)* to cropping systems. These results are parallel with those obtained by Metwally *et al.* (2009a), who indicated that grain yields per plant and per unit area were not affected by the interaction between cropping systems and soybean varieties.

With respect to response of maize varieties to soybean varieties, ear leaf area, grain yields per plant and per ha did not reach the 5 per cent level of significance (Table 3). These data show that each of these two factors act independently on all the studied traits of maize meaning that maize varieties responded similarly *($P > 0.05$)* to soybean varieties.

With respect to the interactions among cropping systems, maize and soybean varieties, ear leaf area, grain yields per plant and per ha did not reach the 5 per cent level of significance (Table 3).

Soybean yield and its attributes

Cropping systems: Intercropping maize with soybean resulted in significant differences for biological yield per ha, plant height, seed index, seed yields per plant and per ha, as well as, harvest index , whereas, numbers of branches and pods per plant were not affected (Tables 4 and 5). Soybean solid culture had higher values *($P \leq 0.05$)* for biological yield per ha, seed index, seed yields per plant and per ha, as well as, harvest index as compared to those grown under intercropping culture, but the reverse was true for plant height.

Shading effects of intercropping pattern 2:4 formed unfavorable conditions for soybean plant during the early periods of soybean plant growth and consequently more amounts of plant hormones. So, the observed response in plant height of soybean may be primarily attributed to an increase of internode elongation of soybean plant as a result of increasing plant hormones. Moreover, as the soybean plant becomes taller, self-shading is enhanced and there may be an exceedingly steep light gradient between the top and bottom of the plant (Addo- Quaye *et al.,* 2011).These results were reported by Undie *et al.* (2012), who revealed that soybean plant height was increased above its sole crop height at all intercrop arrangements.

Numbers of branches and pods per plant in intercrops were statistically equal ($P > 0.05$) to those grown under solid culture. These results are in agreement with those obtained by Yusuf *et al.* (2012), who found that the number of soybean pods produced per plant, were not significantly different between the intercrop treatments in one season only. Also, Amjadian *et al.* (2013) investigated that the planting ratio (100 % soybean + 0 % corn, 50 % soybean + 50 % corn and 0 % soybean + 100 % corn) had no significant effect on number of pods per plant.

On the other hand, intercropping soybean with maize decreased ($P \leq 0.05$) seed index, seed yields per plant and per ha by 3.80, 5.48 and 23.94 per cent, respectively, as compared to soybean solid culture (Table 5). This may be due to the adverse effects of intercropping culture which increased inter-specific competition between maize and soybean plants for basic growth resources (Mohta and De, 1980 and Olufajo, 1992) as compared with soybean solid culture. These data indicated that soybean plant had lower ability to use availablegrowth resources during the vegetative growth stages than maize plant under intercropping conditions.

It is obvious that intercropping pattern 2:4 formed unfavorable conditions for soybean plant which reflected on the severe decrease in yield attributes of soybean as compared with soybean solid culture. These results are in the same context of those obtained by Mudita *et al*. (2008), who revealed that intercropping soybeans with maize severely affected soybean yields. Also, Egbe (2010) investigated that intercropped soybean produced lower seed yield than their sole crop counterparts. Metwally *et al*. (2012) showed that solid plantings of soybean had the highest weight of 100 seeds, seed yields per plant and per ha as compared with intercropping cultures. Moreover, Ijoyah *et al.* (2013) showed that intercropping soybean with maize reduced ($P \leq 0.05$) soybean yield by 43.8 per cent and 55.6 per cent, respectively, in 2011 and 2012.

On contrary, Amjadian *et al*. (2013) found that intercropping corn with soybean increased 1000 – grain weight and seed yield by 3.3 and 31.8 per cent, respectively, in comparison with solid planting of soybean.

Maize varieties: Maize varieties affected significantly biological yield per ha, seed index, seed yields per plant and per ha, as well as, harvest index by the maize varieties, whereas, plant height, numbers of branches and pods per plant were not affected (Tables 4 and 5). Biological yield per ha, seed index, seed yields per plant and per ha, as well as, harvest index were decreased by the maize varieties. Intercropping maize variety S.C. 166 with soybean plants had little negative effect on soybean seed yield and its attributes as compared with those intercropped with the other maize varieties. This may be due to canopy structure of S.C. 166 variety played an important role to minimize the adverse effects on soybean yield attributes and consequently seed yield per ha. Maize variety S.C. 166 had leaves with acute angle which lead to penetrate more solar radiation to adjacent soybean plants and consequently great efficiency in photosynthesis process and more dry matter accumulation and finally obtain the highest seed yield per unit area. These results are in agreement with those obtained by Dolijanovic *et al.* (2013), who indicated that low yields of the above-ground biomass of soybean were recorded in the intercrops with late maturity maize hybrids in 2005 in comparison with the other maize hybrids.

Soybean varieties: Soybean varieties differed significantly for biological yield per ha, plant height, seed index, seed yields per plant and per ha, as well as, harvest index, whereas, numbers of branches and pods per plant were not differed (Tables 4 and 5). These results are in harmony with those obtained by Metwally *et al.* (2012), who investigated that the two soybean varieties (Giza 22 and Giza 111) did not differ significantly for number of pods per plant.

Soybean variety Giza 22 recorded the highest values of seed index, seed yields per plant and per ha, as well as, harvest index, whereas, soybean variety Giza 111 had higher values of biological yield per ha and plant height in comparison with the others. This may be due to canopy structure of soybean variety Giza 22 have narrow leaves than the others which permit more solar radiation to the other leaves of the plant and led to increase in accumulation of dry matter in different organs of the plant which reflected on the highest seed yield per plant. These data showed that soybean varieties differed in yielding ability. Similar variability indicating considerable diversity for seed yield per plant was observed by Noureldin *et al*. (2002), who studied behavior ten Egyptian soybean genotypes in sandy soil conditions and they showed that Giza 82 genotype recorded higher seed yield per plant followed by Crawford genotype. Moreover, Egbe (2010) found that soybean varieties Samsoy 2 and TGX 923-2E gave significantly higher seed yield than TGX 536-O2D. Finally, Metwally *et al.* (2012) proved that soybean variety Giza 22 gave significantly higher seed yield per plant than the other variety (Giza 111).

Interactions among cropping systems, maize and soybean varieties: With respect to response of maize varieties to cropping systems, biological yield per ha, plant height, seed index, seed yields per plant and per ha, as well as, harvest index did not reach the 5 per cent level of significance (Tables 4 and 5). These data show that each of these two factors act independently on all the studied traits of soybean meaning that maize varieties responded similarly *($P > 0.05$)* to cropping systems. These results are in agreement with those obtained by Metwally *et al.* (2009 b), who indicated that there was no significant effect of intercropped corn varieties on soybean plant characters and seed yield per ha.

Table 4. Effect of cropping systems, maize and soybean varieties, and their interactions on biological yield, plant height, numbers of branches and pods per soybean plant at harvest (combined data across 2011 and 2012 seasons)

Characters	Maize varieties	Biological yield (ton/ha)				Plant height (cm)				Branches (No/plant)				Pods (No/plant)			
		Soybean varieties			Mean	Soybean varieties			Mean	Soybean varieties			Mean	Soybean varieties			Mean
Cropping systems		Giza 22	Giza 35	Giza 111		Giza 22	Giza 35	Giza 111		Giza 22	Giza 35	Giza 111		Giza 22	Giza 35	Giza 111	
Intercropping culture	S.C. 122	8.10	7.11	8.37	**7.86**	87.88	83.13	88.53	**86.51**	2.84	2.68	3.05	**2.85**	35.02	32.31	35.21	**34.18**
	S.C. 166	9.23	8.34	9.46	**9.01**	86.06	81.78	87.31	**85.05**	3.08	2.87	3.18	**3.04**	35.86	33.58	36.04	**35.16**
	S.C. 176	8.54	8.10	8.99	**8.54**	87.13	81.91	87.96	**85.66**	3.01	2.84	3.16	**3.00**	35.34	33.43	35.89	**34.88**
Average of intercropping		**8.62**	**7.85**	**8.94**	**8.47**	**87.02**	**82.27**	**87.93**	**85.74**	**2.97**	**2.79**	**3.13**	**2.96**	**35.40**	**33.10**	**35.71**	**34.74**
Recommended solid culture		10.81	10.39	10.94	**10.71**	86.54	80.17	86.81	**84.50**	3.16	2.96	3.28	**3.13**	37.08	35.08	37.32	**36.49**
General mean of soybean varieties		**9.71**	**9.12**	**9.94**	**9.59**	**86.78**	**81.22**	**87.37**	**85.12**	**3.06**	**2.87**	**3.20**	**3.04**	**36.24**	**34.09**	**36.51**	**35.61**
L.S.D. at 5% of Cropping systems (C)					2.19				1.19				N.S.				N.S.
L.S.D. at 5% of Maize varieties (M)					1.11				N.S.				N.S.				N.S.
L.S.D. at 5% of Soybean varieties (S)					0.79				1.02				N.S.				N.S.
L.S.D. at 5% of C x M					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of C x S					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of M x S					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of C x M x S					N.S.				N.S.				N.S.				N.S.

Table 5. Effect of cropping systems, maize and soybean varieties, and their interactions on seed index, seed yields per plant and per ha of soybean, as well as, harvest index (combined data across 2011 and 2012 seasons)

Characters	Maize varieties	Seed index (g)				Seed yield (g/plant)				Seed yield (ton/ha)				Harvest index (%)			
		Soybean varieties			Mean	Soybean varieties			Mean	Soybean varieties			Mean	Soybean varieties			Mean
Cropping systems		Giza 22	Giza 35	Giza 111		Giza 22	Giza 35	Giza 111		Giza 22	Giza 35	Giza 111		Giza 22	Giza 35	Giza 111	
Intercropping culture	**S.C. 122**	12.02	10.31	11.86	**11.39**	8.77	6.43	7.53	**7.57**	1.85	1.48	1.80	**1.71**	22.83	20.81	21.50	**21.71**
	S.C. 166	12.48	10.89	12.19	**11.85**	9.01	6.79	7.92	**7.90**	2.12	1.72	2.00	**1.95**	22.96	20.62	21.35	**21.64**
	S.C. 176	12.40	10.77	11.92	**11.69**	8.89	6.65	7.81	**7.78**	1.97	1.58	1.85	**1.80**	23.06	19.50	20.57	**21.04**
Average of intercropping		**12.30**	**10.65**	**11.99**	**11.64**	**8.89**	**6.62**	**7.75**	**7.75**	**1.98**	**1.59**	**1.88**	**1.81**	**22.95**	**20.31**	**21.14**	**21.46**
Recommended solid culture		12.61	11.21	12.49	**12.10**	9.28	7.08	8.26	**8.20**	2.54	2.24	2.37	**2.38**	23.49	21.55	21.66	**22.23**
General mean of soybean varieties		**12.45**	**10.93**	**12.24**	**11.87**	**9.08**	**6.85**	**8.00**	**7.97**	**2.26**	**1.91**	**2.12**	**2.09**	**23.22**	**20.93**	**21.40**	**21.85**
L.S.D. at 5% of Cropping systems (C)					0.42				0.43				0.55				0.73
L.S.D. at 5% of Maize varieties (M)					0.33				0.29				0.21				0.60
L.S.D. at 5% of Soybean varieties (S)					0.27				0.19				0.18				0.52
L.S.D. at 5% of C x M					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of C x S					N.S.				N.S.				N.S.				N.S.
L.S.D. at 5% of M x S					N.S.				0.40				0.49				N.S.
L.S.D. at 5% of C x M x S					N.S.				N.S.				N.S.				N.S.

With respect to response of soybean varieties to cropping systems, biological yield per ha, plant height, seed index, seed yields per plant and per ha, as well as, harvest index did not reach the 5 per cent level of significance (Tables 4 and 5). These data reveal that cropping systems x soybean varieties interaction was not observed for all the studied traits of soybean. Similar results were reported by Sharma and Mehta (1988), who found that cropping system x soybean variety interaction was insignificant for seed index. Moreover, Mudita *et al*., (2008) showed that the interaction between soybean cultivar and intercropping was not significant for soybean yield.

With respect to response of maize varieties to soybean varieties, seed yields per plant and per ha were affected significantly by the interaction between maize and soybean varieties, whereas, biological yield per ha, plant height, seed index and harvest index were not affected (Tables 4 and 5). These data show that each of these two factors act dependently on seed yields per plant and per ha meaning that soybean varieties did not respond similarly *($P \leq 0.05$)* to maize varieties for these traits. Maize variety S.C. 166 x soybean variety Giza 22 interaction had the highest seed yields per plant and per ha, whereas, the lowest seed yields per plant and per ha were obtained by intercropping maize variety S.C. 122 with soybean variety Giza 35 as compared with the other varieties (Table 5). This advantage of the highest seed yields per plant and per ha by intercropping maize variety S.C. 166 with soybean variety Giza 22 over the others may be due to canopy structure of maize variety S.C. 166 (Table 3) which reflected on the low shading around intercropped soybean variety Giza 22. Canopy structure of soybean variety Giza 22 which have narrow leaves as compared with the other varieties (Metwally *et al*., 2012) was more efficient in utilizing solar energy with maize variety S.C. 166 and consequently more dry matter accumulation in different parts of soybean plant organs as compared with the other varieties. These results implied that canopy structure of soybean variety Giza 22 integrates with canopy structure of S.C. 166 and consequently reducing inter-specific competition between the two species for basic growth resources (Olufajo, 1992), which resulted in minimizing the adverse effects of shading maize on adjacent soybean plant which known as a compatibility between two different species. These results are in the same context with those obtained by Mudita *et al*. (2008), who revealed that soybean variety Storm yielded better than soybean variety Solitaire when intercropped, the yield difference was greater when intercropped with maize variety SC513. However, Fang *et al*. (2011) indicated that plant roots could integrate information on P status and root behavior of neighboring plants. When intercropped with its kin, maize or soybean roots grew close to each other, when maize GZ1 was grown with soybean HX3, the roots on each plant tended to avoid each other and became shallower on stratified P supply, but not found with maize NE1.

The interactions among cropping systems, maize and soybean varieties did not affect biological yield per ha, plant height, seed index, seed yields per plant and per ha, as well as, harvest index (Tables 4 and 5). These data show that each of these three factors act independently on all the studied traits of soybean meaning that there was no effect *($P > 0.05$)* of cropping systems x maize varieties x soybean varieties on all the studied traits of soybean.

Competitive relationships

Land Equivalent Ratio (LER): The values of LERs were estimated by using data of recommended solid cultures of both crops. Relative yields of maize and soybean were affected significantly by the cropping systems (Table 6 and Fig. 2). Intercropping pattern 2:4 had higher values *($P \leq 0.05$)* for relative yields of maize and soybean as compared with soybean solid culture. Number of maize and soybean plants played a major role in increasing productivity yields of maize and soybean under intercropping. Relative yield of maize was affected by the maize varieties, whereas, relative yield of soybean was not affected (Table 6 and Fig. 2). Intercropping soybean plants with maize variety S.C. 166 had higher value for relative yield of maize, whereas, lower relative yield of maize was obtained by growing soybean plants with maize variety S.C. 122. These data indicated that intercropping soybean plants with maize variety S.C. 166, which had acute leaf angle, caused significant increase in soybean yields per plant and per ha than intercropping soybean plants with maize variety S.C. 122 which had obtuse leaf angle.

Relative yield of maize was affected by the soybean varieties, whereas, relative yield of soybean was not affected (Table 6 and Fig. 2). These data indicated that soybean varieties responded similarly *($P > 0.05$)* to maize varieties under intercropping pattern. Relative yields of maize and soybean were not affected by all the interactions (Table 6 and Fig. 2).

Intercropping maize with soybean increased LER as compared to solid cultures of both crops (Table 6 and Fig. 2). It ranged from 1.29 (by intercropping maize variety S.C. 122 with soybean variety Giza 35) to 1.54 (by intercropping maize variety S.C. 166 with soybean variety Giza 22) with an average of 1.42. The advantage of the highest LER by intercropping soybean variety Giza 22 with maize variety S.C. 166 over the others could be due to canopy structures for these varieties which led to minimize adverse effects of shading maize on intercropped soybean plants. These results are in accordance with those obtained by Hayder *et al.* (2003), who reported that the relative yield total of corn and soybean was greater in intercropping than monoculture, and the highest LER (1.52) were obtained in intercropping. Also, Metwally *et al.* (2005) found that intercropping cultures increased LER as compared to solid plantings of groundnut and maize where it ranged from 1.20 to 1.80 under sandy soil conditions. Moreover, Ijoyah *et al.* (2013) showed that intercropping soybean and maize gave land equivalent ratio (LER) values of 1.40 and 1.29 respectively, in years 2011 and 2012, indicating that higher productivity per unit area was achieved by growing the two crops together than by growing them separately. With these LER values, 28.6 per cent and 22.5 per cent of lands were saved respectively, in 2011 and 2012, which could be used for other agricultural purposes.

LER varied between maize varieties. Maize variety S.C. 166 gave higher LERs than those obtained by maize variety S.C. 122. LER varied between soybean varieties. Soybean variety Giza 22 gave higher LERs than those obtained by soybean variety Giza 35. These results may be due to more penetrated and intercepted light by leaves of soybean and maize plants (Metwally *et al.* 2009b). LER were not affected by all the interactions.

It could be concluded that growing maize variety S.C. 166 with soybean variety Giza 22 under intercropping pattern (2 : 4) could be recommended to increase intercropped maize with soybean yields and land equivalent ratio. Similar results were reported by Metwally *et al.* (2009a and b), who found that the intercropping caused advantages in land use under all applied patterns.

Relative crowding coefficient (RCC): The relative dominance of one species over the other in this intercropping study was estimated by the use of relative crowding coefficient (RCC). When the value of RCC is greater than 1.00, there is intercrop advantage; when RCC is equal to 1.00, there is no yield advantage; when RCC is lesser than 1.00, there is a disadvantage. In the present investigation, all values of the RCC were exceeded 1.00 (Fig. 3). The lowest RCC was obtained by intercropping maize variety S.C. 122 with soybean variety Giza 35, whereas, intercropping maize variety S.C. 166 with soybean varieties (Giza 111 and Giza 22) gave the highest RCC in the combined data across 2011 and 2012 growing seasons. This data suggest that canopy structures of maize variety S.C. 166 and soybean variety Giza 111 or Giza 22 were suitable for intercropping which led to low competitive pressure of component crops, indicating that these varieties are complementary and suitable in mixture.

Aggressivity: Aggressivity determines the difference in competitive ability of the component crops in intercropping association. The positive sign indicates the dominant component and the negative sign indicates the dominated component. Higher numerical values of aggressiveness denote greater difference in competitive ability, as well as, bigger difference between actual and expected yield in both crops. The results indicated that the value of aggressivity of maize was positive for all treatments, whereas, the values of aggressivity was negative for all intercropped soybean with maize plants in the combined data across 2011 and 2012 growing seasons (Fig. 4). These data showed that maize and soybean plants are dominant and dominated components, respectively.

In general, the highest negative values were obtained by growing soybean variety Giza 35 with maize plants, especially with maize variety S.C. 166. On the other hand, intercropping soybean variety Giza 111 with maize plants has the lowest negative values, especially with maize variety S.C. 176 in the combined data across 2011 and 2012 growing seasons.

Table 6. Relative yields of maize and soybean, as well as, land equivalent ratio as affected by cropping systems, maize and soybean varieties, and their interactions (combined data across 2011 and 2012 seasons)

Characters / Cropping systems	Maize varieties	Relative yields: L_{maize} Soybean varieties Giza 22	Giza 35	Giza 111	Mean	$L_{soybean}$ Soybean varieties Giza 22	Giza 35	Giza 111	Mean	LER Soybean varieties Giza 22	Giza 35	Giza 111	Mean
Intercropping culture	S.C. 122	0.66	0.63	0.63	**0.64**	0.72	0.66	0.75	**0.71**	1.38	1.29	1.38	**1.35**
	S.C. 166	0.71	0.69	0.70	**0.70**	0.83	0.76	0.84	**0.81**	1.54	1.45	1.54	**1.51**
	S.C. 176	0.67	0.64	0.65	**0.65**	0.77	0.70	0.78	**0.75**	1.44	1.34	1.43	**1.40**
Average of intercropping		**0.68**	**0.65**	**0.66**	**0.66**	**0.77**	**0.70**	**0.79**	**0.75**	**1.45**	**1.36**	**1.45**	**1.42**
Recommended solid culture		1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	**1.00**
L.S.D. at 5% of Cropping systems (C)					0.08				0.06				0.32
L.S.D. at 5% of Maize varieties (M)					0.06				N.S.				0.11
L.S.D. at 5% of Soybean varieties (S)					0.04				N.S.				0.08
L.S.D. at 5% of C x M					N.S.				N.S.				N.S.
L.S.D. at 5% of C x S					N.S.				N.S.				N.S.
L.S.D. at 5% of M x S					N.S.				N.S.				N.S.
L.S.D. at 5% of C x M x S					N.S.				N.S.				N.S.

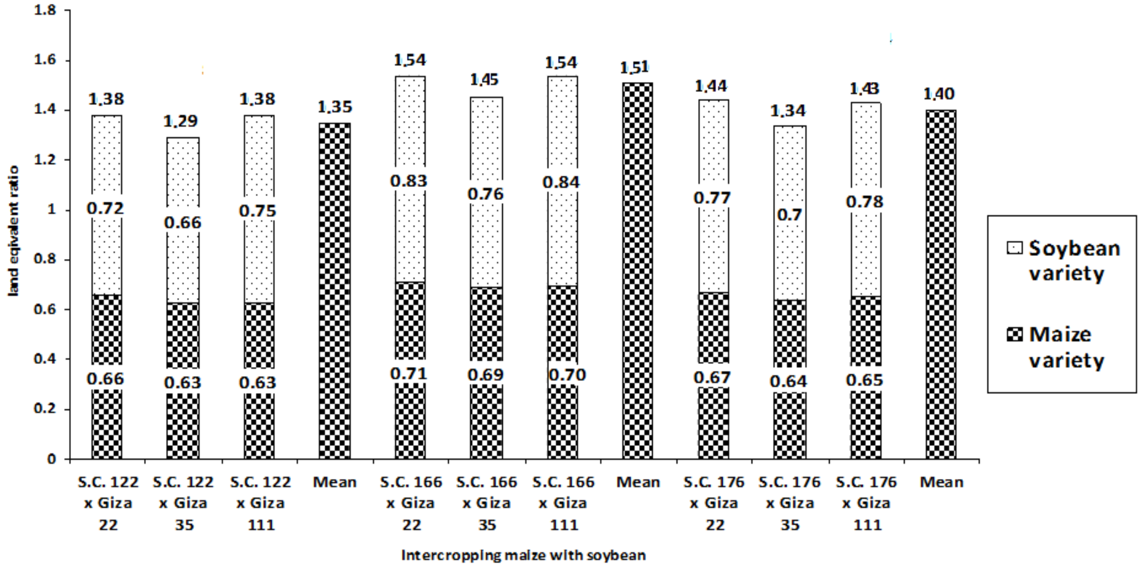

Fig. 2. Relative yields of maize and soybean and land equivalent ratio (LER) as affected by cropping systems, maize and soybean varieties and their interactions (combined data across 2011 and 2012 seasons)

It is clear that canopy structure of soybean varieties played a major role in coexistence or compatible with tall plants which have great canopy structure. Soybean variety Giza 35 is short variety as compared with the other soybean varieties (Table 4) and consequently this variety have canopy structure can't coexist with tall plants, especially with maize variety S.C. 122 (Table 3), whereas, soybean variety Giza 111 is tall variety in comparison with the other two soybean varieties and having broad leaves (Metwally *et al.*, 2012), which lead to face canopy structure of maize plants when growing together, especially with maize variety S.C. 176.

Characteristics of soybean variety Giza 111 enhanced self-shading and there may be an exceedingly steep light gradient between the top and bottom of the plant and consequently little dry matter accumulation which reflected on the economic yield. Maize variety S.C. 176 has leaves with acute angle in the second rank after maize variety S.C. 166 (Table 3), which affected negatively interception of solar radiation and consequently the final yield.

Soybean variety Giza 22 (the 2nd rank for the negative values of aggressivity) has suitable canopy structure for intercropping with maize plants which led to higher seed yields per plant and per ha than soybean variety Giza 111 under intercropping conditions (Metwally *et al*., 2012). Maize variety S.C. 166 has leaves with the highest acute angle in comparison with the other two maize varieties (Table 3) which may be resulted in low self – shading within the maize canopy and consequently more solar radiation within the maize (S.C. 166) and soybean (Giza 22) canopies under intercropping culture and finally high yield of both crops per ha.

These results are parallel with those obtained by Rezvani *et al.* (2011), who indicated that the value of aggressivity of corn was positive for all combinations, although the aggressivity index of soybean was not shown, but soybean was considered as the less-dominant crop in the system. Positive value of aggressivity indicates to corn, as dominant crops in the present study.

It could be concluded that the incorrect selection of crops, *i.e.* intercropping of incompatible species, can result in one crop completely suffocating the other; that is adverse effects (competition). The selection of the major crop (due to interest in yields) is as important as the minor crop. A minor crop should be a variety that will not expose the major crop to competitive pressure. The local variety of soybean Giza 22 is more compatible with local variety of maize S.C. 166 for intercropping under sandy soil conditions. Since the land use efficiency resulting from intercropping two maize ridges with four soybean ridges was advantageous in comparison with solid cultures of both crops, this pattern should be encouraged in peasant farming in new reclaimed soils.

This paper emphasizes there is a critical need for several scientific studies including morphological and physiological characteristics to provide plant breeder information about the most important characteristics in selection for high yield of intercropped crops under sandy soil conditions which known as the compatibility between two different species.

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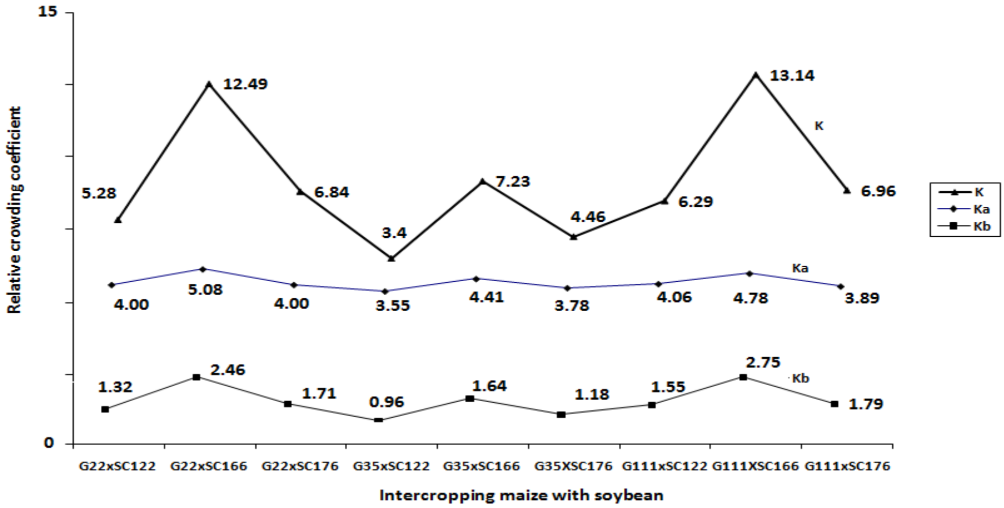

Fig. 3. Relative crowding coefficient (RCC) as affected by cropping systems, maize and soybean varieties, and their interactions (combined data across 2011 and 2012 seasons)

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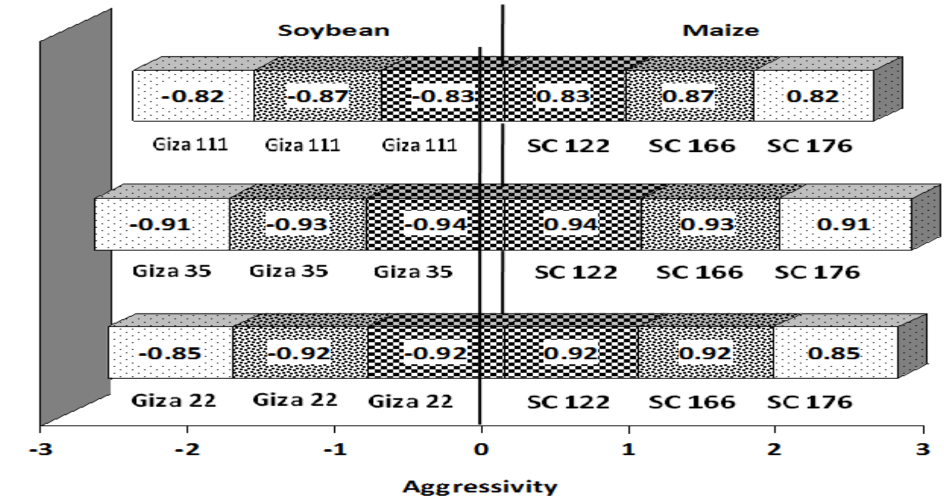

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Assessment of Soybean Based Cropping System Productivity Trends and Sustainability under Various Tillage Systems

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ABSTRACT

Field experiments were conducted at Directorate of Soybean Research, Indore 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 yield were not influenced by the tillage systems. Soybean prior to wheat did not show appreciable higher yield than that grown before chickpea. Soybean yields when grown prior to wheat were more sustainable than those grown prior to 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. Minimum tillage was more stable than conventional and zero tillage with regards to soybean. In rabi *crops; no-till was more stable than rest two tillage systems. Total crop productivity in terms of soybean equivalent yield 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 required more energy input and produced higher energy 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

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 envisaged the making all efforts to optimize production from a unit area in unit time at lower cost. Keeping sustainability in mind, 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,

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water and weeds, and increase the farm mechanization. Among these measures, manipulation of tillage system by changing land configuration for planting and curtailing the extent of tillage operations work 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 reduce cost of production. Moreover, the latter is instrumental in providing sustainability to crop production. Although, the commercial cultivation of soybean in India is slightly less than four decades old, the crop has made a special niche in cropping systems of Central India, particularly in the area covered with 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.

MATERIALS 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 cropping systems, 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 to Haplusterts. Soil had pH 7.86, EC 0.14 dS per m, organic carbon 0.30 per cent, available P 4.80 kg per ha and available K 298 kg per ha. The pooled 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) followed by 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 favorable 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 slightly higher than that cropped before chickpea. The later yielded slightly (2.3 %) lower than former. Soybean yields in case of soybean-wheat was maximum (1,594 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 (1,562 kg/ha), which was 3.6 per cent and 0.8 per cent higher than minimum tillage and conventional tillage, respectively. Comparison of tillage systems revealed that there were no perceptible differences between them, thus, 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 can be accounted variability in monsoon, its pattern and distribution. Higher sustainable yield index (SYI) values for soybean prior to wheat indicated that the soybean yields were more sustainable than that soybean taken prior to 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.

Trend analysis (Table 4) revealed that soybean yield linearly increased over the years under all the three tillage systems. Irrespective of cropping system, the highest increment was recorded under minimum tillage (11.1 %/year) followed by conventional tillage (9.38 %/year) and no tillage (6.80 %/year). Calculation of the soybean yield under different cropping systems indicated that highest (10.60 %/year) seed yield was associated with minimum tillage in soybean–wheat system followed by no-till (8.36 %/year) and conventional tillage (6.79 %). In case of soybean–chickpea, it was maximum under zero tillage (12.20 %/year) followed by minimum tillage (9.90 %/year) and conventional tillage (9.83 %/year). The trend analysis flays the myth that continuous cropping of soybean over years reduces the performance of crops including soybean. On the contrary, placing legume like soybean in cropping systems either under irrigated or rainfed regimes are 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' =

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*

0.990) and minimum till ('b' = 0.995) had an edge over conventional tillage ('b' = 0.981) 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 better 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.

Wheat and chickpea yield

Both the *rabi* crops performed better under minimum tillage followed by conventional and no till. As compared to no till (wheat 2,425 kg/ha; chickpea 1,018 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). Similar results were also reported by Billore *et al* (2005). The variation in productivity over years was higher in chickpea (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). Similar were the observations 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 of wheat over years revealed that there has been steady increase in yield under minimum tillage (CV = 40.90 %) as compared to conventional (39 %/year) and no till (39 %/year), thereby showing highest average yield in wheat under minimum tillage over years Chickpea as well revealed 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 zero (12.5 %) and minimum tillage (10.2 %).

Stability analysis (Table 5) indicated that both the *rabi* crops (wheat as well as chickpea) performed well under favourable conditions of 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 with no-till system ('b' = 0.448 for wheat and 0.710 for chickpea). 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 relatively more stable.

System productivity

Evaluation of cropping system productivity in terms of soybean equivalent yield (SEY) established the numerical superiority of minimum tillage (3,300 kg/ha) over conventional (3,190 kg/ha) and no till (3,000 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, can be compensated by reduced cost on tillage operation leading to almost similar net profit.

The productivity (SEY) of the two cropping systems soybean-wheat and soybean-chickpea followed the same trend under three tillage systems. To start with the minimum tillage showed slight advantage in SEY. However, after five years the effect was not visible but again in the tenth year the conventional tillage recording slightly higher productivity as compared to no-tillage.

The yearly variation in the productivity was possibly due to variation in the intensity and the duration of precipitation received in that particular period/ year.

The variation under the tillage systems are not seen to be pronounced and are as expected since the experiments conducted were on such a soil, which is vertic in nature that means the soil become self-ploughed due to inversion caused by the cracking and shrinking properties of these 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 year, 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 compensate in the cost of tillage operations.

Rating the two cropping systems in terms of sustainability values (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 zero tillage (11.6 %) followed by conventional (11.0 %) and minimum tillage (10.5 %). While in case of soybean–wheat, the rate of increment linearly increased with the increases in the frequency of tillage (from 3.7 to 5.7 %). Contrary to these observations, a declining trend in yield of rice was reported (Singh *et al.,* 2004) over a period of time. Singh *et al.* (2004) could not observe any change in trend in case of wheat.

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

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*

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	1542	1563	1594	1508	1551	1550	1550	1550	1576	1533
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	48.05
SYI	0.35	0.30	0.33	0.38	0.29	0.34	0.34	0.30	0.32	0.36	00.30
b(Tillage)	0.901	1.079	0.99	1.067	0.923	0.995	0.912	1.049	0.981	0.982	1.167
Rabi(Wheat and chickpea)											
Mean	2425	1018	1723	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	38.04	61.35
SYI	0.36	0.12	0.24	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	1.123	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	1.135	0.999	1.001	0.999	1.000

** Soybean – wheat, ** Soybean – chickpea* 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 was more stable than minimum and conventional tillage and minimum tillage had better stability than conventional tillage. This indicates that the reduction in extent of tillage enhanced 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 intensiveness (0.43 MJ/Rs) was higher in soybean-chickpea than soybean-wheat on account of variations in energy input, productivity and sell price of output.

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 (Rs 38,357 and 23,129/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 returns (Rs 36,289/ha) than conventional tillage, whereas no till had the lowest value. Minimum tillage maintained its superiority in terms of net return (Rs 21,935/ha) over no till and conventional tillage. Benefit: cost ratios were almost same for no till and minimum tillage, but both were superior to conventional tillage.

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 for both the cropping systems.

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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 (Rs/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**	SEm (±)	**CD**	SEm (±)	**CD**	SEm(±)	**CD**	SEm (±)	**CD**
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**

**S-W : Soybean-wheat, **S-C : Soybean-chickpea*

Table 8. Economics of cropping systems under different tillage systems

Treatment	Gross returns (Rs/ha)			Net returns (Rs/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
Conventional 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**

**S-W : Soybean-wheat, **S-C : Soybean-chickpea*

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Influence of Diverse Environments on the Growth and Productivity of Soybean Genotypes in Northern India

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ABSTRACT

A field experiment was conducted during kharif *(rainy season) 2012 at research farm of Punjab Agricultural University, Ludhiana (30° 54´N, 75° 48´E, altitude 247 m), India to study the influence of sowing date and seed rate on the growth and productivity of soybean genotypes. The experiment was laid out in split plot design with four replications. The treatments included three dates of sowing (5 June, 15 June and 25 June) in main plots, three genotypes (SL 958, SL 900 and SL 744) in sub-plots and three seed rates (62.5, 75 and 87.5 kg/ha) in sub-sub plots. The 5 June sowing produced the highest seed yield (2,713 kg/ha), which was significantly higher than 25 June (2,402 kg/ha) and at par with 15 June (2,654 kg/ha) sowings. The early sowing (5 June) registered 2.2 and 12.9 per cent higher seed yield over 15 June and 25 June sowings, respectively. The 5 June sowing recorded the highest plant height, pods per plant, seed index and straw yield. Seed rate and genotypes did not influence the seed yield of soybean significantly. Among the genotypes, SL 958 produced higher seed yield (2,637 kg/ha) than SL 900 (2,578 kg/ha) and SL 744 (2,554 kg/ha) though the differences were non-significant. Days to 50 per cent flowering and maturity decreased with delay in sowing. The genotypes SL 958 and SL 744 were early in days to 50 per cent flowering, however, all the genotypes took almost similar number of days to maturity. Under Punjab conditions, 5-15 June was found to be the optimum sowing time, 62.5 to 75.0 kg per ha optimum seed rate and SL 958 and SL 900 the promising genotypes of soybean.*

Key words: Environment, genotypes, seed rate, sowing dates, soybean

Soybean [*Glycine max* (L.) Merrill], the world's leading oilseed crop, is becoming increasingly popular due to its high quality oil (20 %) and protein (40 %) contents. It can aptly be called as "miracle crop" of 20th century. Sowing time is an important non-monetary input which determines the yield potential of any crop. It has a pronounced effect on the growth and development of plants. All the crops are vulnerable to different temperature stresses during the crop season and

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differential response of temperature change to various crops has been noticed under different production environments (Kalra *et al*., 2008). Effect of sowing date on soybean yield has also been reported by other researchers (Egli and Bruening 2000, Ahmed *et al*., 2010, Rekha and Dhurua 2010, Moosavi *et al*., 2011). Several phenological models have been prepared to predict the duration required to attain different phenophases by using growing degree-days (GDD), photo-thermal units(PTU) and other crop thermal units (Esfandiary *et al*., 2009). Similarly, different genotypes may require different environment for their proper growth. Therefore, performance of a genotype over diverse environments needs to be tested with different environments under which it is to be grown. Based on these points in mind, a field experiment was planned to study the influence of diverse environments on the growth and productivity of soybean genotypes in northern India

MATERIAL AND METHODS

A field experiment was conducted during *kharif* (rainy season) 2012 at the research farm of Punjab Agricultural University, Ludhiana (30° 54´N, 75° 48´E, altitude 247 m), India on a loamy sand soil. The soil of the experimental site was low in organic carbon (0.24 %), low in available nitrogen (182.5 kg/ha), medium in available phosphorus (33.5 kg/ha) and high in potassium (222.5 kg/ha) with a pH of 8.4. Data on meteorological conditions experienced by the crop are presented in Fig.1. A rainfall of 381.8 mm (32 rainy days) was received in *kharif* season during 2012 during crop growth period. The experiment was laid out in split plot design with four replications. The treatments included three dates of sowing (5 June, 15 June and 25 June) in main plots and three genotypes (SL 958, SL 900 and SL 744) in sub- plots and three seed rates (62.5, 75 and 87.5 kg/ha) in sub-sub plots. Nutrients *viz.*, 30 kg nitrogen and 60 kg P_2O_5 per ha were applied entirely as basal dose to the crop and the crop was sown in rows 45 cm apart.

Data on plant height and pods per plant were recorded at harvest from randomly selected five plants from each plot. Biological yield and seed yield were recorded on a plot basis and then converted into kg per ha. The data on seed index were recorded after taking 100 randomly selected seeds. Harvest index was calculated by dividing seed yield by biological yield and multiplied by 100. Data were subjected to analysis of variance (ANOVA) as per the standard procedure.

Days taken to 50 per cent flowering and maturity were recorded. Growing degree days were determined as per Nuttonson (1955).

$GDD = T_{mean} - T_b$

Where, Tmean is mean temperature (^oC) during a day and T_b is base temperature of 10.0 ^oC

Helio-thermal units (HTU) = GDD × actual sunshine hours

Photo-thermal units (PTU) = GDD × day length

Where day length refers to maximum possible sunshine hours.

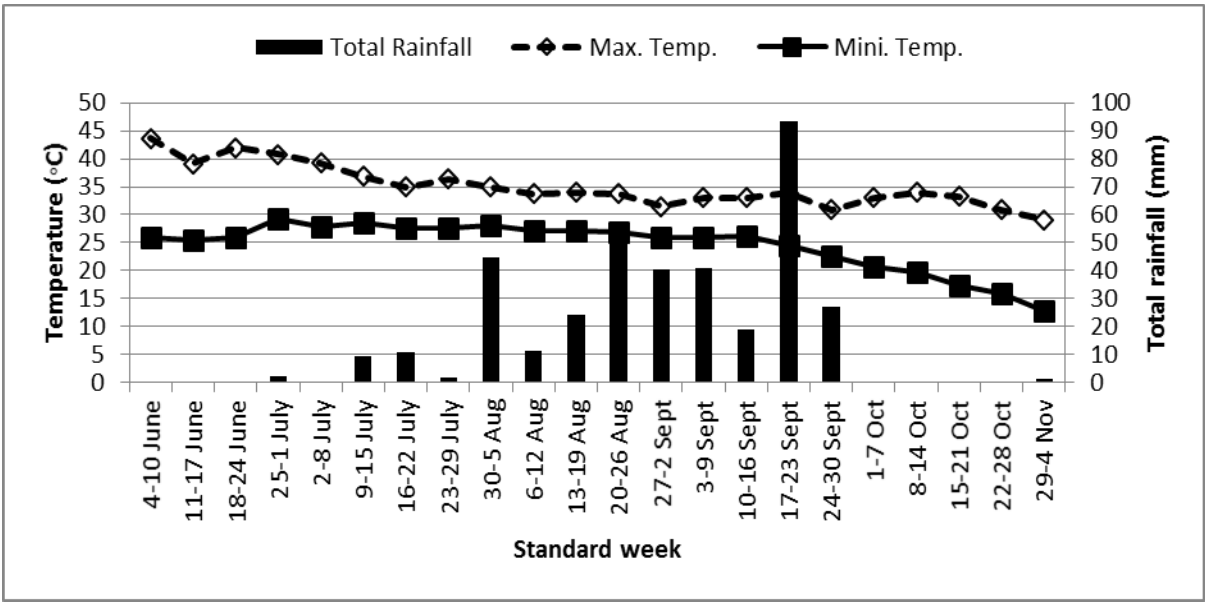

Fig. 1. Weather conditions during 2012 growing season

RESULTS AND DISCUSSION

Effect of sowing time

Days to 50 per cent flowering and maturity decreased with delay in sowing (Table 1). Kumar *et al*. (2008) also reported that number of days to maturity was decreased with delay in sowing. Decrease in minimum temperature near maturity (Fig. 1) might have accelerated maturity of the crop. Accumulated agro-climatic indices *i.e.*, growing degree days, helio-thermal units and photo-thermal units computed for soybean genotypes under different dates of sowing from sowing to 50 per cent flowering and physiological maturity are given in Table 2. The 5 June sown crop required higher agro-climatic indices for 50 per cent flowering and maturity than 15 and 25 June sown crop.

The plant height was decreased with delay in sowing from 5 June to 25 June and the reduction in plant height was significant after 15 June (Table 3). Similarly, pods per plant and seed index were significantly higher in 5 June sowing than the other sowings, pods per plant was, however at par with 15 June sowing. Straw yield was the highest in 5 June sowing. It could be due to more vegetative growth as reflected in plant height. The 5 June sowing produced the highest seed yield (2,713 kg/ha), which was significantly higher than 25 June (2,402 kg/ha) and at par with 15 June (2,654 kg/ha) sowing. The early sowing (5 June) registered 2.2 and 12.9 per cent higher seed yield over 15 June and 25 June sowings, respectively. The higher seed yield in 5 June sowing could be due to more pods per plant and seed index. Furthermore, the timely-sown crop used heat more efficiently than late-sown crop (Table 2), which might have resulted in higher seed yield under 5 June sowing than under 5 June to 25 June sowings. The harvest index

Table 1. Effect of date of sowing on days to 50 per cent flowering and maturity in different genotypes of soybean

Date of sowing	50 % flowering			Mean	Maturity			Mean
	Genotype				Genotype			
	SL 958	SL 900	SL 744		SL 958	SL 900	SL 744	
5 June	74	86	75	78	147	147	146	147
15 June	67	76	66	70	137	136	136	136
25 June	62	66	63	64	127	127	126	127
Mean	67	76	67		137	137	136	

Table 2. Effect of dates of sowing, genotypes and seed rate on different agro-climatic indices, i.e. GDD, PTU and HTU (°C day) at different stages of soybean

Treatment	50 % Flowering			Physiological maturity		
	AGDD	APTU	AHTU	AGDD	APTU	AHTU
Date of sowing						
5 June	1718	23812	12084	2863	37740	20619
15 June	1527	20966	10247	2636	34260	18647
25 June	1346	18167	8111	2387	30366	16324
Genotype						
SL 958	1474	20263	9945	2637	34206	18594
SL 900	1635	22335	10464	2628	34113	18524
SL 744	1481	20348	10033	2622	34048	18474
Seed rate (kg/ha)						
62.5	1529	20966	10155	2627	34101	18513
75.0	1531	20987	10143	2630	34139	18543
87.5	1531	20993	10144	2629	34127	18535

AGGD-Average growing degree days; APTU-Average photo-thermal units; AHTU- Average helio-thermal units was found to be influenced non-significantly by different sowing dates. The gross returns, net returns and B:C ratio were significantly higher in 5 June sowing than 25 June sowing, which were, however at par with 15 June sowing. Billore *et al*. (2009) also reported that under Malwa plateau of central India, timely planting of soybean (last fortnight of June) showed superiority over the late planting with respect to plant growth and yield attributing characters, seed yield and economics.

Performance of genotypes

The genotypes SL 958 and SL 744 were early in days to 50 per cent flowering, however, all the genotypes took almost similar number of days to maturity (Table 1). For physiological maturity, all the genotypes during the study period acquired almost similar accumulated growing degree days, photo-thermal units and helio-thermal units (Table 2).

The plant height was significantly higher in SL 958 than the other genotypes and SL 744 had the lowest plant height (Table 3). SL 958 and SL 900 were at par but significantly superior to SL 744 in pods per plant and seed index. The differences in seed yield, straw yield and harvest index were found to be non-significant among different genotypes. SL 958 produced higher seed yield (2,637 kg/ha) than SL 900 (2,578 kg/ha) and SL 744 (2,554 kg/ha) though the differences were non-significant. SL 958 gave the maximum gross returns, net returns and B:C ratio but the differences were non-significant. Genotypic differences in yield and other characters were also reported by other researchers (Siddiqui *et al*., 2007; Billore *et al*., 2009; Shegro *et al*., 2010).

Effect of seed rate

The seed rates did not influence the days to 50 per cent flowering and maturity (Table 1) and accumulation of heat units (Table 2). The seed rates did not differ significantly in plant height, pods per plant, seed index and seed yield (Table 3). Straw yield increased and harvest index decreased with increase in seed rate, possibly due to higher plant population. The seed rate did not affect the gross returns, net returns and B:C ratio significantly.

Under Punjab conditions, 5-15 June was found to be the optimum sowing time, 62.5 to 75.0 kg/ha optimum seed rate and SL 958 and SL 900 the promising genotypes of soybean.

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Table 3. Effect of date of sowing, genotypes and seed rate on plant characters, straw yield, seed yield and economics of soybean

Treatment	Plant height (cm)	Pods/ plant	Seed index (g)	Straw yield (kg/ha)	Seed yield (kg/ha)	Harvest index (%)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Date of sowing									
5 June	102.5	78.9	14.06	7471	2713	27.01	69465	50418	3.65
15 June	99.3	73.1	13.71	7127	2654	27.36	67950	48903	3.57
25 June	89.0	66.4	13.62	6073	2402	28.41	61498	42451	3.23
SEm (±)	2.10	2.07	0.05	124	26	0.38	693	693	0.03
CD (P=0.05)	**7.18**	**8.28**	**0.20**	**432**	**93**	**NS**	**2399**	**2400**	**0.13**
Genotype									
SL 958	102.1	75.3	13.84	7055	2637	27.55	67523	48476	3.54
SL 900	96.6	74.3	14.12	7098	2578	26.97	66008	46961	3.46
SL 744	92.1	68.8	13.43	6518	2554	28.26	65383	46336	3.43
SEm (±)	1.37	1.43	0.10	173	45.0	0.65	1173	1173	0.06
CD (P=0.05)	**4.07**	**5.16**	**0.36**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Seed rate **(kg/ha)**									
62.5	95.7	71.0	13.72	6215	2519	28.85	64494	46072	3.50
75.0	97.1	74.6	13.84	7057	2610	27.29	66831	47784	3.51
87.5	98.1	72.8	13.82	7399	2640	26.63	67588	47916	3.43
SEm (±)	1.31	1.32	0.10	130	36.0	0.46	924	924	0.01
CD (P=0.05)	**NS**	**NS**	**NS**	**370**	**NS**	**1.30**	**NS**	**NS**	**NS**

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Soybean Research (Special Issue): 67-71: 2014

Optimization of Seed Rate and Row Spacing of Soybean Varieties

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ABSTRACT

A field experiment was carried out in rainy seasons of 2009, 2010 and 2011 at Agharkar Research Institute, Pune, Maharashtra to study the effect of seed rate and row spacing on yield and other traits of newly released soybean varieties. Experiment was conducted in the split plot design with four treatment combinations of two row spacing's (30 and 45 cm) and two varieties (RKS 18 and MAUS 61) as main plot treatments and three seed rates (55, 65 and 75 kg/ha) as sub-plot treatments. Sowing with row spacing of 30 cm was at par with row spacing of 45 cm for seed yield. Variety RKS 18 produced significantly higher seed yield (3,045 kg/ha) than variety MAUS 61 (2,607 kg/ha). Crop sown with seed rate 65 kg per ha produced significantly highest seed yield (2,899 kg/ha) and was at par with 75 kg per ha (2,807 kg/ha). Variety RKS 18 with 30 cm row spacing recorded maximum seed yield (3,062 kg/ha) followed by RKS 18 with 45 cm row spacing (3,028 kg/ha) and MAUS 61 with 45 cm row spacing (2,654 kg/ha). The results indicated that the seed rate for soybean varieties RKS 18 and MAUS 61 can be reduced to 65 kg per ha from recommended seed rate of 75 kg per ha for soybean in India.

Key words: Recommended seed rate, row spacing, improved soybean varieties, soybean seed yield

Soybean [*Glycine max* (L.) Merrill] is a miracle crop of the world being the most important oilseed and pulse crop. It is unique two in one crop having both high quality proteins (40-42 %) and oil (18-20 %) content. Soybean itself has established as an important rainy season crop in India, particularly in the central part. Thearea under this crop is increasing steadily and at present it is cultivated on 12.03 million hectares with a productivity of 1,017 kg per ha with production of 12.23 million tonnes (SOPA, 2013). In spite of high yield potential (4.5 tonnes/ha), productivity of soybean is much less in India (1.07 tonnes/ha) than the world average of 2.43 tonnes per ha (FAOSTAT, 2011). Soybean plays an important role to support the agricultural economy of India. The low productivity of crop is due to several constraints like lack of irrigation facility, improper management practices, lack of

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information on optimum seed rate, optimum spacing, suitable sowing method, improved varieties, balanced nutrition and water management. Among the several factors, use of improved cultural practice and adequate management is important for increasing production. Among the cultural practices suitable method of sowing, optimum spacing and optimum seed rate may increase the yield of soybean. Optimum spacing and seed rate influences yield and yield contributing characters of soybean (Kolarik and Marek, 1980). Grain yield increases with increase in seed rate up to certain limit, beyond which yield tends to decrease (Chen *et al.*, 1992). Keeping in view the inter-plant competition for nutrition, sunlight, moisture and aeration it is essential to find out fair combination of suitable method of sowing with optimum spacing and seed rate to achieve maximum yield of soybean.

MATERIAL AND METHODS

The experiment was conducted during rainy seasons (*kharif*) of 2009, 2010 and 2011 at experimental farm of Agharkar Research Institute, Pune. Soil of the experimental field belonged to order Vertisols with slight alkaline pH (7.4). The rainfall during the cropping season (from sowing up to harvesting) was 468 mm in 2009, 299 mm in 2010 and 301 mm in 2011. The experiment was designed in split plot with three replications with four treatment combinations of two row spacing (30 cm and 45 cm) and two varieties (RKS 18 and MAUS 61) as main plot treatments and three seed rates (55, 65 and 75 kg/ha) as sub plot treatments. The uniform basal dose of 20:80:20:: $N:P_2O_5:K_2O$ (kg/ha) was applied through di-ammonium phosphate, single super phosphate and muriate of potash. All the recommended package of practices was followed for raising the good crop. The observations on plant height (cm), number of pods per plant, number of branches per plant were recorded at harvest on five randomly selected plants from each plot. Seed yield (kg/ha) was recorded on net plot basis and then converted to kg per ha, Harvest index (%) was worked out by utilizing the total biological produce and the seed yield of soybean. Seed index was recorded as weight of random 100 seeds in grams. Statistical analysis was carried out using standard analysis of variance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Row spacing and variety

Significant differences among means of treatment combinations of row spacing and variety were found. Soybean variety RKS 18 recorded significantly higher seed yield at both the row spacing than other variety-MAUS 61. However, difference between average seed yield of row spacing for both the varieties was non-significant. Thus, the results indicated that the row spacing has no effect on seed yield for both the varieties. Similar results were reported by Singh (2011). Superior performance of RKS 18 over MAUS 61 for seed yield was attributed to more branches per plant, seed index and harvest index. RKS 18 due to its higher yield than MAUS 61, it also showed significantly higher net returns and B:C ratio than MAUS 61.

Seed rate

Average seed yield for seed rates, 65 kg (2899 kg/ha) and 75 kg per ha (2807 kg/ha) was at par with each other and significantly superior over seed rate 55 kg per ha (2772 kg/ha). Thus the results indicate that reduction in recommended seed rate (75 kg/ha) up to 10 kg has no significant effect on seed yield (Table 1). Seed is an important input in any crop production. Present studies indicate that input cost for seed for soybean crop can be reduced up to cost of 10 kg seed for recommended released varieties RKS 18 and MAUS 61. However, since proper germination of seed plays important role in getting good seed yield, while reducing the seed rate care has to be taken to ensure good germinability of the seed used. Thus, it can be concluded that for both the varieties under study recommended seed rate (75 kg/ha) can be reduced by 10 kg per ha without affecting seed yield significantly.

Interaction Effect

Analysis of the data on the seed yield indicated non-significant differences among mean seed yield for interaction component (Table 2). However, data indicated that variety RKS 18 when planted at 30 cm row spacing gave the higher seed yield (3,169 kg/ha) at the seed rate of 75 kg per ha. On the other hand the same variety (RKS 18) when planted at 45 cm row spacing maximum seed yield of 3,082 kg per ha was recorded at the seed rate 55 kg per ha. In other words to obtain good seed yield and to save seed cost of 20 kg per ha, the variety RKS 18 should be planted at 45 cm row spacing. The data for seed yield of variety MAUS 61 at two row spacing and three seed rates (Table 2) indicated that the seed rate of 65 kg per ha (10 kg/ha less seed rate than recommended 75 kg/ha) gives maximum seed yield for both the row spacing.

Thus, it can be concluded that row spacing has no influence on seed yield of soybean varieties RKS 18 and MAUS 61. However, results on effect of seed rate indicate that seed yield of both the varieties was not significantly affected when seed rate was reduced up to 65 kg/ha. It can be safely recommended to reduce seed rate by 10 kg without affecting the seed yield.

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Table 1. Growth, yield contributing characters and seed yield of soybean as affected by row spacing, varieties and seed rate

Treatment	**Plant height (cm)**	**Branches (No/ Plant)**	**Pods (No/ Plant)**	**100 seed weight (g)**	**Harvest index (%)**	**Seed yield (kg/ha)**	**Net returns (Rs/ha)**	**B:C ratio**
Row spacing and variety								
30 cm, RKS 18	62	3.36	40	14.01	52.82	3062	41594	2.96
45 cm, RKS 18	58	2.99	35	13.82	50.94	3028	40147	2.93
30 cm, MAUS 61	60	2.32	38	13.44	40.61	2560	31596	2.48
45 cm, MAUS 61	59	1.90	39	13.62	42.96	2654	33648	2.58
SEm (±)	2.28	0.41	3.40	0.35	2.01	129.4	4406	-
C D (P = 0.05)	**3.4**	**0.60**	**5.05**	**0.51**	**2.99**	**192**	**6547**	**-**
Seed rate								
55 kg/ha	58	2.94	38	13.82	47.92	2772	36167	2.74
65 kg/ha	63	2.69	41	13.58	47.39	2899	37736	2.79
75 kg/ha	59	2.98	36	13.77	45.19	2807	36336	2.69
SEm (±)	2.10	0.32	2.35	0.21	9.12	79.60	1612	-
C D (P = 0.05)	**3.0**	**0.45**	**3.35**	**0.29**	**NS**	**113**	**2291**	**-**
SEm (±)	4.11	0.66	5.13	0.48	15.03	183.4	5132	-
C D (P = 05) (Interaction)	**5.8**	**NS**	**7.2**	**0.68**	**NS**	**NS**	**NS**	**-**

Table 2. Interaction table of variety, spacing and seed rate for seed yield

Spacing and variety	Seed rate (kg/ha)			Mean
	55	**65**	**75**	
30 cm, RKS 18	2943	3073	3169	3062
45 cm, RKS 18	3082	3070	2931	3028
30 cm, MAUS 61	2444	2717	2519	2560
45 cm, MAUS 61	2620	2735	2607	2654
Mean	2772	2899	2807	
SEm (±)	183.4			
C D (P = 0.05)	**NS**			

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ICT Based Plant Protection Solutions in Soybean Based Cropping System in Maharashtra

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ABSTRACT

Agriculture in Maharashtra is predominantly rainfed and as such rural economy is mainly dependent on kharif *crops. Cotton and soybean are the two major* kharif *crops of Maharashtra. During 2008-09, there was sudden outbreak of soybean leaf defoliators (*Spodoptera litura*,* Helicoverpa armigera *and semi-looper) and 48 per cent of area under soybean crop was infested resulting into estimated losses to the tune of Rs 139.2 million. State Government has paid financial assistance worth Rs 45 million to farmers. On that background Agriculture Department of Government of Maharashtra has formulated and implemented an innovative project "Crop Pest Surveillance and Advisory Project (CROPSAP)" based on Information and Communication Technology (ICT) in the field of plant protection since 2009-10. Software was developed for scientific pest surveillance and monitoring. The entire activity of pest surveillance and issuance of advisories to farmers is on-line. The project is multi-stakeholder involving four Central Crop Research Institutes viz. DSR, Indore; IIPR, Kanpur; CICR, Nagpur; CRRI, Cuttack and Central Research Institute for Dryland Agriculture (CRIDA, Hyderabad) along with four State Agriculture Universities (MPKV, Rahuri; BSKKV, Dapoli; VNMAU, Parbhani; PDKV, Akola). It is a first of its kind project in the country. The project has helped immensely to protect soybean/cotton based cropping system from pest problems. Looking to the success of project, it was extended to arhar and gram crops. Subsequently, in 2011-12 rice crop was also included in the project. The project was further extended to horticultural crops namely, mango, pomegranate and banana in 2011. Since inception of the project till date, despite unfavorable climatic conditions there is no major outbreak of any pests and disease on selected crops in the State. Consistent pest monitoring coupled with adoption of appropriate pest management strategies at proper crop growth stages, the productivity of soybean crop that had dropped down to 600 kg per ha in 2008-09 is consistently on rise from 2009-10 onwards. The average productivity of soybean in past four years is 762 kg per ha with an increase of around 27 per cent.*

Key words: Advisories, forecast, monitoring, pest surveillance, *Spodoptera litura*

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Soybean is a wonder crop of twentieth century. It is an excellent source of protein and oil. It is a two dimensional crop as it contains about 40-42 per cent of high quality protein and 20-22 per cent oil. It also contains 20-30 per cent carbohydrates. Hence, it is well established fact that soybean is cheap source of protein and edible oil. These characteristics have made soybean to fit well in sustainable agriculture. During the late sixties and early seventies, the soybean crop was considered to be comparatively safe crop as regards to insect-pest attack. However, Gangrade (1976) reported over 99 insect species attacking soybean crop at Jabalpur, but now the situation has changed and as many as 275 insect species have been recorded attacking soybean crop in India. Researchers in many parts of India have confirmed that seed yield and seed quality are being adversely affected by major insect-pests *viz*., girdle beetle, tobacco leaf eating caterpillar, green semi-looper, *Helicoverpa armigera*, jassids and white fly (Netam *et al*., 2013).

Agriculture in Maharashtra is a predominantly rainfed, thus, rural economy largely depends on dryland agriculture. Cotton and soybean are two major *kharif* crops of Maharashtra covering 7.36 million hectares *i.e.*, 51.41 per cent of the total *kharif* area. In 2008-09, soybean crop in Maharashtra particularly in Marathwada and Vidarbha regions was severely damaged by pest attack causing serious economic losses. The existing pest monitoring system has miserably failed to combat the sudden pest outbreak. Central Government deputed a team of experts to study the reasons of outbreak. Their findings were taken in right spirit to develop long-term strategies for pest management. Following this, a scientific pest surveillance project entitled 'Crop Pest Surveillance and Advisory Project' (CROPSAP)was prepared in consultation with National Centre for Integrated Pest Management (NCIPM), New Delhi involving different stakeholders of related field. First time in the country software was developed and implemented for online e-pest surveillance of soybean, cotton, tur, rice and gram crops. Use of Information Technology (IT) was effectively made for real time pest monitoring and latest Communication Technology (CT) was used for instant advisories to field staff through emails and advisory SMSs to registered farmers. The unique feature of the success of project lies in effective use of ICT to help the farming community in reducing the risk of crop losses due to unpredictable pest problems and to tackle the pest attack on real time basis. The vast data generated through project will be of immense use to researchers for developing pest forecasting modules for future. The project envisages reduction of crop losses and less expenditure on pest management with better return to farmers through use of ICT tools.

MATERIAL AND METHODS

Taking into consideration multitasking duties of field staff of Agriculture Department and time bound nature of work; the field surveillance activity was outsourced to a team of Pest Scouts, Pest Monitors and Data Entry

Operators. Pre-seasonal trainings are imparted to field staff, contractual staff and farmers for knowledge updating. Pest scouts collect data on pest/disease incidence from fixed and random plots in selected representative villages twice every week. Each Pest Scout records data from 4 plots (2 fixed plots and 2 random plots) from 8 villages in prescribed formats (covering approx. 12,000 ha) on every Monday, Tuesday and Thursday, Friday. The observations recorded are passed on to Pest Monitors. The Pest Monitors conduct surprise checks and random compilation of data collected by the scouts also conduct roving survey. The data so obtained by Data Entry Operators on Monday/Tuesday and Thursday/Friday is transmitted on-line to the computer system on every Wednesday and Saturday on website (www.ncipm.org.in).The data is instantly analyzed through software and reports are generated by NCIPM, Delhi. These reports are scientifically interpreted by the experts at State Agricultural University (SAUs) and necessary real time detail and short advisories are issued. Taluka-wise advisories with hot spot locations are issued on-line to Sub-divisional Agriculture Officer (SDAOs) on every Thursday and Monday. SDAOs transmit the messages in form of detail advisories through e-mail to Taluka Level offices. The advisories are displayed at Gram Panchayat in form of Jumbo Xerox; pest situation is discussed in weekly farmers meetings at village level by field staff. Short advisories SMSs are sent to registered farmers by SDAOs with free of cost. Wide media publicity is given for creating mass awareness. Experts visit are organized to hot-spots for guidance.

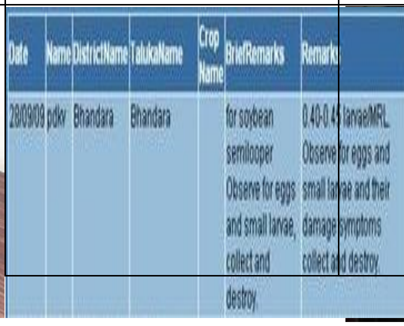
For e-pest surveillance of soybean, cotton, tur, rice and gram crops, following steps for online data feeding are followed.

Software, data uploading and processing: E-pest surveillance software with three tier architecture was developed using SQL Server 2000 application for an off-line data entry and uploading data base for on-line reporting and an advisory system based on expert analysis on www.ncipm.org.in. While the pest data could be viewed/updated by user Department, the advisory on the basis of the data analysed was open to all.

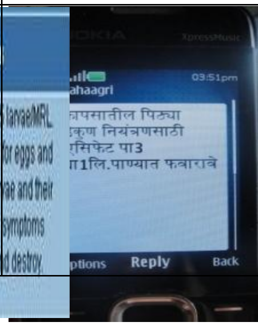
Pest scenario and GIS mapping: The software has advance features of reporting system *viz*., current, temporal and temporal-cum-spatial pest scenarios and location of hotspots through GIS maps generated for any point of time, *etc*.

Advisory dissemination: Location specific *taluka* level advisories are transmitted by the system through text messages (SMS) by Sub-Divisional Agriculture Officer to the registered farmers of the *talukas* concerned. Detail advisories are also prominently exhibited in village *panchayat* offices, *etc*. in form of Jumbo Xerox displayed on notice board and also used by the field staff of the Agriculture Department for disseminating the information. The process involves regular (weekly) monitoring of standing crops for selected major pests/diseases and direct feeding of the data generated for expert analysis at NCIPM. The results of the analysis are passed on in the form of advisories on real time basis to farmers and

Survey	Online data feeding	Data analysis and Advisories by SAUs	Dissemination of advisory by SDAO
Monday and Tuesday	Wednesday	Thursday	Thursday
Thursday and Friday	Saturday	Monday	Monday



Date	Name	DistrictName	TalukaName	Crop Name	BriefRemarks	Remarks
28/09/09	pdkv	Bhandara	Bhandara		for soybean semilooper Observe for eggs and small larvae, collect and destroy.	0.40-0.45 larvae/MRL. Observe for eggs and small larvae and their damage symptoms collect and destroy.



other stakeholders using mobile/ internet connectivity for taking appropriate remedial measures.

RESULTS AND DISCUSSION

From the year 2009-10, the impact of the CROPSAP project was highly significant and showed the positive results. From the year 2009 pest incidence on soybean was continuously on decline.

Farmers' response to SMS and advisories

The details of farmers registered for SMS advisory system, number of advisories issued and SMS sent from 2009-10 to 2013-14 are shown below (Table 1)

It is evident that considering the utility of project, there is an increasing response from the farmers for the SMS advisory system (Table 1). The success of the project lies in making good and effective use of the latest developments in information and communication technology (ICT) to help the farming community in reducing the risk of crop losses due to unforeseen pest infestation.

Cost Effectiveness

The details of project cost, area covered and per hectare cost incurred is shown below (Table 2).

As the infrastructure cost involved is only at the beginning of project, per hectare cost is steadily declining, however, the benefit of project through production will continue to increase.

Comparison of productivity of crops in project

The productivity of crops under project has never declined to that of 2008-09 despite dry spells prevailing in 2010-11 and 2011-12 (Table 3).

Table 1. Details of farmers registered, advisories issued and SMS sent between 2009-10 and 2013-14

Year	Farmers registered for SMS service(Nos.)	Advisories issued (Nos.)	SMS sent (Nos.)
2009-10	163000	13517	3193000
2010-11	240000	55602	11200000
2011-12	311000	62410	19906000
2012-13	340000	62515	36083000
2013-14 (Up to15 December)	390000	71905	43875000

Table 2. Details of total area covered, cost of the project and total production

Year	Total area covered under project (million ha)	Cost of Project (million Rs)	Project Cost (Rs/ha)	Total Production (million tonnes)	Project Cost (Rs/tonne)
2009-10	8.794	230.0	26.15	9.34	24.6
2010-11	9.396	65.8	7.00	14.07	5.0
2011-12	10.631	95.7	9.00	15.30	6.3
2012-13	11.219	104.0	9.27	16.54	6.0
2013-14	11.367	120.0	10.55	In progress	

Project cost is less than Rs 10 per ha and production cost is less than Rs. 1 per 100 kg

Table 3. Productivity of crops during the project period

Crops	Productivity (kg/ha)						
	Normal	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14 (Estimated)
Soybean	1204	601	741	1581	1313	1531	1302
Cotton	239	257	285	322	262	267	343
Rice	1480	1419	1474	1766	1836	1964	1799
Tur	733	600	833	750	677	829	874
Gram	685	677	892	904	733	826	932

There are various factors that govern productivity like varietal preference, prevalent weather conditions, rainfall distribution, fertilizer application *etc.*, however, pest and disease incidence normally contribute 20-30 per cent losses in yield. These losses could be well taken care of under this project that contributed to increase in productivity.

Comparative pest situation in soybean crop in project

The incidence of tobacco leaf eating caterpillar, *Spodoptera litura* from the year 2010 was comparatively low till the year 2013 (Fig. 2).

Fig. 3 shows that the pest situation of semilooper was comparatively high by recording highest number of ETL villages *i.e.*, 213 villages in the year 2010, while in the year 2011 incidence of semilooper was gradually decreased with recording least number of ETL villages in the year 2013.

In comparative study, number of ETL villages was found higher in 2011 i.e. 84 villages in 31st SMW of July while, more or less number of ETL villages has been recorded in rest of the years. The infestation of girdle beetle generally observed during 31st to 38th SMW i.e. August to September (Fig 4).

Use of GIS/GPS in Soybean crop for identifications of hot spots

NCIPM, New Delhi had developed *taluka* wise GIS mapping system for soybean, cotton, paddy, tur and gram pests. The maps generated through this system can be used for identifying endemic area of particular pest. Weekly pest status data was used for the development of maps. Intensity wise area packets of pest can be identified through this system.

Weather data analysis and development of pest forecasting modules

Prasad *et al.* (2013) have developed two forecast models to estimate *Spodoptera litura* population in soybean. Model one

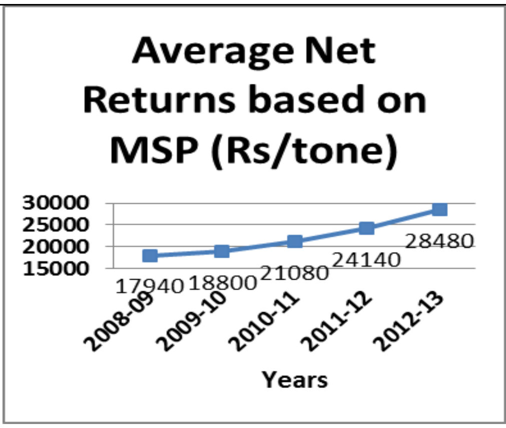


Fig. 1 A. Average net return based on MSP (Rs/tone)

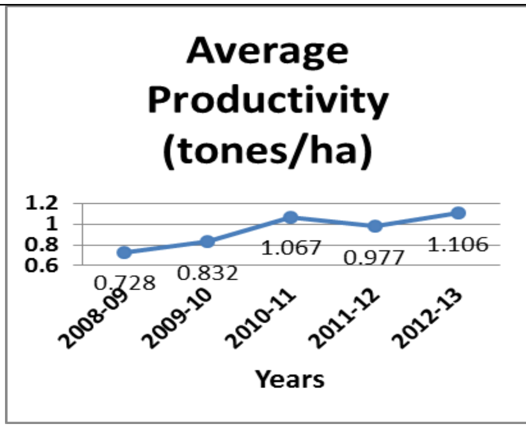


Fig. 1 B. Average Productivity (tones/ha)

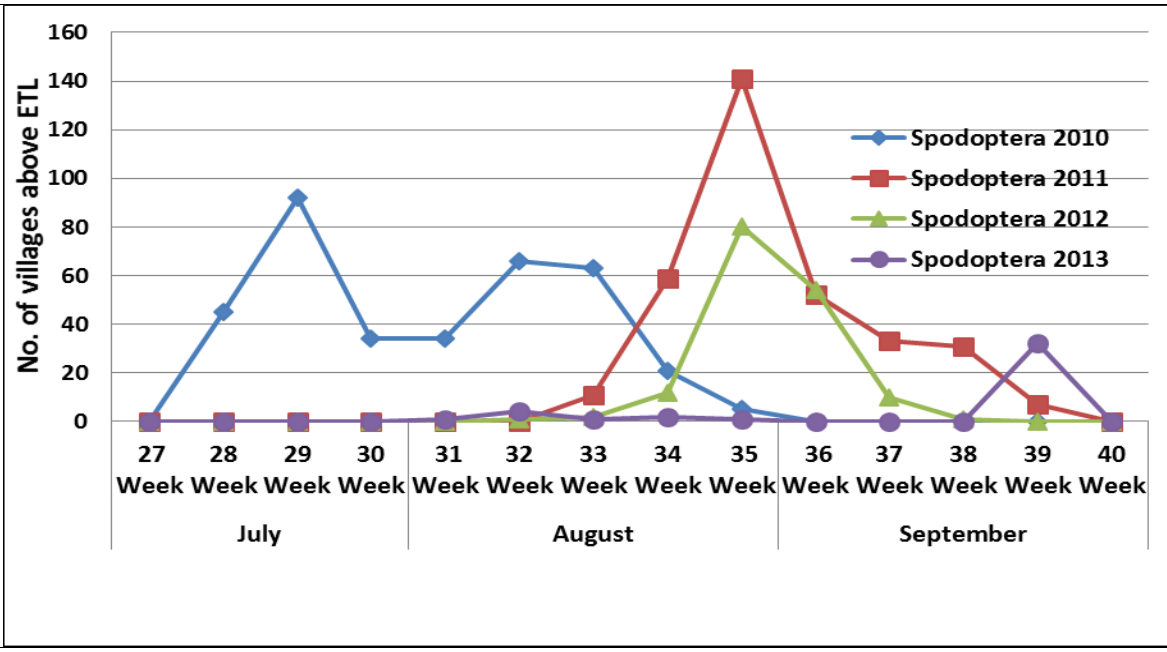


Fig. 2. Comparative pest situation of *Spodoptera litura* from the year 2010 to 2013

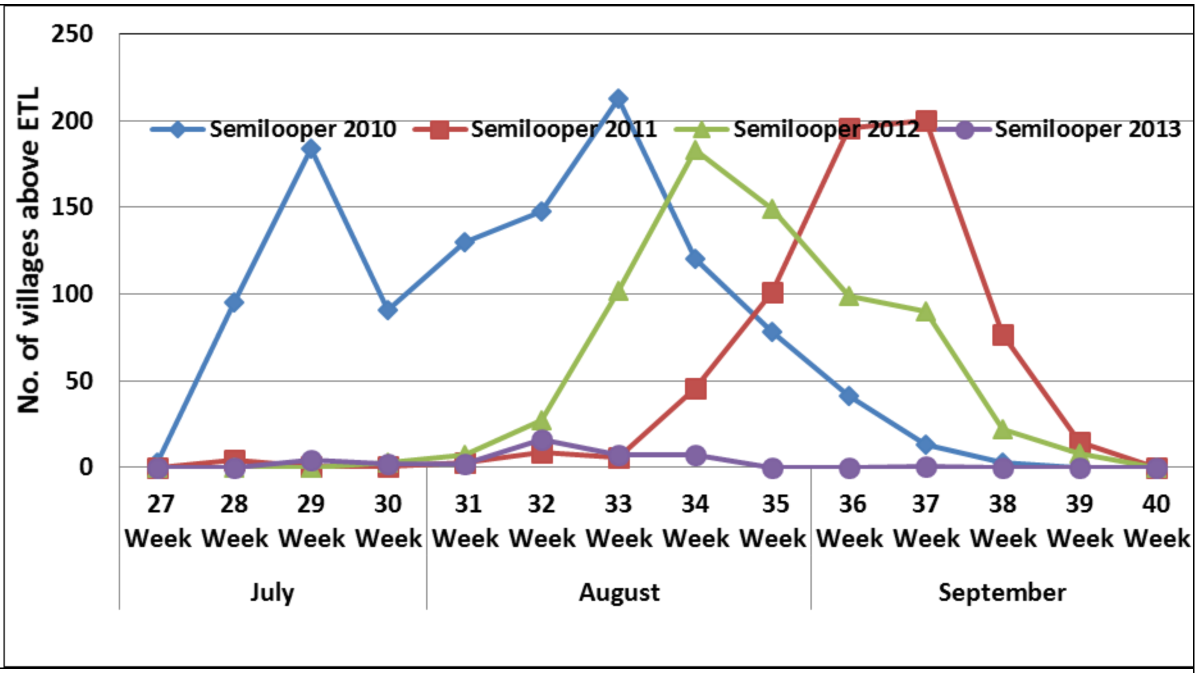


Fig. 3. Comparative pest situation of semilooper from the year 2010 to 2013

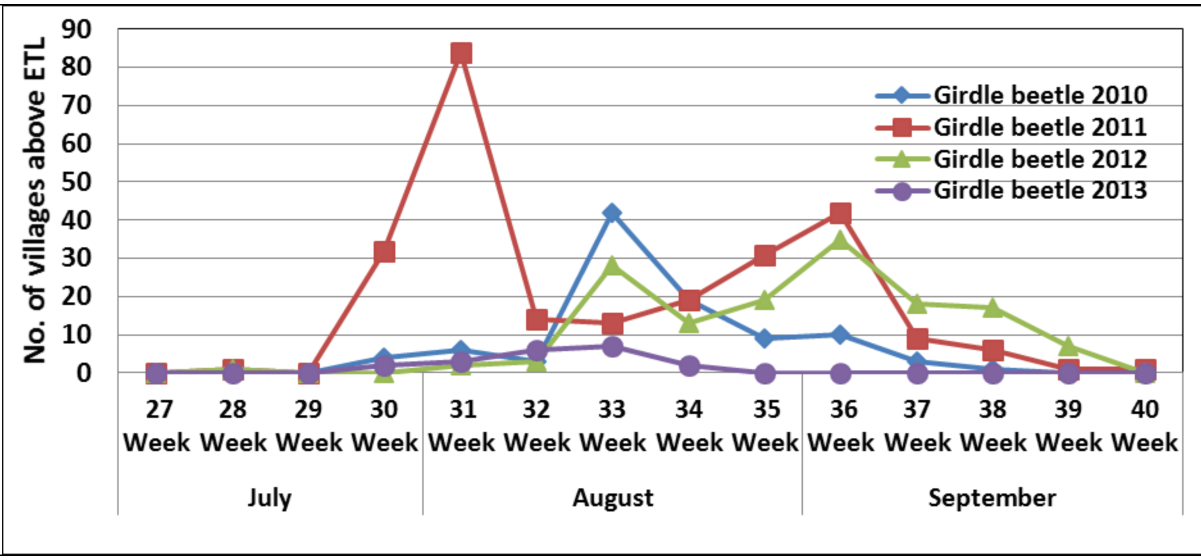


Fig. 4. Comparative pest situation of girdle beetle from the year 2010 to 2013

estimated *S. litura* population by the end of July and explained 70 per cent of the variation in pest incidence over three seasons *i.e.*, 2009 to 2011. Whereas, the second model estimated *S. litura* population by mid-August considering an additional parameter of number of rainy days (with >20 mm rainfall). These models can be used to estimate *S. litura* severity on soybean in 15 endemic blocks across districts in Maharashtra.

General appreciations

The project was appreciated at National Level during Zonal and National Conferences. Realizing its potential for preventing crop losses due to pest/diseases, the project has been adopted for implementation by other states *viz.*, Odisha and Gujarat. Government of India has advised all the States to replicate the project. Government of India has included the initiative in their guidelines for Accelerated Pulses Production Programme at national level. The project was also awarded with e-Governance 2011 Gold award at National level. NCIPM has adopted the concept in their Vision Document 2050. The project also serves as base line while formulating research project National Initiative for Climate Resilience (NICRA).

Third party project evaluation (Agriculture Finance Corporation Evaluation Report, 2013)

The findings of third party project evaluation carried out through Agriculture Finance Corporation are summarised (Table 4).

The major conclusions of the evaluation study were as follows:

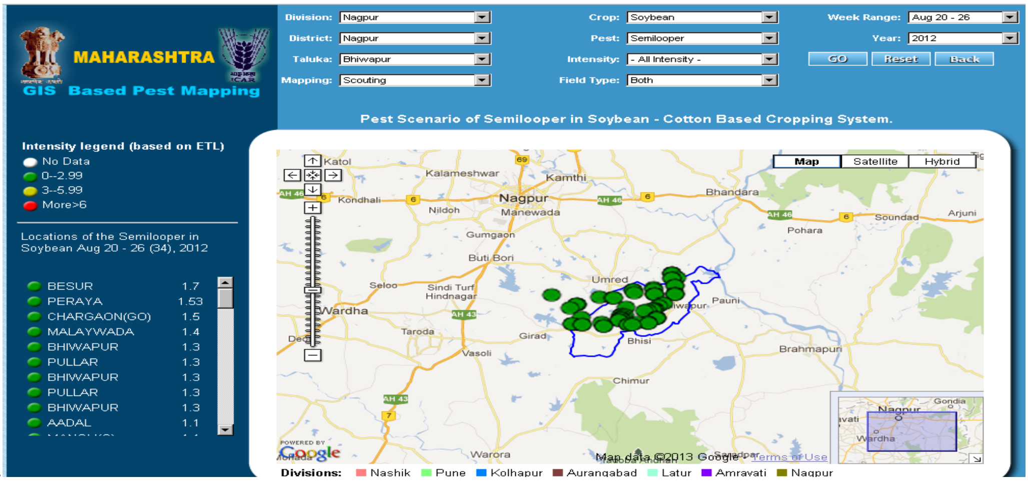


Fig. 5. GIS pest map showing situation of semilooper during standard meteorological week (SMW) period 20-26 August, 2013 in Bhiwapur block of Nagpur district

The level of literacy was found little higher amongst the beneficiary farmers as compared to control farmers. This shows that more and more literate farmers started participating in this vital campaign.

1. The overall opinion of the training received can be termed as good and very satisfactory.
2. The farmers were very much convinced and used the essential inputs and taken timely preventive measures to control the attack of crop pest in order to avoid probable yield losses of the crops included in the project.
3. Series of awareness programmes conducted has increased the status of identification of insects and pest by the farmers.
4. The timely guidance received by farmers through SMS enabled them to take protection measures in time that has resulted in reduction of losses in the yield of selected crops.
5. There has been considerable decrease in the cost incurred on crop protection measures due to CROPSAP. Moreover there has been good increase in crop production and net income to the farmers. Since the farmers could control the damage due to pest infestation very effectively.
6. The model of efficient control of crop pest through CROPSAP concept can be very well replicated and continued at different locations in the State as well as in the country.

Following are the points emerged by the execution of CROPSAP programme.

1. Scientific e-Pest surveillance on regular basis on large scale involving of key stakeholders has redefined Lab to Land concept in interactive mode.

Table 4. Third party evaluation of project by Agriculture Finance Corporation

Crop	Cost of pesticide application (Rs/ha)			Increase in yield / income		SMS response by farmers	
	Project	Non-Project	Difference	Yield (kg/ha)	Income (Rs/ha)	Shared with others	Measures adopted
Cotton	11750	12735	985	580	20300	15.14%	69.14%
Soybean	2021	2358	337	287	7175		
Tur	1097	1365	268	151	10550		
Gram	1340	1548	208	297	11885		

2. Understanding the ETL concept by farmers helped to adopt appropriate plant protection measures instead of calendar based spraying that resulted into saving wasteful expenditure on pesticides.
3. Real time and location specific scientific advisories dissemination through mass communication systems like SMS were found to be highly effective to take proper plant protection approach.
4. The data so generated from the project in a scientific and systematic manner will be of immense use for establishing correlation between weather parameters with pest dynamics and developing pest management modules accordingly.
5. The data bank so generated will be further useful to conduct advance research in the field of Entomology, Pathology and Agro-Meteorology.
6. Thus, pest surveillance using ETL concept on project mode leads to effectively monitor and control the pest and disease on wider areas in most cost effective manner.
7. Best use of ICT for real time advisory dissemination to farmers proved effective to get rid of pest losses. Use of ICT has improved the services in the G2G and G2C domain.

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Effect of Row Spacing and Seed Rate on Morpho-physiological Parameters, Yield Attributes and Productivity of Soybean (*Glycine max* L. Merrill) Cultivars under Rainfed Condition of Vindhyan Plateau of Madhya Pradesh

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ABSTRACT

A field experiment was laid out in split plot design during the kharif *2009, 2010 and 2011 at the RAK College of Agriculture, Sehore. The treatments comprised 2 cultivars (JS 95-60 and JS 97-52) and 3 row spacing (30, 45 and 60 cm) in main plots and 3 seed rates (55, 65 and 75 kg/ha) in sub-plots replicated three times. The cultivar JS 95-60 recorded significantly higher nodules (52.10) and nodules dry weight per plant (108.46 mg), chlorophyll content (1.452 mg/g fresh leaf wt.), NAR (0.008 mg/cm^2/day), photosynthesis rate (19.90 µ mol CO_2/m^2/sec), stomatal conductance (0.643 mol H_2O/m^2/s), seed index (11.73 g), HI (51.64 %), seed yield (2,274 kg/ha), net returns (38,577 Rs/ha), B: C ratio (4.37) and protein content (38.96 %) as compared to JS 97-52. The row spacing of 45 cm produced significantly more dry weight per plant and LAI at 45 and 60 DAS, CGR, RGR at 30-45 DAS, photosynthesis rate, stomatal conductance, transpiration rate, chlorophyll content, harvest index, seed yield and net returns as compared to row spacing of 30 and 60 cm. Protein and oil content were unaffected due to row spacing. Seed rate 75 kg per ha recorded significantly higher seed yield, net returns and B:C ratio as compared to seed rate 55 kg per ha but was statistically at par with seed rate 65 kg per ha. However, the nodules number and dry weight, and oil content was significantly higher with 55 kg per ha seed rate. The seed rate was not influenced the protein content. The data on seed yield indicated that two factor interaction between row spacing and cultivar and seed rate and cultivar was significantly influenced the seed yield. Cultivar JS 95-60 gave higher seed yield with 75 kg per ha seed rate planted at 30 cm row spacing. Whereas, cultivar JS 97-52 gave higher seed yield at 45 cm spacing with 55 kg per ha seed rate but was at par with 65 kg per ha. Similar trend was noted in net returns and B: C ratio.*

Key words: Physiological, productivity, rainfed, row spacing, seed rate, soybean

Soybean (*Glycine max* L. Merrill) with its 40 – 42 per cent protein and 20 -22 per cent oil has emerged as one of the major oilseed crop in India. It has now been established as one of the most important oilseed crops in the world, accounting for

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more than 50 per cent of oilseeds production and 30 per cent of the total supply of all vegetable oils. In spite of its high yield potential (4.5 t/ha), soybean productivity is much less in India (1.07 t/ha) than the world average of 2.43 tonnes per ha (FAOSTAT, 2011). Madhya Pradesh has first rank in soybean production since last 10 years. It contributed nearly 65 per cent with respect to area and 56 per cent to production. Soybean has much greater scope as it has diverse uses including soya nuts, soya milk, cheese, *etc*. Due to consumers' preference, soybean demand is going to increase in coming years in India. India imports vegetable oil, so soybean production in the country will not only help in meeting vegetable oil requirements but also save foreign exchange (Pan *et al., 2008*). Seed rate, row spacing and varieties/cultivars are known to influence the seed yield considerably (Billore *et al.*, 2000). Soybean canopy development is a function of row spacing, seed rate and environmental conditions. The relative equidistant plant distribution leads to increased leaf area development and greater light interception early in the season. This increases crop growth rate, dry matter accumulation and seed yield (De Bruin and Pedersen, 2008). For realizing the potential of any high yielding cultivar, row spacing and optimum plant stand are very important. An advantage of narrow row spacing is to increase crop growth rate, dry matter accumulation and soybean seed yield even in abiotic and abiotic stresses condition. Moisture stress has been documented to reduce the yield benefit from narrow row spacing (Elmore, 1998 and Heitholt *et al.*, 2005). Solar energy being unlimited, inexhaustible and non-pollutant, its efficient utilization for crop production could be major consideration, especially for a row crop like soybean. The low productivity of the crop is due to several constraints; among them genotypes, their spacing and seed rates are important (Dhaliwal and Kler, 1995). Therefore, field experiment was conducted to find out the best cultivar, row spacing and seed rate for harnessing yield potential of soybean.

MATERIAL AND METHODS

The field experiment was carried during 2009, 2010 and 2011 at Sehore, Madhya Pradesh on typic Chromusterts. The soil had pH 7.5, organic carbon 0.35 per cent and available N, P, K contents 212, 15.6, 314 kg per ha, respectively. The experiment was laid out in split plot design with treatments involving two soybean cultivars (JS 97-52 and JS 95-60), three row spacing (30, 45 and 60 cm) in main plots and three seed rates (55, 65 and 75 kg/ha) in sub-plots replicated three times. The recommended dose of fertilizer for soybean (20, 26.6, and 16.6 kg of N, P and K per ha, respectively) was applied through urea, single super phosphate and muriate of potash. The recommended package of practices was followed for the crop. Seeds of soybean inoculated with *Bradyrhizobium japonicum* and phosphate solubilizing bacteria were sown on 29th June, 2009, 05th July 2010 and 27th June, 2011. The total rainfall received during the crop season was 1,029, 576 and 1,166 mm in 2009, 2010 and 2011, respectively. Chlorophyll content in leaves of soybean was determined at 60 days after sowing (DAS) using standard procedure (Yoshida *et al*., 1972). The leaf area index (LAI), net assimilation rate (NAR) and crop growth rate (CGR) was worked out in between 30-45 and 45-60 DAS (Watson, 1952). Leaf area and photosynthesis rate, stomatal conductance and transpiration rate were recorded by using automatic leaf area meter and Li-cor 6400 photosynthesis system, respectively. The data on yield attributes and grain yield were collected at the time of harvest. The harvest index was calculated dividing grain yield by biological yield. Net monetary returns and cost: benefit ratio were calculated based on prevailing market price of inputs and produce.

RESULTS AND DISCUSSION

Row spacing

Row spacing had significant effect on morpho-physiological parameters, yield attributes and yield of soybean. However, plant height, nodules number and dry weight, CGR, RGR, NAR, and pods per plant were not significantly influenced by row spacing. The highest seed yield was recorded with 45 cm row spacing and it was at par with 60 cm row spacing. Both 60 and 45 cm row spacing recorded significantly higher seed yield than 30 cm. Similar results were also reported by De Bruin and Pedersen (2008) and Billore *et al.* (2000) where closer spacing could not increase the seed yield. The highest photosynthesis rate, stomatal conductance and harvest index were recorded with 45 cm row spacing followed by 60 and 30 cm. It might be due to optimum plant coverage in the field which facilitated more aeration, greater light interception and more photosynthetic activity. The highest LAI, transpiration rate and chlorophyll content were estimated with 45 cm row spacing followed by 30 and 60 cm (Table 3). These results may be due to early leaf area development and maximum interception of solar energy condition favoring translocation efficiency of dry matter to the seed resulted to get the highest yield. The highest net returns were observed with 45 cm row spacing while, B:C ratio gave non-significant trend. Protein and oil contents were unaffected due to row width. However, 45 cm row spacing showed superiority over 30 and 60 cm spacing with regards to oil and protein content.

Cultivar

The growth parameters like plant height, branches, nodules number and dry weight, physiological parameters like LAI, CGR, NAR, photosynthesis rate, stomatal conductance, transpiration rate and chlorophyll content, yield attributes like pods, seed index, straw yield and harvest index and quality characters like oil and protein content differed significantly for cultivars (Table 1 - 4). Cultivar JS 95-60 showed distinct edge over JS 97-52. The seed Index coupled with NAR, nodules number and dry weight, photosynthesis rate, stomatal conductance and chlorophyll content led to its better performance yield wise. Although JS 97-52 which produced higher plant height, number of branches, LAI, CGR and RGR could not yield better on account of their lower seed index (7.05 g). Cultivar JS 95-60 yielded significantly higher (2,274 kg/ha) as compared to JS 97-52 (1,630 kg/ha), indicating its distinct superiority (Table 4). Kumar *et al*. (2005) also reported genotypic differences with respect to pods per plant. Genotypes of soybean do differ in seed yields (Dubey and Billore, 1993 and Billore *et al*., 2009). Cultivar JS 95-60 recorded significantly higher photosynthesis rate, stomatal conductance, transpiration rate and chlorophyll content. It might be due to better photosynthate partioning during reproductive development for flower initiation, pod emergence and seed development in cultivar Js 95-60, while JS 97-52 showed better partioning during vegetative phase to determine the higher

Table 1. Effect of row spacing and seed rate on growth parameters and chlorophyll content of soybean cultivars (Pooled data of 3 years)

Treatment	Plant height at harvest (cm)	Branches at harvest (No/ plant)	Dry weight (g/plant) 30 DAS	45 DAS	60 DAS	Nodules at 60 DAS (No/plant)	Nodules dry weight /plant 60 DAS (mg)
Row spacing **(cm)**							
30	67.03	4.15	2.29	7.81	15.26	42.50	85.68
45	69.41	4.70	2.47	8.68	15.69	48.17	95.40
60	67.63	4.42	2.40	8.58	15.27	46.52	91.32
S Em (±)	1.01	0.13	0.08	0.17	0.11	2.80	3.70
C D (P = 0.05)	**NS**	**0.39**	**NS**	**0.53**	**0.34**	**NS**	**NS**
Cultivar							
JS 95-60	42.80	3.97	2.40	8.33	15.00	52.10	108.46
JS 97-52	83.40	4.94	2.31	8.39	15.81	43.60	88.20
S Em (±)	1.37	0.15	0.06	0.03	1.08	2.15	3.44
C D (P = 0.05)	**4.31**	**0.48**	**NS**	**NS**	**NS**	**6.40**	**10.60**
Seed rate (kg/ha)							
55	66.16	4.51	2.39	8.54	15.32	47.90	96.10
65	68.00	4.42	2.33	8.42	15.41	47.81	95.20
75	68.92	4.34	2.35	8.12	15.48	42.30	85.70
S Em (±)	2.27	0.90	0.08	0.10	0.95	1.60	2.88
C D (P = 0.05)	**NS**	**NS**	**NS**	**0.32**	**NS**	**4.90**	**8.90**

DAS: Days after sowing; NS: Non-significant

Table 2. Effect of row spacing and seed rate on physiological parameters of soybean cultivars (Pooled data of 3 years)

Treatment	**LAI**		**CGR ($g/m^2/day$)**		**RGR ($mg/cm^2/day$)**		**NAR ($mg/cm^2/day$)**	
	45 DAS	**60 DAS**	**30 – 45 DAS**	**45 – 60 DAS**	**30 – 45 DAS**	**45 – 60 DAS**	**30 – 45 DAS**	**45 – 60 DAS**
Row spacing (cm)								
30	4.44	4.83	4.19	1.76	0.113	0.045	0.005	0.003
45	4.76	5.16	3.54	1.68	0.119	0.041	0.006	0.005
60	3.92	4.12	2.37	1.58	0.110	0.029	0.005	0.003
S Em (±)	0.23	0.23	0.29	0.08	0.002	0.006	0.001	0.001
CD (P=0.05)	**0.66**	**0.70**	**0.88**	**NS**	**0.007**	**NS**	**NS**	**NS**
Cultivar								
JS 95 60	4.08	4.64	2.47	1.61	0.108	0.040	0.008	0.007
JS 97 52	4.54	4.92	4.15	1.73	0.118	0.043	0.004	0.001
S Em (±)	0.11	0.08	0.23	0.03	0.004	0.003	0.001	0.002
CD (P=0.05)	**0.32**	**0.24**	**0.72**	**0.10**	**NS**	**NS**	**0.003**	**0.006**
Seed rate (kg/ha)								
55	4.03	4.30	2.80	1.23	0.111	0.041	0.005	0.003
65	4.65	5.30	3.35	1.75	0.122	0.041	0.006	0.005
75	4.18	4.80	3.78	2.03	0.109	0.043	0.004	0.004
S Em (±)	0.15	0.19	0.11	0.07	0.003	0.002	0.001	0.001
CD (P=0.05)	**0.45**	**0.58**	**0.31**	**0.21**	**0.009**	**NS**	**NS**	**NS**

DAS: Days after sowing; NS : Non-significant; LAI: Leaf Area Index; CGR; Crop Growth Rate; RGR: Relative Growth Rate; NAR: Net Assimilation Rate

Table 3. Effect of row spacing and seed rate on photosynthesis rate, stomatal conductance and transpiration rate, and chlorophyll content of soybean cultivars (Pooled data of 3 years)

Treatment	Photosynthesis Rate at 60 DAS (μ mol $CO_2/m^2/s$)	Stomatal conductance at 60 DAS (mol $H_2O/m^2/s$)	Transpiration rate at 60 DAS (m mol $H_2O/m^2/s$)	Chlorophyll content at 60 DAS (mg/g fresh leaf weight)
Row spacing (cm)				
30	16.42	0.413	3.92	1.304
45	18.65	0.543	4.40	1.364
60	17.27	0.422	3.88	1.118
S Em (±)	0.53	0.030	0.15	0.048
C D (P = 0.05)	**1.60**	**0.101**	**0.48**	**0.146**
Cultivar				
JS 95 60	19.90	0.643	5.01	1.452
JS 97 52	17.80	0.448	4.08	1.293
S Em (±)	0.60	0.040	0.21	0.041
C D (P = 0.05)	**1.85**	**0.120**	**0.60**	**0.124**
Seed rate (kg/ha)				
55	17.06	0.490	4.28	1.348
65	18.85	0.618	4.77	1.426
75	18.72	0.578	4.68	1.255
S Em (±)	0.05	0.030	0.13	0.050
C D (P = 0.05)	**0.15**	**0.090**	**0.40**	**0.152**

DAS: Days after sowing

LAI and CGR. The highest biological yield was recorded in cultivar JS 97 52 which was significantly higher than JS 95-60. The net returns (Rs 38,577/ha) and BC ratio (4.37) was highest in cultivar JS 95-60 which was significantly higher than JS 97 52. Cultivar JS 97-52 significantly higher oil content (17.80 %) over than JS 95-60 (17.40 %). However, the reverse trend was noted for protein content 38.96 and 37.50 per cent for JS 95-60 and JS 97-52, respectively.

Seed rate

Seed rate significantly influenced the nodules number and dry weight, LAI, CGR, photosynthesis rate, stomatal conductance, transpiration rate, pod per plant, seed yield, straw yield, harvest index, net returns and B:C ratio. However,

Table 4. Effect of row spacing and seed rate on yield attributes and yield of soybean cultivars (Pooled data of 3 years)

Treatment	Pods (No/ plant)	Seed index (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Net returns (Rs/ha)	B: C ratio	Oil content (%)	Protein content (%)
Row spacing (cm)									
30	46.51	9.41	1867	3202	37.95	29638	3.68	17.05	38.10
45	48.85	9.48	2022	3038	42.02	33042	3.88	17.08	38.30
60	47.38	9.23	1967	3286	41.15	31837	3.68	16.90	38.18
S Em (±)	0.90	0.09	40	67	0.94	801	0.08	0.09	0.15
C D (P = 0.05)	**NS**	**NS**	**119**	**205**	**2.83**	**2405**	**NS**	**NS**	**NS**
Cultivar									
JS 95 60	34.91	11.73	2274	2219	51.64	38577	4.37	17.40	38.96
JS 97 52	60.12	7.05	1630	4132	29.11	29247	3.13	17.80	37.50
S Em (±)	1.23	0.08	35	68	0.52	816	0.07	0.07	0.41
C D (P = 0.05)	**3.70**	**0.25**	**106**	**207**	**1.54**	**2491**	**0.20**	**0.20**	**1.20**
Seed rate (kg/ha)									
55	49.27	9.37	1873	3190	41.04	30077	3.60	17.03	38.55
65	51.22	9.44	1986	3117	41.12	33270	3.82	16.98	38.50
75	45.66	9.40	1997	3308	38.96	32170	3.83	16.65	38.41
S Em (±)	1.12	0.10	37	58	0.70	883	0.06	0.09	0.13
C D (P = 0.05)	**3.39**	**NS**	**110**	**177**	**2.08**	**2604**	**0.18**	**0.27**	**NS**

NS: Non-significant

Table 5. Interaction effect of seed rate and row spacing on cultivar of soybean (Pooled data of 3 years)

Treatment	Seed yield (kg/ha)				Net returns (Rs/ha)			
	55	65	75	Mean	55	65	75	Mean
Cultivar JS 95-60								
30 cm	2196	2416	2541	**2385**	37172	41707	44164	**41014**
45 cm	2099	2271	2424	**2265**	35036	38505	41588	**38376**
60 cm	2006	2162	2348	**2172**	32983	36126	39913	**36341**
Mean	**2100**	**2283**	**2438**		**35064**	**38779**	**41888**	
Cultivar JS 97-52								
30 cm	1330	1433	1288	**1350**	18107	20075	16597	**18260**
45 cm	1825	1823	1691	**1780**	29012	28652	25459	**27708**
60 cm	1786	1818	1684	**1763**	28152	28551	25296	**27333**
Mean	**1647**	**1691**	**1554**		**25090**	**25759**	**22451**	
	Spacing (S)	**Cultivar (C)**	**Seed Rate (R)**		**Spacing (S)**	**Cultivar (C)**	**Seed rate (R)**	
CD (P = 0.05)	**81**	**66**	**53**		**1788**	**1460**	**1159**	
	SxR	**CxR**	**SxC**	**SxCxR**	**SxR**	**CxR**	**SxC**	**SxCxR**
CD (P = 0.05)	**NS**	**75**	**115**	**NS**	**NS**	**1639**	**2529**	**NS**

NS: Non-significant

plant height, branches, dry weight per plant except 45 DAS, RGR 45–60 DAS, NAR 30–45 and 45–60 DAS, seed index and protein content were found to be non-significant. The seed rate 65 kg per ha recorded the highest LAI (5.30), RGR (0.122 mg/cm^2/day) at 30-45 DAS, photosynthesis rate (18.85 μ mol CO_2/m^2/s) and stomatal conductance (0.618 mol H_2O/m^2/s) which was significantly superior than seed rate of 55 kg per ha but was statistically at par with 75 kg per ha seed rate. The seed rate 65 and 75 kg/ha showed higher LAI with photosynthesis rate, stomatal conductance and transpiration rate as compared to 55 kg/ha. It might be due to efficient interception of radiant energy to the crop surface require adequate leaf area, uniformly distributed to give complete ground cover supporting to higher yield. It might be due to competition among plant for resources like nutrients, space and sunlight. Seed yield is ultimate outcome of various physiological, biochemical and phonological processes occurring in the plant system. Data showed that seed rate significantly affected the pods per plant and seed yield. Pooled data of 3 years show significantly higher seed yield with seed rate of 75 kg per ha over 55 kg per ha but remained at par with 65 kg per ha seed rate (Table 4). When seed rate was increased from 55 to 65 kg per ha, the yield was increased by 6.00 per cent. When seed rate was decreased 36.36 per cent (75 to 55 kg/ha), the yield was also decreased by 6.62 per cent. Similar trend was obtained with net returns and B: C ratio. Mean oil content 17.03 and 16.98 per cent were significantly increased by seed rate 55 and 65 kg per ha, respectively over 75 kg per ha. Protein content was not significantly affected by seed rate.

The results revealed that the average performance of 2009 and 2011 was superior to 2010. This could be due to well distributed rains and favorable weather conditions conducive to the better growth and development of crop with less infestation of insects and pests (Chouhan and Joshi, 2005 and Wells 1991, 1993).

Interaction effect

The pooled analysis of three years data indicated that seed yield and net returns were significantly influenced by two factor interactions of seed rate x cultivar and spacing x cultivar. Cultivar JS 95-60 yielded higher with 75 kg per ha seed rate planted at 30 cm row spacing. Whereas, cultivar JS 97-52 gave higher yield at 45 cm row spacing with 55 kg per ha seed rate but was at par with 65 kg per ha seed rate. The similar trend was noted in case of net returns. Significant interaction indicated that there is differential requirement of seed rate and spacing of these two varieties for yield. This is expected due to variation in physiological parameters: LAR, CGR and NAR as well as in growth parameters, particularly in nodules, branches and pods per plant and thus resulting into seed yield variation.

Thus, it may be concluded that cultivar JS 95-60 with 75 kg per ha seed rate planted at 30 cm row spacing and cultivar JS 97-52 at 45 cm row spacing with 55 kg seed per ha were found beneficial for enhancing physiological parameters, yield attributes and soybean productivity in Vertisol under rainfed condition of Vindhyan plateau of Madhya Pradesh.

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Nutritional Quality Evaluation of Defatted Soyflour Incorporated *Idli*

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ABSTRACT

*This study determines the fermented product formulation (*idli*) and the effect of defatted soyflour on nutritional properties of fermented food product. For the preparation of* idli *batter, rice and blackgram were taken in the ratio of 2:1 and the pulse substituted by defatted soyflour at the levels of 0, 25, 50, 75 and 100 per cent. The best mix was selected on the basis of water requirement for* idli *batter, batter volume at different levels of fermentation and sensory evaluation. The best ratio of the rice: blackgram: DSF was 200:25:75. Data suggest that incorporation of standardized mixture of rice/ blackgram dhal with DSF in the ratio of 200:25:75 enhanced the protein by 61.14 per cent, ash content by 12.70 per cent and decreased fat content by 17.91 per cent and fibre by 24.59 per cent in comparison to control where no DSF was added. In defatted soyflour substituted* idli *iron, calcium and phosphorus increased by 178.78 per cent, 71.27 per cent and 34.41 per cent respectively in comparison to control with no added DSF. Per cent protein digestibility improved to 81.46 per cent in 75 per cent defatted soyflour substituted* idli *whereas in-vitro iron bioavailability decreased to 12.70 per cent with respect to control. It might be concluded that defatted soyflour can be substituted for pulse flour at the level of 75 per cent in* idli *without impairing its acceptability characteristics to yield low-cost and more nutritious product with improved digestibility.*

Key words: Blackgram, defatted soyflour, fermented product, *idli,* nutritional quality

Malnutrition takes several forms and has many causes with only one known cure, *i.e.* an adequate and well balanced diet. It is not sufficient to consume adequate quantity of food, we must also be concerned with food quality, because too many children in developing countries are doomed by malnutrition to lives of irreversible physical and mental damage. Access to nutritious food by poor people is being increasingly hindered by failure of food security system, and decreasing real income value in most developing countries undergoing structural adjustment programs. The major nutritional problems in India are protein

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energy malnutrition, iodine deficiency disorder, vitamin A deficiency and anaemia.

Major protein component of Indian diet comes from pulses but per capita availability has declined from 52g to 31.6 g a day in the past five decades (The Financial Express, 2013) as against the FAO/WHO's recommendation of 80g per capita per day. These escalating prices of pulses coupled with availability of protein rich defatted soyflour (DSF) prompted the study of substitution of pulses with defatted soyflour. Defatted soyflour contains about 50 per cent high quality protein Soy proteins are unique among plant protein by virtue of relatively higher biological value and essential amino acid pattern (Schroder *et al.*, 1976). It has the ability to lower cholesterol along with lowering risk of developing breast, colon and lung cancer; inhibit growth of prostate cancer, prevent osteoporosis, boost immunity, slow kidney damage, reduce menopause symptoms, aid in control of diabetes and cataract. When these benefits are coupled with fermentation which improves nutritive value of food with improved digestibility, a synergistic effect is seen. Fermented foods have added benefits of enhancing flavour, increased digestibility and pharmacological values (Jeyaram *et al.*, 2009). *Idli* which is a fermented/steamed product (breakfast food) of South India has good quality protein because of presence of dehulled black gram (*Phaseolus mungo*) coupled with rice (*Oryza sativa*). Soy proteins if, added to *idli* may enhance the quality even further and may help children suffering from PEM. Hence, the present study was planned and conducted to explore possibilities of using DSF in *idli*, optimize its proportion and to study the nutritional property of DSF incorporated fermented product, *idli*.

MATERIAL AND METHODS

Edible grade defatted soyflour was procured from Indore, India and other ingredients for product development (*idli*), *i.e.* rice, dehulled blackgram dhal, iodized salt were procured from the local market Pantnagar (Uttrakhand), India.

Preparation of flour: Grains were cleaned, washed under tap water and immediately placed in hot air oven at 55-60° C for 1-2 hours. They were ground using electric grinder to specified mesh size (30 mesh size for rice, 100 mesh size for dehusked blackgram dhal).

Preparation of blends: Different proportions of rice flour / blackgram flour / DSF were used for preparation of *idli* blends (Table 1).

Table 1. Composition of blends (w/w) for *idli*

Rice Flour	Blackgram flour	Defatted soyflour
200	100	00
200	75	25
200	50	50
200	25	75
200	00	100

Product formulation: *Idli* was prepared using the procedure suggested by Yajurvedi (1980) with some modifications. Batter was prepared from blends of rice flour/blackgram flour/ defatted soyflour by adding appropriate amount of water to form slurry. To it, 1.0 per cent NaCl (w/w) was added and was subjected to natural fermentation at 30 °C for 0, 12, 14, 16, 18 h in an incubator. At the end of fermentation, the slurry was poured onto an *idli* stand with shallow depression (10 cm in diameter and 2 cm deep). Steam cooking for 7-8 min produced raised cakes of *idli. Idlies* with different levels of fermentation were subjected to sensory evaluation by a panel of 10 judges from the Department of Foods and Nutrition, College of Home Science, Pantnagar. Fermentation time which yielded maximum batter volume resulted in best organoleptic acceptance. Hence, fermentation time was standardised for different blends.

Organoleptic evaluation: *Idli* prepared using different levels of defatted soyflour were evaluated for sensory quality characteristics using nine point hedonic scale to test liking or disliking of the product and score card method to test various attributes which contribute to acceptability of the product.

Chemical analysis: *Idli* samples were dried in hot air oven at 60 °C for 48 h and ground to powder form of 30 mesh size in moisture free environment followed by packing in air tight containers.

Proximate composition: Moisture, crude protein, crude fibre, total ash, crude fat in idli samples were determined according to AOAC (2000) procedures.

Carbohydrates- The carbohydrate content present in samples was expressed as per cent and calculated by subtracting the sum of per cent moisture, protein, fat, fibre and ash from 100.

Calorific value- The calorific value (Kcal/100 g) of products was calculated by summing up the products of multiplication of percent protein, fat and carbohydrate present in the samples by 4, 9 and 4, respectively (Mudambi and Rajagopal, 1983)

Iron, calcium and phosphorus: Iron was determined colorimetrically (AOAC, 2000), calcium by titrametric method (AOAC, 2000) and phosphorus by colorimetry (Ranganna, 1986).

In-vitro bioavailability of iron: Soluble and ionizable iron was extracted using procedure given by Rao and Prabhavati (1978).

In-vitro protein digestibility: It was estimated using pepsin-pancreatin enzymes. A modified procedure of Akeson and Stahman (1964) was used for this purpose.

Per cent digestibility was calculated using formula:

Per cent digestibility = Nitrogen in digested sample/crude nitrogen in sample x 100

RESULTS AND DISCUSSION

Proximate composition of *idli* prepared using rice / blackgram / defatted soyflour blends

In black gram substituted *idli* to

the extent of 75 per cent had 42.49 per cent moisture content whereas control *idli* had 38.52 per cent moisture content. Jain 2013 reported moisture content of 61.7-86.6 per cent in black gram substituted soybean *idli*. Protein content of *idli* prepared from rice and black gram (2:1), *i.e.* control was 15.93 per cent whereas, black gram substituted defatted soyflour *idli* showed a remarkable increase in protein content, *i.e.* 25.67 per cent (Table 2). Protein content of rice and black gram were 6.46 g, and 24.16 and optimized *idli* was found to be 10.21 g (Durgadevi, 2012). Ash content of black gram substituted defatted soyflour *idli* was 0.71 per cent whereas control *idli* had ash content of 0.63 per cent. Jain (2013) reported ash content in between 0.8-4.8 per cent. Fat content of the control *idli* was 0.67 per cent and that of blackgram substituted defatted soyflour *idli* showed a decrease in fat content (0.55 %). It may be due to less content of fat in defatted soyflour substituted *idli.* Fibre content of control *idli* was estimated to be 0.61 per cent and black gram substituted defatted soyflour *idli* to an extent of 75 per cent had fibre content of 0.46 per cent. Carbohydrate content of control *idli* was estimated as 81.71 per cent whereas having black gram substitution by defatted soyflour to an extent of 75 per cent had carbohydrate content of 72.09 per cent; a decrease of 11.77 per cent as compared to control product.

Energy content (Kcal / 100 g) of control *idli* was calculated as 396.59 Kcal/100 g. Defatted soyflour incorporation led to increase in protein but

Table 2. Proximate composition* of *idli* prepared using rice/ blackgram/ defatted soyflour blends

Rice: Blackgram: Defatted soyflour	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Fibre (%)	Carbo-hydrate (%)	Energy (Kcal/ 100g)
200:100:00	38.52 ± 2.67	15.93 ± 1.76	0.63 ± 0.013	0.67 ± 0.33	0.61 ± 0.041	81.71	396.59
200:75:25	39.36 ± 1.38 (+ 2.18)**	18.67 ± 1.59 (+ 17.20)	0.66 ± 0.089 (+ 4.76)	0.62 ± 0.028 (- 7.46)	0.55 ± 0.136 (- 9.84)	79.49 (- 2.72)	398.22 (+ 0.22)
200:50:50	41.10 ± 2.61 (+6.70)	21.33 ± 1.86 (+ 33.90)	0.69 ± 0.072 (+ 9.52)	0.59 ± 0.019 (- 11.94)	0.52 ± 0.089 (- 14.75)	76.76 (- 6.06)	397.67 (+ 0.27)
200:25:75	42.49 ± 2.33 (+ 10.31)	25.67 ± 1.90 (+ 61.14)	0.71 ± 0.063 (+ 12.70)	0.55 ± 0.036 (- 17.91)	0.46 ± 0.081 (- 24.59)	72.09 (- 11.77)	395.99 (- 0.15)
200:00:100	44.60 ± 2.89 (+ 15.78)	28.30 ± 1.81 (+ 77.65)	0.72 ± 0.059 (+ 14.29)	0.53 ± 0.048 (- 20.90)	0.41 ± 0.108 (- 32..79)	69.47 (- 14.89)	395.85 (- 0.19)

**Expressed on dry matter basis ± S.D.; ** Percentage increase/decrease over control* decrease in fat and carbohydrate content. Blackgram flour substituted by defatted soyflour to an extent of 75 per cent decreased the energy content to 395.99 Kcal per 100 g.

Mineral composition of defatted soyflour incorporated *idli*

Iron content of control *idli* was 3.11 mg per 100g whereas iron content increased to 8.67 mg per 100 g which was 178.78 per cent more than the control values of iron content. Calcium content of control *idli* was 46.10 mg per 100 g and that of black gram substituted defatted soyflour *idli* to an extent of 75 per cent showed a significant increase and the content of calcium increased to 78.96 mg per 100 g (Table 3). Phosphorus content which was reported to be 253.40 mg per 100 g in control showed an increase of 34.41 per cent in black gram substituted defatted soyflour to an extent of 75 per cent *idli* and the phosphorus content increased to 340.60 mg per 100g.

Table 3. Mineral composition (on oven dry basis)* of defatted soyflour incorporated *idli*

Rice: Black gram: Defatted soyflour	Iron (mg/100g)	Calcium (mg/100g)	Phosphorus (mg/100g)
200:100:00 (Control)	3.11 ± 0.27	46.10 ± 1.82	253.40 ± 1.54
200:75:25	5.16 ± 0.43 (65.92)**	61.06 ± 1.76 (+ 32.45)	281.80 ± 1.86 (+ 11.21)
200:50:50	6.78 ± 0.39 (118.10)	71.02 ± 1.89 (+ 54.056)	311.20 ± 1.77 (+ 22.81)
200:25:75	8.67 ± 0.56 (178.78)	78.96 ± 1.86 (+71.27)	340.60 ± 1.73 (+ 34.41)

**Mean of triplicate observation ± S.D.; **Per cent increase over the control*

In-vitro* protein digestibility of *idli

Substitution of black gram by defatted soyflour increased protein digestibility to 81.46 per cent, when level of substitution was 75 per cent as compared to control which was 76.46 per cent (Table 4). Protein digestibility increased with increasing level of defatted soyflour. This might be due to better protein digestibility of defatted soyflour, which is 62.97 per cent as reported by Gahlawat and Seghal, (1998) compared to that of blackgram dhal, 41.32 per cent (Sharma and Khetarpaul, 1997).

Table 4. ***In-vitro*** **protein digestibility of** ***idli***

Rice: Blackgram: defatted soyflour	Crude protein in sample (%)	Crude protein in digested sample (%)	Protein digestibility (%)
200:100:00 (Control)	15.93	12.18	76.46
200:75:25	18.67	14.56	77.99
200:50:50	21.33	17.16	80.45
200:25:75	25.67	20.91	81.46
SEm (±)	4.15	3.74	
CD (P = 0.01)	**0.36**	**0.20**	

In-vitro iron bioavailability of defatted soyflour incorporated *idli*

The soluble iron and ionizable iron at pH 1.35 and 7.5 were determined. At pH 1.35 the soluble iron was slightly higher than the ionizable iron. When the pH was increased from 1.35 to 7.5, both the ionizable and soluble iron decreased however, decrease in ionizable iron was of greater magnitude. The values of ionizable iron at pH 7.5 are used to predict the in-vitro values. With the incorporation of defatted soyflour, both total iron and ionisable iron increased but iron bioavailability decreased because the increase in total iron content was much greater compared to rise in ionizable iron. It implies much of soy iron goes unutilized compared to iron from pulses, as in black gram. Traditional food preparation processes such as soaking, germination and fermentation can activate native phytases and substantially degrade phytic acid thus increasing iron bioavailability (Hurrell, 2003). Jain (2013) reported total iron content in soybean *idli* in range of 1.3-8.7mg per 100 g. *In-vitro* iron bioavailability of defatted soyflour incorporated *idli* are given in table 5.

From the study it could be concluded that on addition of defatted soyflour the nutritional quality of *idli* increased. Hence, it can be substituted for pulse flour at level of 75 per cent without impairing its acceptability characteristics to yield economical and more nutritious product with improved digestibility.

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Table 5. ***In-vitro*** **iron bioavailability of defatted soyflour incorporated** ***idli***

Rice: Blackgram: defatted soyflour	Total Iron (mg/ 100 g)	pH = 1.35				pH = 7.5			
		Soluble Iron		Insoluble iron		Soluble iron		Insoluble iron	
		Dry Matter	%	Dry matter	%	Dry matter	%	Dry matter	%
200:100:00 (Control)	3.11	0.98	31.51	0.91	29.26	0.58	18.64	0.52	16.72
200:75:25	5.16	1.58	30.62	1.50	29.07	0.82	15.89	0.74	14.34
200:50:50	6.78	1.95	28.76	1.87	27.58	0.99	14.60	0.89	13.13
200:25:75	8.64	2.43	28.13	2.39	27.66	1.18	13.66	1.08	12.50
SEm (±)	2.35								
CD (P = 01)	0.23								

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Effect of Different Heating Methods on the Yield and Quality of Tofu

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ABSTRACT

Soft tofu was made using three different heating methods (conventional heating, microwave heating and ohmic heating). Tofu made from soymilk heated by microwave method had a lower yield, but higher hardness, gumminess, springiness, chewiness and cohesiveness than tofu made from milk heated by conventional and ohmic heating method. Whereas tofu made from soymilk heated by ohmic heating method had the higher yield followed by conventional and microwave. Protein and moisture content were not much varied by different heating methods of soymilk. Textural properties were related to heating methods of soymilk. Microwave heated soymilk was appropriate for tofu making with good textural properties, ohmically heated soymilk was appropriate for higher yield.

Key words: Conventional heating, microwave heating, ohmic heating, soft tofu

Soybeans have been an important source of protein, fat, and flavor for oriental people for thousands of years. With the increase in population and wide prevalence of protein malnutrition, attempts are being made to utilise protein from several unconventional sources (Liener, 1972). Soybean protein is unique among plant proteins by virtue of its relatively high biological value (Schroder *et al.*, 1973; Liener, 1972). It has been the subject of extensive investigation as a source of protein for the human diet. Direct use of soybean products as human food is a more efficient way of utilizing the highly nutritional soy protein as compared to feeding animals and then eating the animal products.

Tofu (soybean curd) is one of the most important and popular food products in East and South Eastern Asian countries (Oboh and Omotosho, 2005). Soymilk is boiled and then treated with a coagulant. Properly prepared tofu is bland, textural characteristics are important determinants of acceptability. A typical soft tofu is characterized by a bland taste and fine texture with 84-90 per cent moisture content (Kohyama *et al.*, 1993).

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The water content of tofu can be varied to produce an array of products with different textures.

This highly nutritious plant-protein based food can be used in soups, salads, pastries, sandwiches *etc*, as it is easy to digest and is substituted for meats, cheeses and certain dairy products in diets for dairy-sensitive individuals, vegans and the elderly. It has very low levels of saturated fat and no cholesterol. The production process involves sorting of beans, steeping, dehulling, grinding, filtration, boiling of milk, coagulant addition and curd formation, pressing, dicing and frying in the case of firm *tofu* (Shurtleff, 2000). It is consumed in significant amounts in Asian countries because of their inexpensive, high quality protein (Koury and Hodges, 1968).

The yield and quality of tofu are influenced by cultivar of soybeans (Shen *et al.*, 1991; Sun and Breene, 1991), processing methods (Shih *et al*., 1997) and different type (Parma *et al.,* 2007; Prabhakaran *et al*., 2006) and concentration of coagulants (Lim *et al.*, 1990; Shen *et al*., 1991; Sun and Breene, 1991). Soybean varieties have been reported to affect tofu yield and quality due to the differences in their chemical compositions (Schaefer and Love, 1992). The yield, moisture content, textural characteristics, and color of tofu are important to product quality and acceptability. Coagulation of soymilk is the most important step in the tofu process and the most difficult to master since it relies on the complex inter-relationship of the following variables: soybean chemistry, soymilk cooking temperature, volume, solid content and pH; coagulant type, amount, concentration and the method of adding and mixing; and coagulation temperature and time (Cai and Chang, 1997; Cai and Chang, 1998).

Processing factors, which affect the quality of tofu, include soaking time and temperature, grinding temperature, soy milk heating rate, stirring speed, type and concentration of coagulant, method of adding coagulant to soy milk, and the weight and time of press (Lu *et al.,* 1980; Tsai *et al*., 1981; Wang and Hesseltine, 1982; Beddows and Wong, 1987; Sun and Breene, 1991). The use of frozen soybeans may also change the quality of soybean products (Noh *et al*., 2005). Also there is a need for further studies on the effects of heat on soybean proteins and soybean protein products (Escueta *et al.*, 1986).

The present study aims to investigate how the three different heating methods namely conventional, microwave and ohmic heating affect the quality and yield of tofu.

MATERIAL AND METHODS

Soybeans (*Glycine max*) were obtained from the local market was used to produce tofu and same variety of soybean was used for all the three cases. They were stored at refrigerated temperature (4-8 °C) before tofu processing. Lemon was also obtained from the local market which was used as a coagulant in this study.

Preparation of soymilk

Soybean (*Glycine max*) (1 kg) was washed and soaked in 10 litres of tap water for 12 h at refrigerated temperature (4-8 °C) to reduce the off odour developed during soaking under hot and humid conditions of Thanjavur. The hydrated beans were drained and weighed to assess the amount of absorbed water. Tap water was added to the soaked beans resulting in a final bean-to-ratio of 1:5 (w/w). Then it was ground using a soymilk grinder/extractor. The grinder/extractor, equipped with grinder, de-odouriser and filter, could separate soymilk from the residue okra. The volume and solids content of the collected soymilk were measured. The total solid content of soymilk was determined as a degree of Brix (Wang and Chang, 1995). The soluble solids content of soymilk was measured with a hand held brix meter (Atago PAL-1) and adjusted to 10°Brix with addition of water (Table. 1a) and analyzed for proximate composition (Table. 1b).

Table. 1a. Adjustment of Brix of soymilk with the addition of water

Initial Brix value of Soymilk	Quantity of water added to 5 litres of soymilk (ml)	Adjusted Brix value
13	300	12
12	300	11
11	400	10

Table. 1b. Chemical composition (%) of soymilk

Protein	3.5
Fat	1.81
Carbohydrates	1.99
Ash	0.40
Moisture	93.29

Heating of soymilk

Three different heating methods namely induction heating (conventional method), microwave heating and a batch type ohmic heating system were adopted for heating soymilk. In all the three types, milk was heated to a temperature of 95 ˚C and allowed to cool down to the coagulation temperature (85 ˚C) before the addition of coagulant. For the ohmic heating of soymilk, an acrylic tray of dimension (15 cm x 15 cm x 5 cm) with the two stainless steel electrodes placed at two opposite ends was used to heat the soymilk with adjusted total soluble solids (TSS). A data acquisition system (DataTaker DT 85, Series 2) for recording temperature was used, from which the heating temperature of soymilk could be read directly. The temperature was monitored using a T-type thermocouple, which connected with the stainless steel electrodes and data acquisition system. The soymilk was heated using a low frequency alternating current from the public utility supply (50 Hz, 230 V).

For the conventional heating method, an induction stove (Prestige PIC 3.0 V2) was employed and experiments were conducted in a stainless steel container. And for the microwave heating, a microwave oven (IFB 30SC2) was used with similar sized container. In all the three cases TSS and the depth of the milk was kept constant.

Preparation of soft tofu from heated soymilk

300 ml of soymilk was taken for each trial and heated using ohmic heater, microwave oven and also conventionally to a temperature of 95 °C. Then it was allowed to cool down to a temperature of 85 °C in all the three cases and 12 ml of the coagulant (lemon juice) was added to separate the curd from the whey. After the addition of the coagulant, the mixing was held for 5 seconds and allowed to coagulate for 10 min. The bean curd formed was then transferred into a muslin cloth-lined stainless steel mold (10 cm x 8 cm x 5 cm) and then pressed (by placing a weight of 12.5 g/cm^2 for 10 min, 25 g/cm^2 for 10 min and 37.5 g/cm^2 for 10 min) over a 80 cm^2 area. At the end of pressing, the cloth was removed and the weight of tofu and the volume of drained whey were recorded. The weight of freshly produced tofu was recorded and the tofu was stored in cold store at 4 °C overnight and analyzed for textural properties. The tofu yield was expressed as g tofu per 100 ml of raw soymilk.

Determination of yield and quality

The amount of tofu produced from soymilk heated using different heating methods was adopted, recorded and expressed as g tofu per 100 ml of raw soymilk. Analyses of the samples from each treatment were made in triplicate. The moisture content of the tofu was determined by drying 5 g of tofu at 105 – 110 °C until the weight was registered constant and the total nitrogen content was determined by the micro-Kjedahl method (AOAC., 1975) on solid samples and the protein content was calculated using a factor of 6.25 x N (Jones, 1931).

The textural properties were measured using a texture. Cubical samples (1 cm dia x 1 cm ht) were cut from the central portion of tofu cake with a stainless steel cutter. Three samples were taken. A cylindrical plunger with 5 cm diameter and a load cell of 30 kg was used. The speed of the cross head was set at 10 mm per min. Textural properties including hardness, cohesiveness, springiness, chewiness and gumminess were calculated. Hardness was measured as the peak of the first bite and springiness was the distance of recovery between the two bites. Areas under the curves were measured by a planimeter. Based on the method of Bourne (1968), cohesiveness, gumminess and chewiness were calculated as representative textural parameters.

RESULTS AND DISCUSSION

The result revealed that there was noticeable difference in the tofu yield produced from each heating method, however ohmic heating gave the highest amount of yield (18.05 g), while conventional and microwave gave the least yield of tofu (Fig. 2). This indicated that the same coagulant used for all the cases may not differ substantially in their coagulating ability, however this slight difference in the yield could only be as a result of different heating methods adopted for heating the soymilk. The higher yield from the ohmically heated

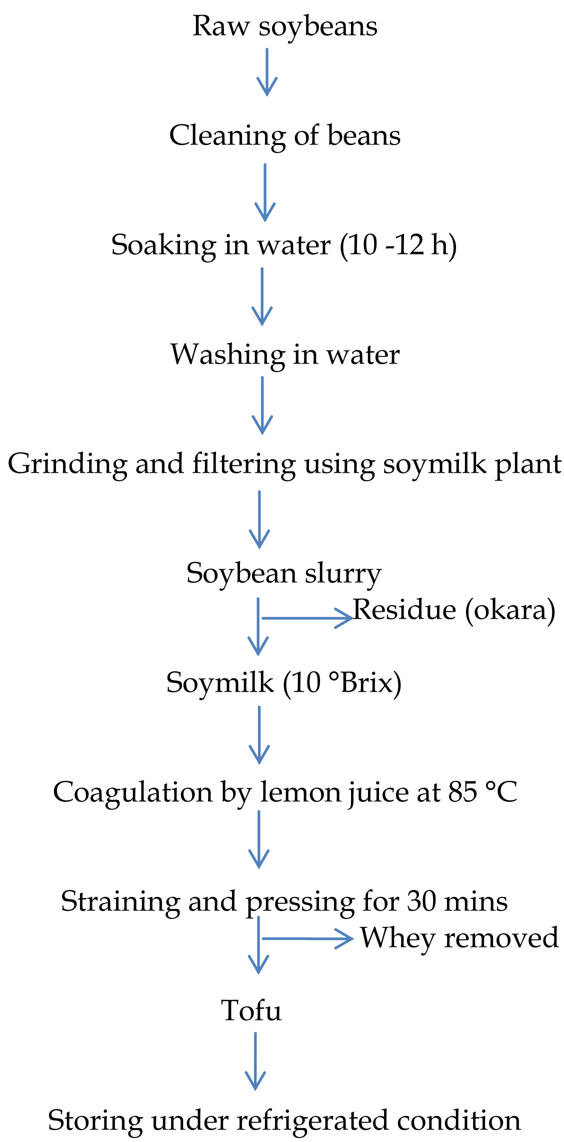

Fig. 1. Process flow chart for the production of soymilk and Tofu

sample may be due to the denaturation of the protein in the soymilk at a higher range than from the conventional and microwave treated samples. And as the denatured soybean protein is negatively charged (Kohyama *et al*., 1993), the protons produced by d-gluconolactone or calcium ions neutralize the net charge of the protein. Thus, the hydrophobic interaction of the neutralized proteins becomes more predominant and induce segregation (Kohyama *et al*., 1995) in the ohmically heated sample.

Protein and moisture content

Table 2 shows the moisture content and protein content of tofu produced by three different heating methods. Conversely, there was not much difference in the protein contents of tofu produced by three different heating methods (Fig. 3.). Though the yield was lesser from the conventional method than the ohmic heating the protein content was slightly higher in conventional than the ohmic heating.

Fig. 4 shows the variation in the moisture contents of the tofu samples produced from the soymilks heated using three different heating methods. A tofu with higher yield would have higher water-holding capacity (Hou *et al*., 1997). Thus, the tofu produced from the ohmically heated milk with the highest yield showed the higher moisture content (17.10 %) than that of tofu produced by conventional (16.95 %) and microwave method (15.50 %). The moisture content of the samples are also related to the textural properties of the samples. The moisture content appears to be very low. This could be due to the heating of soymilk in an open pan as there is moisture loss due to evaporation, it could also be due to the high pressure applied during pressing of tofu as it removed 70 per cent of water as whey (Fig. 5)

Determination of textural properties

Table 3 shows the textural characteristics of tofu prepared from soymilk heated with different heating methods. The highest mean hardness reported here is 229.47 g which corresponds to the tofu sample prepared from soymilk heated using microwave treatment. The mean value for springiness, chewiness, cohesiveness and gumminess reported here are 0.593, 67.543, 0.50 and 130.94, respectively corresponding to the tofu sample produced from soymilk heated using microwave treatment and these values were higher compared to the textural values of samples produced by other two heating methods. As mentioned earlier, this may be due to the water-holding capacity of the tofu. Hardness (229.47 g) of the tofu produced from microwave heated sample was found be higher with the least moisture content (15.5%). A positive relationship was observed between yield, moisture content and textural properties of tofu produced from three different heating methods. A tofu with higher yield has higher moisture content but lower textural property values which is given in the tables 2 and 3.

The textural properties of tofu produced from all three different heating methods were compared (Table 3). The hardness force of the tofu samples ranged

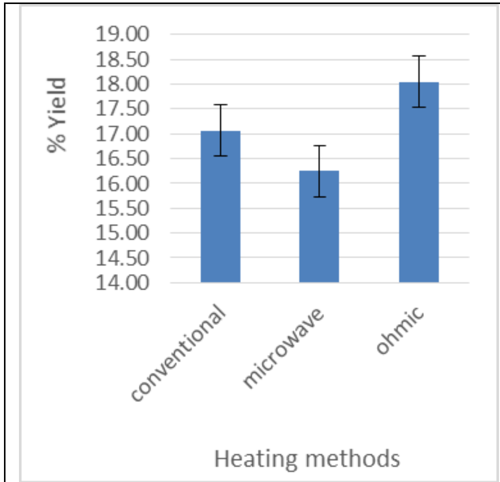

Fig. 2. The yield of tofu produced by three different heating methods (conventional; microwave; ohmic heating)

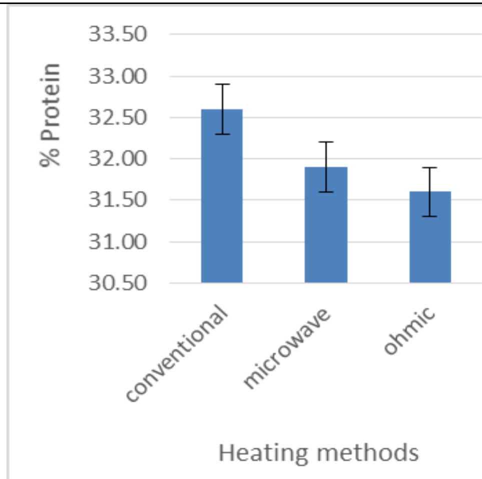

Fig. 3. The Protein content of tofu produced by three different heating methods (conventional, microwave and ohmic heating)

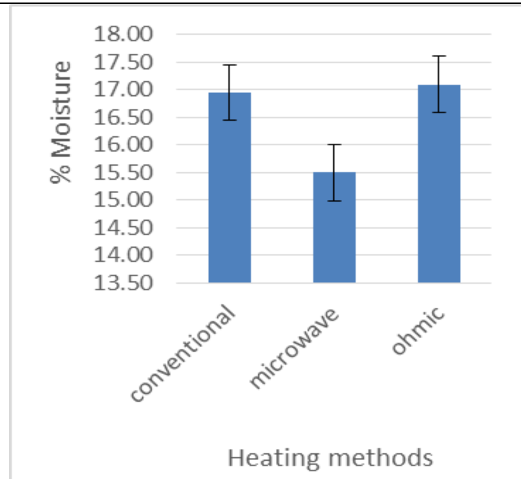

Fig. 4. The moisture content of tofu produced by three different heating methods (conventional, microwave and ohmic heating)

Table 2. Yield, moisture and protein content of tofu using different methods

Heating methods	Yield (g /100ml)	Moisture (% wb)	Protein (% db)
Conventional	17.067 ± 0.008	16.95±0.032	32.6±0.015
Microwave	16.25±0.132	15.50±0.055	31.9±0.010
Ohmic	18.05±0.0321	17.10±0.060	31.6±0.005

Table 3. Texture profile analysis of tofu prepared using different methods of heating soymilk

Heating methods	Hardness (g)	Spring-iness (mm)	Chewi-ness	Cohesi-veness (g.s)	Gumminess (g)
Conventional	226.087 ± 0.008	0.574 ± 0.001	59.197 ± 0.002	0.450 ± 0.0001	102.595 ± 0.052
Microwave	229.469 ± 1.717	0.593 ± 0.001	67.543 ± 0.022	0.500 ± 0.0100	130.935 ± 0.023
Ohmic	165.003 ± 0.016	0.550 ± 0.010	35.824 ± 0.014	0.400 ± 0.0060	66.340 ± 0.020

from 165 to 230 g, springiness ranged from 0.550 to 0.593 mm, chewiness from 35.824 to 67.543, cohesiveness from 0.400 to 0.500 and gumminess from 66.340 to 130.935. The wide range of hardness indicated that different heating methods produced different textures of tofu. This may be due to the different water holding capacity and yield obtained from different heating methods of soymilk.

In conclusion, it may be said that the tofu made from ohmically heated soymilk had higher yield but lower textural properties. Tofu made from microwave heated soymilk had lesser yield but had higher textural properties. However, different heating methods had no significant effect on the protein content and moisture content of tofu. The protein content was 32-33 per cent, lower than 53.6 per cent reported by Wang *et al.* (1982). This difference is probably due to the lower protein content of soybean in this study, since soybean and tofu protein is positively correlated. Similarly the moisture contents were in the range of 15 to 17 per cent, which is usually below 76 per cent may fall under the category dry tofu (Wang *et al.,* 1982). Yield was higher in ohmically treated soymilk followed by conventional and microwave. This may be due to the higher denaturation of protein and the rate of heating.

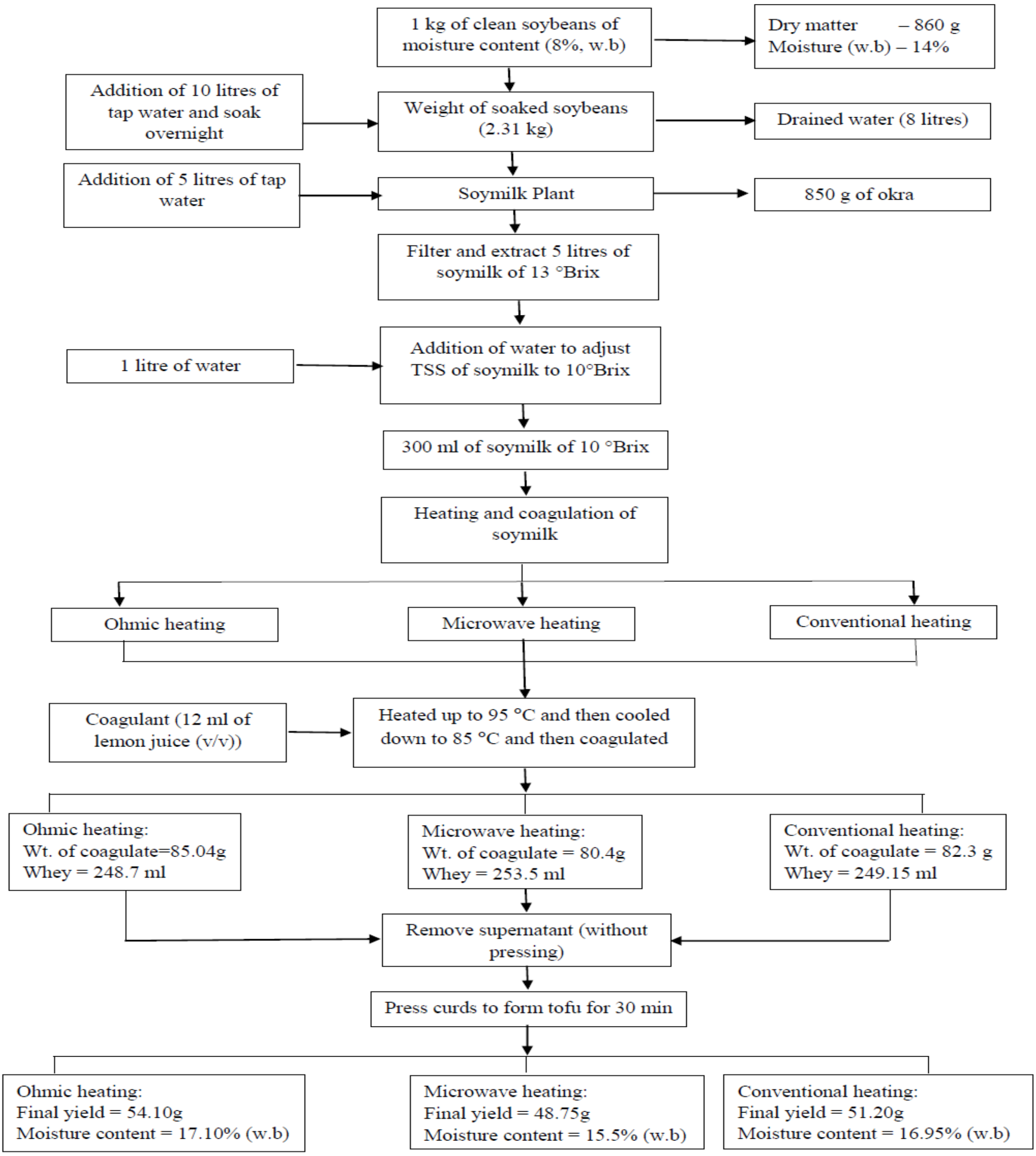

Fig. 5. Material balance chart for the production of soy milk and tofu from soybean

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Optimization of Extrusion Process to Produce Soy-Rice Snack Foods using Response Surface Methodology

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ABSTRACT

The expanded snacks with rice - soy were developed by process optimization for product quality. The snack products were analyzed in regard to mass flow rate, specific length of extrudates, and sectional expansion index. Five blends of soy and rice (8, 10, 12, 14and 16 % soybean in blend) at varying moisture contents (19, 20.5, 22, 23.5 and 25% wb) were extruded in laboratory single screw Brabender extruder at different barrel temperatures in the range of 180–200^{0}C keeping feed rate 0.25kg per h. The optimization with response surface methodology to obtain the product with maximum crispness and minimum hardness. The regression analysis of experimental data showed that the coefficient of determination, R^2 was above 85 per cent in all responses. The optimum process conditions for best quality soy-fortified extrudates were obtained at 187.2^{0}C barrel temperature, 21.28 per cent moisture content of feed, and 12 per cent blend ratio at feed rate 0.25 kg per h.

Keywords: Extrusion cooking, optimization, response surface methodology, rice, soybean

A majority of world population suffers from qualitative and quantitative insufficiency of dietary protein and calories intake. In all such cases physiological maintenance and growth are impaired resulting in under-nutrition. In this context, soybean can play a significant role as it is a very good source of quality protein, fat and minerals like Ca, Mg and P and to some extent of vitamin A, D and B-complex (Ali, 2005). A variety of food product can be prepared from soybean to fit into Indian dietary protein. Among that, soy-fortified snack can surely be an option to reduce nutritional deficiency in India at an affordable cost.

Main ingredient of extruded snacks is cereal which has low protein content and limited in lysine. The two essential amino acids methionine and cysteine are high in cereals. In contrast, soy protein is high in lysine but low in methionine and cysteine. Combination of both will produce highly nutritious products (Boonyasinikool and Charunuch, 1986). Chapman (1985) developed texturising and extrusion techniques for the production of meat like proteins from

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vegetable matter, especially soybean, and outlined the incorporation of textured soy – protein into foods and discussed its nutritional value. Horvath *et al.* (1989) evaluated the effect of extrusion of full fat soy flour at 120, 160 and 200^{0}C on physico-chemical properties of the product extruded in Brabender extruder. As the temperature increased, water absorption capacity increased and fat absorption capacity decreased. Protein digestibility and trypsin inhibitors decreased with increase in temperature. Garg and Singh (2010) used the defatted soy-sorghum flour in 30:70 proportions and a laboratory extruder to produce crispy snack food at different process variables; moisture content 14 – 22 per cent, barrel temperature 160 – 200^{0}C and screw speed 80-120 rpm. Multiple regression analysis of data indicated that diameter of extrudates, sectional expansion index, volumetric expansion index, water absorption index had significantly high degree correlation with process variables. Kulkarni *et al.* (1997) used the Wenger X-5 laboratory extruder for production of snacks from corn, rice, wheat and potato at 10 per cent blending of defatted soy flour. Boonyasinikool *et al*. (2000) developed a nutritious soy fortified snack with good texture and protein quality from 18 per cent of soy flour in broken rice and corn grits blend, with 2 per cent soybean oil. The obtained snack had expansion ratio, bulk density and compression force of 3.9, 3.958 g per cm^3 and 60.17 N, respectively. Subsequently sensory evaluation was also done for preference and acceptability. Protein content in the developed snack sample was 9.9 per cent. Singh *et al*. (2003) studied the effect of extrusion processing parameters of blend composed of soy-maize at different moisture content, temperature and blending ratio on quality of extrudates.The objectives of present work were to develop soy-fortified snacks by using soybean and rice blend and optimization based on physical characteristics *i.e.*, moisture content of blend, blending ratio and barrel temperature of extruder of soy-fortified extruded ready to eat snacks.

MATERIAL AND METHODS

The soybean (*Glycine max* (L.) Merrill) and rice (*Oryza sativa* L.) were used to make soy-fortified snack. Soybean dehulling machine and hammer mill was used for dehull of soybean and for grinding soybean and rice to obtain the required quantities of flour respectively and the same was used for extrusion where it is subjected to high temperature (180-200^{o}C) which is enough for inactivation of trypsin inhibitor. Vidal-Valverde *et al.* (1997) also reported that higher processing temperatures result in the greatest inactivation of soybean trypsin inhibitors. In the preparation of this snack product, the levels of different parameters like moisture content, blend ratio, and barrel temperature were selected (Table 1). The response surface methodology was used (Thompson, 1982; Desai *et al*., 1992). Therefore, the optimization of the variables for development of best quality of extrudates was done by response surface methodology (RSM). In this study we have chosen physical properties of product. Physical properties like sectional expansion index, mass flow rate and specific length were taken for determining the quality of expanded products. (Alvarez-Martinez *et al*., 2005) also reported the same. Physical property is a very important product quality attribute from the view of commercial production of extruded products (Medeni and Aylin, 2011). In this study we have taken sectional expansion index and specific length to describe effects on expansion quality and MFR is related to throughput of the machine. Most of the researchers attend the physical properties to describe product quality (Garg and Singh, 2012; Basediya *et al*., 2013)

A second order polynomial of the following form was fitted to data of all responses.

$$Y = a_o + \sum_{i=1}^{n} a_i Xi + \sum_{i=1}^{n} a_{ii} Xi^2 + \sum_{i=1}^{n-1} \sum_{\substack{j=2 \\ i \le j}}^{n} a_{ij} XiXj$$

a_o, a_i a_{ii} a_{ij} = Regression coefficients

X_i, X_j = Independent variables, Y = Dependent variables

Process flow diagram for preparation of soy fortified snack from soy-rice blends is given in fig. 1. Overall effects of independent variables on mass flow rate, specific length, and sectional expansion index were measured. Mass flow rate was determined during the extrusion process by collecting extruded samples at 1 minute interval and calculated as gram per second (Oke *et al*., 2010). Specific length is calculated by ratio of length of extrudate to mass of exrudate (Garg and Singh, 2012). Sectional expansion is calculated by the ratio of diameter of extrudate and the diameter of die, (Alvarez-Martinez *et al*., 2005).

Extrusion cooking

Extrusion cooking of soybean and rice blends was done on Brabender single screw extruder available at Soy bean Processing and Food Engineering Laboratory, JNKVV, Jabalpur. As soon as the extrudates comes out from die, it get puffed and expanded due to sudden release of pressure and moisture in vapour form. To have the desired size of extrudates, cutter was used at the end of die. Regression models were developed for establishing the relation between extrudate characteristics (dependent variables) and independent variables.

RESULTS AND DISCUSSION

The values pertaining to physical properties of extrudate samples (Table 2) revealed that mass flow rate ranged from 7.14 to 16.23. Even though feed rate is constant throughout the study, mass flow rate may vary due to variation in the material flow in different zones of extrusion. Specific length ranged from 3.59 to7.28 and sectional expansion index ranged from 1.61 to 3.62 (Table3). The regression analysis of experimental data

Table 1. Independent and dependent variables for extrusion process

Process parameters	Level	Values
Moisture content in blend (%) w.b.	5	19, 20.5, 22, 23.5 and 25 %
Blend ratio (%)	5	8, 10, 12, 14 and 16 %
Barrel temperature (^{0}C)	5	180, 185, 190, 195 and 200 ^{0}C
Screw speed (rpm)	1	100
Feed rate, (kg/h)	1	0.25 kg /h
Die diameter (mm)	1	5
Dependent variables	**Unit**	**Equation**
Mass flow rate	(g/s)	Weight of sample collected/Time taken to collect sample, gram per sec (Oke *et al*., 2010)
Specific length	(mm/g)	Length of extrudate/Mass of extrudate (Garg and Singh, 2012)
Sectional expansion index	-	Diameter of extrudate^2/ Diameter of die^2 (Alvarez-Martinez *et al*., 2005)

showed that the coefficient of determination, R2 was above 85 per cent in all responses. Higher value of R2 indicated that all the parameters had significantly affected the physical properties of extrudates.

The sign and magnitude of the regression coefficient indicated the effect of the variables on responses. The positive coefficient at linear level indicated that increase in response with increase in level of selected parameter and *vice versa*. Negative quadratic terms indicate that the maximum value of the response is at the centre point while positive quadratic term gives the minimum response. Negative interaction suggests that the level of one of the variables can be increased while that of other decreased to get same response value.

Effect of Independent variables on mass flow rate

The mass flow rate of extrudates were measured and found maximum (16.23) at 22 per cent moisture content, 200^{o}C barrel temperature and 12 per cent blending ratio and was minimum (7.14 g/sec) at 19 per cent moisture content, 190^{o}C barrel temperature and 12 per cent

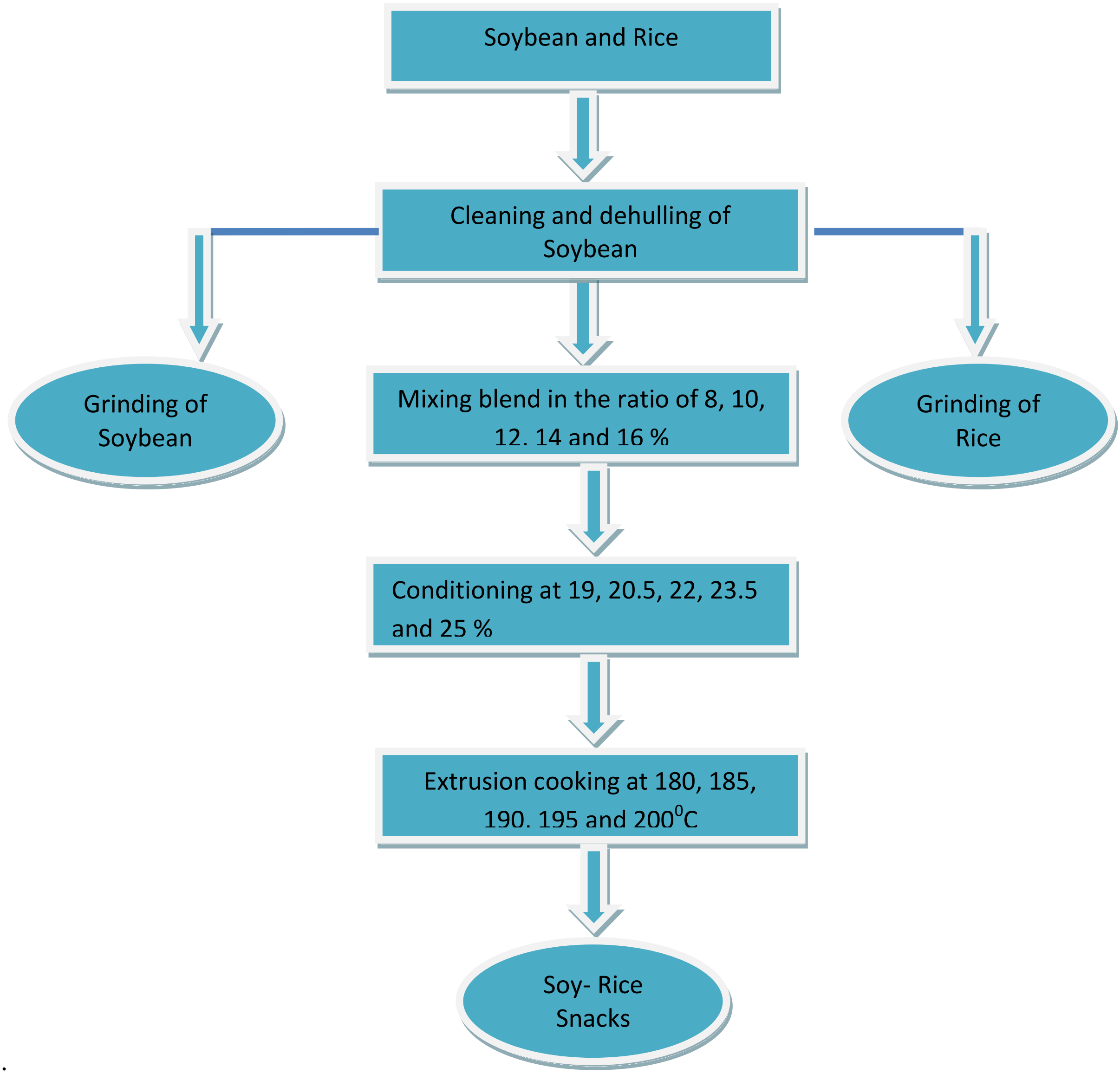

Fig. 1. Flow chart of preparation of soy-fortified snacks

blending ratio . The multiple regression analysis of the mass flow rate versus feed moisture content, blend ratio, and barrel temperature yielded following polynomial model:

If, X_1 = Moisture content; X_2 =Blend ratio; X_3 = Barrel temperature

$$\text{Mass flow rate} = 9.074 + 1.132 X_1 + 0.185 X_2 + 1.734 X_3 + 0.371 X_1{*} X_2 - 0.599 X_1{*}X_3 + 0.221 X_2{*}X_3 + 0.164 X_1^2 - 0.299 X_2^2 + 1.699 X_3^2 \quad \ldots\ldots\ldots\ldots 1$$

The coefficient of determination (R^2) was 96.26 per cent suggesting the adequacy of second order model. All independent variables gave positive effect on mass flow rate but for negative interactive level of moisture content and barrel temperature. Well puffed extrudates were produced at low moisture content, high temperature and low blending ratio. As it was noted that mass flow rate decreased when blend ratio increased.

Effect of independent variables specific length of extrudates

Maximum value of specific length (7.28 mm/g) was obtained at 19 per cent moisture content, 190°C barrel temperature and 12 per cent blending ratio and specific length was minimum (3.59 mm/g) at 23.5 per cent moisture content, 195°C barrel temperature, and 14 per cent blending ratio. The multiple regression analysis of the mass flow rate versus feed moisture content, blend ratio, and barrel temperature yielded following polynomial model.

$$\text{Specific Length of extrudates} = 6.271 - 0.980 X_1 + 0.171 X_2 - 0.046 X_3 - 0.264 X_1 * X_2 - 0.243 X_1{*}X_3 + 0.011 X_2 * X_3 - 0.150 X_1^2 - 0.419 X_2^2 - 0.340 X_3^2 \ldots\ldots\ldots\ldots 2$$

The value of R^2 was 90.95 per cent with F-value of 11.17 at 1 per cent level of significance showed that model was adequacy. It was found that specific length was highly affected by blending ratio and barrel temperature and it increased with increase or decrease in these levels (Fig.3).

Effect of independent variables on sectional expansion index

Maximum value of sectional expansion index (3.62) was obtained at 20.5 per cent moisture content, 195°C barrel temperature and 10 per cent blending ratio and it was minimum (1.61) at 23.5 per cent moisture content, 195°C barrel temperature, and 14 per cent blending ratio. The multiple regression analysis of the mass flow rate versus feed moisture content, blend ratio, and barrel temperature yielded following polynomial model.

$$\text{Sectional expansion index} = 2.981 - 0.324 X_1 - 0.438 X_2 + 0.073 X_3 - 0.151 X_1 * X_2 - 0.074 X_1 * X_3 - 0.164 X_2 * + 0.063 X_1^2 + 0.038 X_2^2 - 0.248 X_3^2 \ldots\ldots\ldots\ldots 3$$

The second order mathematical model was fitted for sectional expansion index and found the value of R2 as 90.51 and F value of 10.59 at 1 per cent level of significance. It was fond that all variables except barrel temperature gave negative effect on sectional expansion index. It was noted that increased independent variables gave negative effect on sectional expansion index (Fig. 4).

Optimization of process parameter

Optimization of process parameter was carried out using design expert software package (Khuri and Cornell, 1987). The optimum levels of independent variables for maximum values of SL, SEI and minimum values of MFR were given in Table 4.

It was concluded that response surface method was used successfully to optimize the level of moisture content in blend, blend ratio, and barrel temperature to develop soy fortified snacks using multi response software package. There is remarkable effect of moisture content of blend, barrel temperature and percentage of soy flour in the blend on physical properties. Further, it was concluded that quality of extrudates were obtained at 187.2^{0}C barrel temperature, 21.28 per cent moisture content of feed and 12per cent blending ratio. The corresponding value of response at optimized parameters were mass flow rate→7.97g per sec, specific length →6.56 mm per g and sectional expansion index 3.01.

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Table 2. Physical properties of soy-fortified snacks at different levels of variables

Extraction No.	Coded value of variables			Actual value of variables			Responses		
	Moisture content	Blending ratio	Barrel temperature	Moisture content (%, wb)	Blending ratio (%)	Barrel temperature (^0C)	Mass flow rate (g/ sec)	Specific length (mm/g)	Sectional expansion index
1	-1	-1	-1	20.5	10	185	8.26	5.93	3.48
2	1	-1	-1	23.5	10	185	10.45	4.92	2.91
3	-1	1	-1	20.5	14	185	7.72	6.61	2.77
4	1	1	-1	23.5	14	185	12.22	4.06	2.42
5	-1	-1	1	20.5	10	195	12.25	6.39	3.62
6	1	-1	1	23.5	10	195	12.87	3.92	3.58
7	-1	1	1	20.5	14	195	13.42	6.63	3.08
8	1	1	1	23.5	14	195	14.70	3.59	1.61
9	-1.68	0	0	19	12	190	7.14	7.28	3.61
10	1.68	0	0	25	12	190	11.23	4.71	2.42
11	0	-1.68	0	22	8	190	10.07	4.46	3.62
12	0	1.68	0	22	16	190	9.06	6.01	2.27
13	0	0	-1.68	22	12	180	10.82	5.35	1.93
14	0	0	1.68	22	12	200	16.23	5.57	2.34
15	0	0	0	22	12	190	9.09	6.21	2.98
16	0	0	0	22	12	190	9.10	6.18	3.00
17	0	0	0	22	12	190	9.10	6.54	2.99
18	0	0	0	22	12	190	9.08	6.27	2.99
19	0	0	0	22	12	190	9.11	6.09	2.99
20	0	0	0	22	12	190	9.09	6.28	2.99

Table 3. Regression coefficient of full second order model for physical properties of extrudates and their significance

Coefficients	Mass flow rate	Specific length	Sectional expansion index
β_0	9.0739	6.2712	2.9807
β_1	1.1327***	-0.9799***	-0.3245***
β_2	0.1854	0.1715	-0.4379***
β_3	1.7346***	-0.0462	0.0732
β_{12}	0.3713	-0.2640	-0.1513
β_{13}	-0.5988**	-0.2435	-0.0738
β_{23}	0.2213	0.0115	-0.1638
β_{11}	0.1644	-0.1504	0.0626
β_{22}	0.2988	-0.4193***	0.0379
β_{33}	1.6988***	-0.3403***	-0.2485
R^2 %	96.26	90.95	90.51
F- value	28.57	11.17	10.59

***** Significant at 1% level; ** significant at 5% level**

Table 4. Optimized condition for preparation of soy-fortified extrudates

Coded value of variables			Actual values of variables			Responses		
Mois-ture Cont-ent	Blen-ding ratio	Barrel Tempe-rature	Mois ture Cont ent (%, wb)	Blending ratio (%)	Barrel Tempe-rature (^{0}C)	Mass flow rate (g/ sec)	Specific length (mm/g)	Sectio nal expan sion index
-0.48	0.00	-0.56	21.28	12	187.2	7.97	6.56	3.01

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Effect of Processing Parameters of Spray-drying on Quality of Soymilk Powder

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ABSTRACT

Spray drying is a process widely used to produce powders from liquid foods. In powders, it results with the good quality, low water activity, easier transport and storage. The physico-chemical properties of powders produced by spray drying depend on the variables of process and/or operating parameters of spray dryer. Experiments were conducted to study the effect of operating variables of spray dryer i.e., inlet air temperature (180-220°C) and atomization pressure (2-3 kg/cm²) on the keeping quality and reconstitution properties of soymilk powder. The air flow rate and feed flow rate were kept constant as 1,250 rpm and 30 ml per min, respectively. It was observed that both the independent variables affected the quality and reconstitution properties of soymilk powder significantly. Residual moisture content was found to be low at higher inlet air temperature and higher atomization pressure. Bulk density was increased with increasing atomization pressure. Increasing the atomization pressure improved the reconstitution properties such as dispersibility and solubility index. However, direct exposure of protein to the higher temperature resulted in protein denaturation which was found to reduce the powder solubility. Color was affected significantly with temperature as increasing the temperature resulted in reduced whiteness of the soymilk powder.

Key words: Pressure, quality, shelf-life, soymilk powder, spray-drying, temperature

Soybean has been known as the best source of plant protein containing about 40 per cent protein of total protein (dry basis). It contains the highest protein content among legumes and cereals and is also rich in nutritive minerals and dietary fiber (Giri and Mangaraj, 2012). Soy proteins are highly digestible after proper heat treatment, and their amino acid profile is well balanced to meet the requirements for human nutrition. Soybean products have emerged as one of the most economical and nutritious foods that can combat diseases ascribed to malnutrition and under nutrition in developing countries. Lately, they are gaining importance in developed nations as well because of their nutraceutical ingredients namely, isoflavone, which lowers the risk of diseases such as breast

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cancer, cardiac arrest, osteoporosis, kidney stone and menopausal blues (Kumar *et al.*, 2003).

Among these soy foods, soymilk has gained much popularity as a healthy food drink. Basically, soymilk is a water extract of soybeans, closely resembling dairy milk in appearance and composition. The basic steps of preparation of soymilk include selection of soybeans, adding water, wet grinding and separation of soymilk from fiber (okara), steaming the wet mash to improve flavor and nutritional value, and filtering (Howell and Caldwell, 1978). It is an important plant protein beverage, rich in iron, unsaturated fatty acids and niacin. Low amounts of saturated fat and cholesterol are good for cardiovascular health. Soymilk is also touted as a healthy food because it is cholesterol and lactose free and contains phytochemicals. It is recommended for those who are allergic to milk protein or have lactose intolerance and those who have special health or religious diet requirements (Liu, 1997; Pomeranz, 1991). The absence of lactose makes it safe for people with lactose intolerance or milk allergy. It can safely replace breast milk for children with galactosemia. Hence, soy milk is considered an excellent economic dairy substitute (Jinapong *et al.*, 2008).

The major limitation associated with soymilk is its short shelf life during storage owing to its high nutritional contents which promote microbial growth. The production of powder product is a convenient method to solve this problem. Also, it requires relatively low transportation cost and storage capacity and the product can be distributed over a wide area. Thus, a process for producing a dried soymilk powder that is soluble and without loss of nutritive value is highly desirable (Jinapong *et al.*, 2008).

Spray drying is the most widely used commercial method for drying milks because of the very short time of heat contact and the high rate of evaporation gives a high quality. It was used for production of dehydrated soymilk powders by Wijeratne (1993). Soymilk powder has a white to light brown color and mixes readily with warm or cold water. It is the product obtained by removal of water from liquid soymilk or by the blending of edible quality soy protein and soybean oil powders. Soymilk powder contains less than 38.0 per cent soy protein, not less than 13.0 per cent soy fat and not less than 90 per cent total solids (Anonymous, 1996).

Spray drying is the transformation of feed from a liquid or slurry form to a dry powder. The feed is atomized into a chamber where the resulting spray mixes with hot air and the liquid droplets are dried in seconds as a result of the highly efficient heat and mass transfers (Toledo, 2007). The quality of any spray-dried powder is of key importance during processing. The desired quality of the powder is ultimately defined by consumer requirements or the needs of further processing steps. During spray drying, the method of atomization, inlet/outlet air temperature, and feed properties influence the final particle-size distribution, handling and reconstitution properties such as bulk density, appearance and moisture content of the resulting powder

(Masters, 1972). The present study has been conducted with the objective to determine effect of processing parameters on various handling and re-constitution properties of soymilk powder.

MATERIAL AND METHODS

Manufacturing of soymilk powder

Soymilk was prepared by soaking the soybeans overnight with distilled water. The excess water was drained out and the beans were ground in soymilk plant (Pristine Plants India (Pvt.) Limited, Faridabad, India) with 1:6 (weight/volume, 1 kg in 6L). Spray-drying was carried out by using a lab-scale spray-dryer (S M Scientech, Kolkata- 700 029) at fixed air flow rate (1,250 rpm), feed flow rate (25 ml/min) and outlet air temperature (80^oC), while varying the air inlet temperature and atomization pressure. The handling and reconstitution properties of prepared soymilk powder were analyzed.

Experimental design

Independent variables: Inlet air temperature - 180^0C, 200^0C, 220^0C; Pressure - 2.0 kg per cm^2, 2.5 kg per cm^2, 3.0 kg per cm^2
Fixed parameters: Air flow rate – 1250 rpm; Feed flow rate – 25 ml per min; Outlet air temperature – 80^0C

Analysis of properties of soymilk powder

Dispersibility: Dispersibility is an important property determining the reconstitution property of the product. The measurement was performed according to procedure described by (A = SNiro Atomizer) with some modifications. Distilled water (10 ml) at 25±1^oC was poured into a 50 ml beaker. The powder (1 g) was added into the beaker. The stopwatch was started and the sample was stirred vigorously with a spoon for 15 s, making 25 complete movements back and forth across the whole diameter of the beaker. The reconstituted soymilk was poured through a sieve (212 mm). The sieved soymilk (1ml) was used to determine per cent total solids.

% Dispersibility = [(10+a) % TS] / a [(100-b)/100]

Where, a is amount of powder (g) being used, b is moisture content in the powder, and per cent total solids is dry matter in percentage in the reconstituted soymilk after it has been passed through the sieve.

Solubility index: Solubility index was measured to analyze the extent of protein denaturation during spray drying. The method described by Lees was used for the measurement (Lee, 1971). A 1.3 g sample was blended with 10 ml distilled water and centrifuged at 1,000 rpm for 5 min. Total solids in the supernatant were determined. Solubility index was expressed as the ratio of total solids in reconstituted solution to that used in the preparation of the original solution.

Bulk density: The bulk density of the soymilk powder obtained from different drying processes and particle sizes was measured following the procedure described in previous studies with modification (Barbosa-Canovas *et al.*, 2005; Goula and Adamopoulus, 2008). Approximately 5 g of soymilk powder was freely poured into a 25 ml glass graduated cylinder (readable at 1 ml) and the samples were repeatedly tapped manually by lifting and dropping the cylinder under its own weight at a vertical distance of 14 ± 2 mm high until negligible difference in volume between succeeding measurements were observed. Given the mass m and the apparent (tapped) volume v of the powder, the powder bulk density was computed asm/v (kg/m^3). The measurements were carried out at room temperature in three replicates for all samples.

Moisture content: Moisture content was measured gravimetrically by drying in a vacuum oven at 70°C until constant weight (AOAC, 2005).

Color of soymilk powder: The color of tuna flavor powder was measured using a colorimeter (Miniscan, Hunterlab, Va, USA) in CIE L*, a*, b* color space. The powder was placed on the light port of color reader. Each value represents a mean of triplicate determination of three different positions for each sample. The values were reported as the average of individual value as L (lightness), a (+a is red, -a is green) and b (+b is yellow, -b is blue). Before measuring the color, the color reader was standardized with black and white calibration tiles supplied with the instrument (Kanpairo *et al.*, 2012).

Statistical analysis

All measurements were made in triplicate for each sample. Results are expressed as mean of the triplicates. A one-way analysis of variance (ANOVA) was used to establish the significance of differences among the mean values of the physical and reconstitution properties of the spray-dried soymilk powder. The data were analyzed using Design Expert version 7.0.0 Minneapolis, USA.

RESULTS AND DISCUSSION

Moisture content

Moisture content is an important parameter because it determines the shelf-life of a product. In our study, moisture content of the final dried product varied from 3.35 per cent to 10.75 per cent (Table 1). Fig. 1 shows the effect of inlet air temperature and atomization pressure on this response is significant ($p<0.05$) (Table 2). It can be seen from the figure that a product with low moisture content is obtained at higher inlet air temperature and atomization pressure. This is similar to results obtained by Tonon *et al.* (2008) and Al-Kahtani and Hassan (1990) who reported lower moisture content in the product at high inlet air temperature and low feed flow rates. Nath and Satpathy (1998), however, have obtained satisfactory residual moisture content in the product at lower inlet temperature of 140°C. Increased air temperature resulted in a greater temperature gradient between atomized feed and drying air, providing a higher driving force for moisture removal and hence lower residual moisture in the final product. The hotter the air, the moisture it will hold before becoming saturated. Thus, high temperature air in the vicinity of the particles will take up the moisture being driven from the food to a greater extent than the cooled air. Similarly, higher atomization pressure gives finer feed droplets in the chamber, which are efficiently dried resulting in lower residual moisture in the final product.

Table 1. Data obtained from experiments

Temperature (°C)	Pressure (kg/cm²)	Bulk density (kg/m³)	Moisture content (%)	Solubility index	Dispersibility	Color (L-Value)
180	2.0	0.2	10.75	0.65	42.15	80.05
180	2.5	0.23	8.67	0.88	44.2	81.62
180	3.0	0.27	4.76	1.27	46.51	87.19
200	2.0	0.14	7.12	1.06	56.51	84.26
200	2.5	0.16	5.54	1.37	62.16	86.56
200	3.0	0.16	3.56	1.74	70.06	90.39
220	2.0	0.13	6.34	0.68	41.93	87.62
220	2.5	0.14	5.32	0.76	42.63	89.83
220	3.0	0.16	3.35	0.89	48.56	90.5

Bulk density

Bulk density is an important parameter determining dimensions and type of packaging material during transportation. It ranged from 0.13 to 0.27 during the whole study (Table 1). In the case of bulk density, the atomization pressure is very important and is found to be a significant factor (Fig. 2) (Table 2). A higher evaporation rate was observed at the higher atomization pressure due to the formation of smaller feed droplets, resulting in particles with higher bulk density. In the region of higher temperature and lower atomization pressure, particles with higher porosity were obtained, because the rate of evaporation was high but the particle size of the feed droplets was comparatively big (Jindal and Boonyai, 2001).

Color

The color of the spray-dried soymilk powder on L, a, b color scale was observed. The L value varied from 80.05 to 90.50 (Table 1). Air inlet temperature was found to be significant in this case ($p<0.05$) (Table 2). It can be observed from table 1 that the whiteness, L value, in the samples decreased with the increased drying temperature (Fig. 3). It may possibly be due to the browning reaction occurring at higher temperature (Singh *et al.*, 2012).

Dispersibility

Dispersibility is an important reconstitution property used to study the effect of various process parameters. It can be seen from Fig. 2 that the dispersibility was found highest at 200ºC at 3.0 kg per cm^2 atomization pressure (Table 1). In previous studies, Goula and Adamopoulos (2005) and Papadakis *et al*. (1998) reported that lower moisture content at higher atomization pressure makes the powder more soluble and dispersible. Lower cohesiveness between particles at low moisture content at higher temperature resulting in higher dispersibility is a possible reason. However, at 220°C, the dispersibility reduced probably due to the formation of very fine particles which form lumps. In general, water wets very fine particles poorly because of its high surface tension (Schubert, 1993).

Solubility index

Solubility index varied from 0.51 to 1.89 during the whole study (Table 1). The quality of protein in the powder product is the main component determining the powder solubility, because insoluble materials are formed during protein denaturation (Jindal and Boonyai, 2001). This may explain the lower values of solubility at higher pressure where the probability of direct exposure of protein to the higher temperature is due more to the formation of smaller feed droplets that may contribute to denaturation (Fig. 5). A similar result has been reported in a previous study, (Goula *et al.*, 2004) where the solubility of tomato powder was found to decrease with an increase in inlet air temperature due to the fact that the higher air temperature resulted in protein denaturation. Similar results were reported earlier by Al-Kahtani *et al.* (1990) in their study on spray drying of roselle extract.

The soymilk powder was prepared by drying soymilk using a lab-scale spray dryer. Based on the above findings, it can be said that spray drying is an efficient method of drying soymilk powder. The inlet air temperature and atomization pressure has a significant effect on physical and reconstitution properties of soymilk powder. Too low temperature resulted in sticky powder due to higher residual moisture content. However, increasing the temperature was found to be responsible for poor reconstitution properties such as dispersibility and solubility index. Hence, 200°C temperature was the most suitable temperature in this study. The atomization pressure of spray dryer plays an important role in achieving desirable level of bulk density and keeping quality of soymilk powder. At 3 kg per cm^2 atomization pressure, the reconstitution properties achieved the maximum value with the least moisture content. Thus, the best quality soymilk powder was achieved at 200°C and at 3 kg per cm^2 atomization pressure.

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Table 2. Statistical analysis of data

Source	Sum of squares	DF	Mean square	F value	p-value Prob> F
Bulk density					
Model	0.02	4.00	0.00	21.25	0.0059
A-temp	0.01	2.00	0.01	36.50	0.0027
B-pressure	0.00	2.00	0.00	6.00	0.0625
Moisture content					
Model	43.32	4.00	10.83	15.97	0.0100
A-temp	16.55	2.00	8.27	12.20	0.0198
B-pressure	26.77	2.00	13.39	19.74	0.0085
Solubility index					
Model	0.99	4.00	0.25	14.90	0.0114
A-temp	0.61	2.00	0.30	18.28	0.0097
B-pressure	0.38	2.00	0.19	11.52	0.0219
Dispersibility index					
Model	794.14	4.00	198.54	31.76	0.0027
A-temp	690.44	2.00	345.22	55.23	0.0012
B-pressure	103.70	2.00	51.85	8.30	0.0377
Color "L" value					
Model	106.84	4.00	26.71	14.20	0.0124
A-temp	62.49	2.00	31.24	16.61	0.0115
B-pressure	44.35	2.00	22.18	11.79	0.0210

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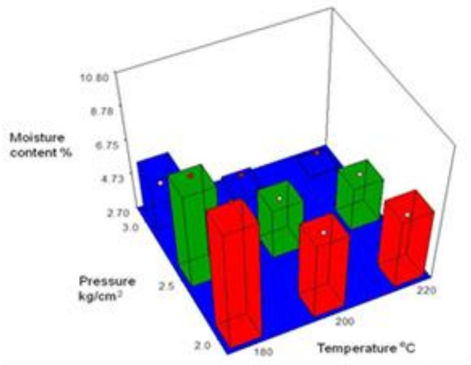

Fig. 1. Moisture content

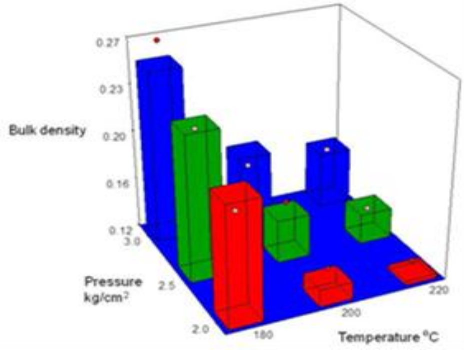

Fig. 2. Bulk density

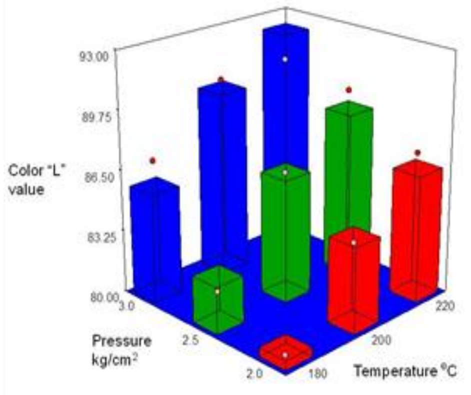

Fig. 3. Color

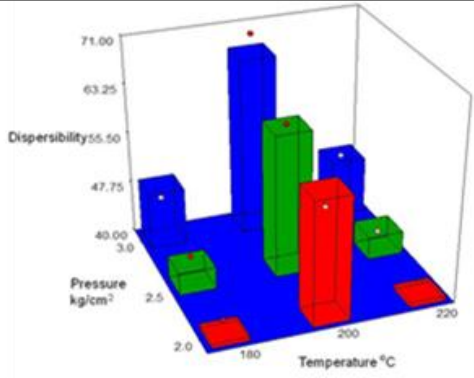

Fig. 4. Dispersibility

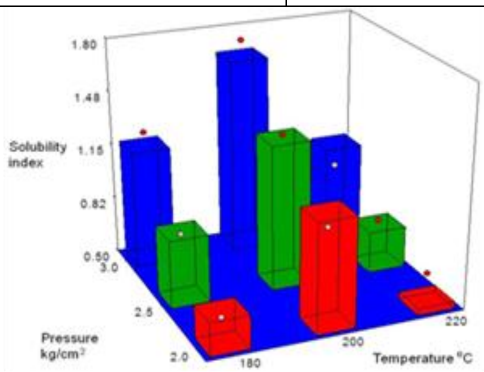

Fig. 5. Solubility index

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Comparative Advantage of Indian Soymeal *Vis-à-Vis* Major Exporters

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ABSTRACT

Soy meal accounts for 67 per cent of world's protein meals production followed by rapeseed meal (13.4 %), cottonseed and sunflower seed meal (6 % each). Soy meal has consolidated its position as the world's major source of protein meal for animal feed. Global export of soy meal has increased rapidly from 5.42 million tons in 1970 to 64.5 million tons in 2010. Soy meal accounts for nearly 75 per cent of world oilseed meals exports in quantity terms and 86 per cent in value terms. In India, its exports generate around Rs 14,150 million and this assumes significance as it is a major component of Indian agricultural exports. It is in this context the study was conducted to evaluate the competitiveness of Indian soymeal vis-à-vis major competitors using 'Revealed Comparative Advantage (RCA)'.

The results indicated that share of Argentina increased from 2.11 per cent in triennium average ending (TE) 1980 to 38.64 per cent in TE 2010 in world soy meal exports. India accounted for merely 0.36 per cent in global soy meal exports during TE 1980 and increased to 6.91 per cent (TE 2010). However, the proportion of USA and Brazil in global soy meal exports declined over the years, although their contribution was 12.56 per cent and 21.13 per cent, respectively. The values of RCAs and RSCAs indicated that Argentina, Brazil, Paraguay and India were highly competitive in soy meal exports, while USA and Netherlands were marginally competitive. However, the trend of RCAs showed that Argentina and India did not have competitive advantage during early 1980s, and became competitive in subsequent years. Argentina gained competitive advantage largely at the expense of USA and Brazil exports. India's competitive advantage showed an increasing trend till 1993 and started decelerating after the liberalization of oilseed sector. Moreover, the growing domestic feed use demand for soy meal, increased domestic prices thereby affecting competitiveness in world markets.

Key words: Comparative advantage, export, NRCA, RCA, RCSA, soy meal

Soybean is a fastest growing high value crop and its production derives economic viability mainly by the commercial utilization of both its sub-products, meal and oil, which, respectively, account for about two thirds and one third of the crop's economic value. Soybean oil is consumed mainly globally

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as food and meal as animal feedstuff. Soy meal is the world's most important source of protein feed because it is high in crude and digestible protein and low in fiber (Houck *et al.*, 1972), accounts for over 67.4 per cent of world protein meal production (624.75 mt) during triennium average ending 2012-13) and occupies a prominent position among protein feedstuffs used for the production of feed concentrates. Soy meal accounted for 74 per cent of the total protein meals exported globally (78.31 mt). The product has consolidated its position as the world's major source of protein meal for animal feed. Moreover, the rapid rise in the demand for compound feed, and thus soy meal, has contributed considerably to the rise in soybean and oil production.

The rapidly growing livestock sectors triggered its demand worldwide, which use soy meal as a key feed ingredient, as well as the rise in human consumption of edible oils as diets change in developing economies. The preference of China, the main driver of global demand for soybeans over the last decade, for imports of whole soybeans for crushing has raised and is likely to continue to raise the global import demand for soybeans *versus* meal and oil (USITC, 2012). Expanding demand for meat and other livestock products has stimulated the growth and commercialization of animal industries in developed countries. Hence, markets for high protein and feedstuffs are mainly in developed countries (Ryan and Houck, 1976; Mattson *et al.*, 2004). However, presently annual consumption growth in developing countries by far exceeds the expansion recorded in developed countries, mainly reflecting changes in consumer habits triggered by income growth.

Soybean is mainly grown in Argentina, Brazil, USA, China and India, which together accounts for about 90 per cent of the total area under soybean and 92 per cent of global soybean production. Though China is the largest consumer of soy meal and oil, being largest producer these countries, except China, are the largest exporters of soy meal which together accounts for nearly 80 per cent of global soy meal exports. Netherlands is also one of the leading importer as well as exporter of soy meal, but exports concentrated mainly within European Union. For the export market these countries compete with each other for capturing the market.

Competitiveness in international commodity markets reflects the ability to deliver a product at the lowest cost. Competitiveness is influenced by many factors: relative resource endowments, agro-climate conditions, macroeconomic policies, agricultural policies, infrastructure and supporting institutions (Schnepf *et al.*, 2001). The combination of farm-level production, transportation, and marketing costs will determine a country's competitiveness on the international stage. For many globally traded agricultural products, delivered cost is the most important criterion in making purchasing decisions. For producers of these goods to be competitive in export markets, they must be able to supply the products to purchasers at or below the price offered by other exporters and domestic producers. The price competitiveness of these suppliers therefore depends on factors that tend to lower or raise their delivered costs *vis-à-vis* the delivered costs of other imported and domestic products in their home market.

Recognising the increasing importance of the soy meal worldwide for feedstuff as well as for other food and industry uses, investigating its competitiveness is of paramount importance for policy makers as well as researchers and academicians. The primary objectives of this paper are a) to examine the comparative advantage in export of soy meal for major exporters; b) to look at the trade policy of major players and c) to analyse the determinants of export demand for soy meal from major exporters. The second section of the paper deals with the data and methodology used in the paper, third section discusses the comparative advantage of soy meal export, soy meal related trade policies of major players and the export demand relationship. The paper ends with the conclusion and policy suggestions.

MATERIAL AND METHODS

The concept of comparative advantage is derived from the traditional theory of international trade that it is more profitable for a country to export goods that it produces at a relatively lower cost, and import goods that it produces at relatively higher cost than other countries. Comparative advantage explains how trade, under unrestricted conditions, benefits nations either through better technology (Ricardian model), or through more efficient use of resource endowments (Heckscher-Ohlin model). Where, comparative advantage reflects relative competitiveness as measured by market shares.

In this paper, we use the Balassa's (Balassa, 1965; 1977) revealed comparative advantage (RCA) to assess comparative advantage of major soy meal exporters. RCA is a measure of international trade specialization. RCA identifies the comparative advantage or disadvantage a country has for a commodity with respect to another country or group of countries. It provides a ranking of commodities by degree of comparative advantage and identifies a binary type demarcation of commodities based on the comparative advantage (Balance *et al.,* 1987). Under the assumption that the commodity pattern of trade reflects the inter-country differences in relative costs as well as non-price factors, the index is assumed to 'reveal' the comparative advantage of the trading countries. The advantage of using the comparative advantage index is that it considers the intrinsic advantage of a particular export commodity and is consistent with the changes in an economy's relative factor endowment and productivity. The disadvantage, however, is that it cannot distinguish improvements in factor endowments and pursuit of appropriate trade policies by a country (Batra and Khan, 2005). The original index of RCA was first formulated by Balassa (1965) and can be written as follows:

$RCA^i_j = (E^i_j/E^w_j)/(E^i_k/E^w_k)$ . . . (1)

where,

E^i_j = Exports of country 'i' of commodity 'j'

E^i_k = Exports of country 'i' of a total agricultural commodities 'k'

E^{w}_{j} = Exports of a world 'w' of commodity 'j', and
E^{w}_{k} = Exports of a world 'w' of a total agricultural commodities 'k'

In the present study, country 'i' refers to soymeal exporting countries in analysis, commodity 'j' refers to soymeal, set of commodities 'k' refers to the total agricultural commodities and 'w' refers to World. If RCA value is greater than unity for a given country in a given commodity, the country is said to have a revealed comparative advantage in that commodity. However, RCA suffers from the problem of asymmetry as 'pure'RCA is basically not comparable on both sides of unity. If the index ranged from zero to one, a country is said not to be specialized in a given sector and if the value of the index ranged from one to infinity, the country is said to be specialized. When the index is made symmetric (Dalum*et al.*, 1998), the resultant index is called 'Revealed Symmetric Comparative Advantage' (RSCA). Mathematically, it can be expressed by the following equation (2)

RSCA = (RCA-1) / (RCA+1). . . (2)

This measure ranges between -1 and +1 and is free from the problem of skewness. A commodity is said to have comparative advantage in its exports if the corresponding RSCA value is positive and vice versa. In the present study, the RSCA was used to look into the comparative advantage of the selected commodities.

In this paper, we also analysed the normalized revealed comparative advantage (NRCA) index as an alternative measure of comparative advantage following the methodology used by Yu *et al.* (2009). This index possesses all the properties necessary for comparative analysis. The key to the derivation of the NRCA index is the comparative-advantage-neutral situation (point). Under the situation of comparative-advantage-neutral, country *i*'s export of commodity *j*, $\hat{E}^{i}_{j}$, would equal $E^{i}_{k}E^{w}_{j} / E^{w}_{k}$. Country *i*'s actual export of commodity *j* in the real world, E^{i}_{j}, would normally differ from $\hat{E}^{i}_{j}$; and the difference can be stated as

$$\Delta E^{i}_{j} \equiv E^{i}_{j} - \hat{E}^{i}_{j} = E^{i}_{j} - (E^{i}_{k}E^{w}_{j})/E^{w}_{k} \quad .....(3)$$

Normalizing _E jiby the world export market, *E*, we obtain the NRCA index (Yu *et. al.*, 2009) as follows

$$NRCA^{i}_{j} \equiv \Delta E^{i}_{j} / E^{w}_{k} = E^{i}_{j} / E^{w}_{k} - E^{i}_{k}E^{w}_{j} / E^{w}_{k}E^{w}_{k} \quad .... \quad (4)$$

The NRCA index measures the degree of deviation of a country's actual export from its comparative-advantage-neutral level in terms of its relative scale with respect to the world export market and thus provides a proper indication of the underlying comparative advantage.

According to Eq. (4), $NRCA^{i}_{j}>0$ (or $NRCA^{i}_{j}<0$) indicates that country *i*'s actual export of commodity *j* (E^{i}_{j}) is higher (or lower) than its comparative-advantage neutral level ($\hat{E}^{i}_{j}$), signifying that country *i* has comparative advantage (or disadvantage) in commodity *j*. The greater (or the lower) the $NRCA^{i}_{j}$ score is, the stronger the comparative advantage (or disadvantage) would be. Since comparative advantage is a relative concept, the interpretation of the magnitude of NRCA is more meaningful within a comparative context in terms of the relative strength of comparative advantage. For instance, $NRCA^i_j$ = 0.01 and $NRCA^i_b$ = 0.05 means that the relative strength of country *i*'s comparative advantage in commodity *j* is five times of its comparative advantage in commodity *b*.

The paper is mainly based on secondary data, collected from Food and Agriculture Organization (FAO), United States Department of Agriculture (USDA), World Trade Organisation (WTO), United Nations Conference on Trade and Development (UNCTAD), International Monitory Fund (IMF), *etc*. for the period 1980 to 2011.

RESULTS AND DISCUSSION

Performance of soy meal exports

Global soy meal exports have increased from 17.6 million tonnes (mt) during triennium average ending (TE) 1981 to 62.1 mt in TE 2011, an increase of about 353 times. Major exporters of soy meal are Argentina, Brazil, United States of America, Netherlands, India and Germany. Globally Argentina dominates the global export market for soymeal. The share of Argentina to world soymeal exports had increased from 2.11 per cent in TE 1980 to 38.64 per cent in TE 2010 (Table 1). The perusal of data revealed that, the share of countries like Brazil and USA in global soymeal export decreased from 36.24 and 40.28 per cent in TE 1980 to 21.13 and 12.56 per cent in TE 2010, respectively. India accounted for just 0.36 per cent of world soy meal exports during TE 1980 which has increased to 6.91 per cent in TE 2010. With the increasing domestic production and processing of soybean in India, and growing demand of soy meal in neighboring countries paved the way for increased export of commodity from the country.

Production and trade of soymeal globally is considerably higher as compared to the other protein meals. During 2012, soymeal production was 180.66 million tons followed by rapeseed meal (36.93 mt). During the same year, 77.5 million tons of soymeal was exported followed by 5.87 million tons of palm kernel meal. Most of soymeal was used as a feed ingredient because it contains high amount of protein as compared to other protein meals. The leading producing countries of soymeal are China (with annual production of 51.44 mt), United States (36.17 mt), Brazil (26.85 mt), Argentina (26.08 mt), and India (7.76 mt) contributing about 25.2, 21.4, 15.9, 15.8 and 5.8 per cent of global soy meal production, respectively (USDA, 2013). Soymeal production in these countries has increased substantially over the last two decades. Among these countries, Argentina and China registered substantial increase in soy meal production. Though, China does not produce significant amount of soybean, but is the largest producer of soy meal mainly due to higher import of soybean from other major producers. Moreover, China has created large oilseed crushing capacity of about 110 million tonnes to meet the domestic demand of edible oil (USB, 2012).

China is the major consumer of soy meal, with an annual consumption of around 42.02 million tons or

Table 1. Share of major exporters in world export of soymeal

Country	In Quantity (%)				In Value (%)			
	TE 1980	TE 1990	TE 2000	TE 2010	TE 1980	TE 1990	TE 2000	TE 2010
Argentina	2.11	18.65	32.42	38.64	1.88	17.49	28.70	35.50
Brazil	36.24	33.93	26.28	21.13	33.92	32.10	24.88	20.77
USA	40.28	19.32	17.10	12.56	40.26	20.53	19.50	13.22
Netherlands	9.32	6.97	6.51	7.73	10.34	8.06	7.38	8.64
India	0.36	3.63	6.50	6.91	0.35	3.58	6.19	7.60
Germany	4.78	3.41	3.38	2.24	5.57	4.03	4.11	2.53
Paraguay	0.25	0.40	1.02	2.03	0.18	0.28	0.97	1.92
China	0.20	8.01	0.05	1.48	0.20	7.48	0.06	1.84

Source: Authors calculations based on data from FAO.

approximately 98 per cent of total domestic production (Table 2), followed by United States and Brazil. These three countries contribute to about 50 per cent of total world soymeal consumption. The European Union, Mexico, Thailand, Japan, Vietnam, India and Indonesia are the countries that consume most of the remaining soymeal. It terms of exports, US dominated the world export of soymeal during 1960s (about 66 %). A significant increase in soybean crushing in countries like Argentina and Brazil has eroded the United States' share of world exports. The soy meal export scenario changed dramatically wherein Argentina and Brazil took over from US in production share, and most of production in these countries is designated for exports. Average annual soymeal export from the Argentina is 25.2 million tonnes (44.7%) as compared to 13.6 million tons (24.1%) and 8.9 million tons (16%) by Brazil and United States, respectively (Table 2)

India is the fourth largest soymeal exporter in the world contributing up to 4.05 million tonnes (7.2 %). A favorable production environment and better quality of soymeal in competing countries such as Argentina, Brazil and India are some of the factors explaining these changes in market shares. The governments of Argentina and Brazil have set up policies that encourage value-added exports. Brazil gained market shares immensely as the country guarantees soymeal protein levels ranging 47 to 48 per cent to the foreign buyers.

However, half of the US soy meal though, containing nearly 47 per cent protein content, but domestic consumption of soymeal had contributed to lower protein soymeal for the export market (Larson and Rask, 1992).

The top export destinations of soy meal for major exporters were worked out (Table 3). The Indonesia (9.78 % of total soymeal exports of Argentina during TE 2012) is the largest importer from Argentina followed by the Netherlands (9.35 %), Thailand, Spain, Italy and Vietnam. Top ten import markets of Argentina accounts for about 60 per cent of total soymeal exports. The soy meal export markets of Brazil were mainly concentrated to European countries. The Netherlands was the largest soymeal import market of Brazil (26.74 %), followed by France, Germany, Thailand and Spain. Top ten export markets of Brazil accounts for 83 per cent of Soymeal exports from United States of America were destined to Canada (14.36 %), Mexico (11.36 %), Venezuela (8.8 %), Egypt (7.33 %), and Morocco (6.41 %). Top ten import markets accounts for 65 per cent of total exports of soymeal from United States of America. India exports soymeal mainly to Japan (19.58 % of total soymeal exports from India), Vietnam (16.6 %), Iran (8.56 %), Pakistan (6.87 %), Thailand (6.8 %), and South Korea (5.74 %).

Table 2. Supply and distribution of soymeal by country

Country	Production	Export	Import	Consumption
World Total	170,453	56,464	54,547	167,853
China	42,881 (1)	1,000 (7)		42,025 (1)
United States	36,462 (2)	8,987 (3)		27,640 (3)
Brazil	27,068 (3)	13,600 (2)		13,534 (4)
Argentina	26,865 (4)	25,219 (1)		876
European Union	9,968 (5)	592 (8)	20,434 (1)	30,080 (2)
India	6,924 (6)	4,049 (4)		2,885 (9)
Mexico	2,874 (7)		1,414 (9)	4,289 (5)
Japan	1,676 (8)		2,035 (5)	3,755 (7)
Russia	1,647 (9)	27		2,120
Taiwan	1,581 (10)			1,639
Bolivia	1,393	1,175 (5)		
Paraguay	1,340	1,153 (6)		
Thailand	1,284		2,560 (4)	3,828 (6)
Canada	1,076	168 (9)	1,124 (10)	2,033
Korea, South	705	83	1,687 (8)	2,348
Iran	655		1,874 (6)	2,491
Vietnam	459		2,605 (3)	3,040 (8)
Norway	324	161 (10)		
Indonesia			2,939 (2)	2,868 (10)
Philippines			1,805 (7)	1,857

Source: USDA, Note: values are average of marketing year 2008-09 to 2012-13 and expressed in 1,000 tonnes; Numbers in parentheses are world rank.

Top ten import markets makes-up to 77 per cent of total soymeal exports from India.

Competitiveness of soy meal exports

The value of Revealed Comparative Advantage (RCAs), Revealed Symmetric Comparative Advantage (RSCA) and Normalized Revealed Comparative Advantage (NRCA) index of soy meal exports for major exporters (Table 4) revealed that during 1980s Argentina had comparative disadvantage in export of soymeal as indicated by the less than unity RCA value, negative RSCA and NRCA value. However, the country gained comparative advantage in export of soymeal from mid 1980s and its comparative advantage is steadily increasing over the years. The RCA values larger than unity and higher values of RSCA (Fig. 1) and NRCA index indicated that Brazil had a significant comparative advantage in export of

Table 3. Export destinations of soymeal

Rank	Argentina	Brazil	USA	India
1	Indonesia (9.78)	Netherlands (26.74)	Canada (14.36)	Japan (19.58)
2	Netherlands (9.35)	France (14.66)	Mexico (11.36)	Vietnam (16.60)
3	Thailand (7.15)	Germany (10.08)	Venezuela (8.80)	Iran (8.56)
4	Spain (6.31)	Thailand (9.66)	Egypt (7.33)	Pakistan (6.87)
5	Italy (5.04)	Spain (3.78)	Morocco (6.41)	Thailand (6.80)
6	Vietnam (5.03)	Slovenia (3.56)	Dominican Republic (4.53)	South Korea (5.74)
7	Iran (4.46)	Republic of Korea Republic (3.23)	Guatemala (3.72)	Bangladesh (3.46)
8	Algeria (4.15)	Romania (2.89)	Ecuador (3.19)	UAE (3.45)
9	Malaysia (3.98)	Vietnam (2.72)	Turkey (2.59)	Indonesia (3.17)
10	United Kingdom (3.97)	Italy (2.69)	Israel (2.58)	France (2.88)

Note: Figures in parentheses are percentage of total quantity of soy meal export from the country for the triennium average year ending 2012-13; Data source: authors calculations based on data collected from UN COMTRADE.

Table 4. Revealed Comparative Advantage of soy meal export

Year	Argentina	Brazil	USA	Netherlands	India
			RCA		
1980	0.69	8.61	2.14	1.58	0.46
1990	8.09	11.27	1.33	1.13	4.87
2000	12.17	7.82	1.25	0.99	5.35
2010	11.84	3.60	1.24	1.27	3.93
2011	11.86	3.70	1.00	1.16	3.80
			RCSA		
1980	-0.19	0.79	0.36	0.23	-0.37
1990	0.78	0.84	0.14	0.06	0.66
2000	0.85	0.77	0.11	-0.01	0.69
2010	0.84	0.57	0.11	0.12	0.59
2011	0.84	0.57	0.00	0.07	0.58
			NRCA		
1980	-1.33	54.78	37.62	7.25	-1.04
1990	24.76	45.08	7.42	1.95	5.96
2000	48.47	35.07	5.74	-0.13	8.68
2010	69.61	31.62	5.52	4.04	11.43
2011	69.04	31.65	-0.02	2.04	12.46

soymeal, however, the trend of these values indicated that comparative advantage is decreasing over the years. USA though, had comparative advantage in exports of soymeal during 1980s, but its comparative advantage is declining over the years and in 2011 the country is at comparative advantage neutral condition.

In case of India, RCA index value was less than unity during 1980s indicating that the country had comparative disadvantage in export of soymeal during that period, the negative RSCA and NRCA index values also supported this. The country has gained comparative advantage during mid 1980s. Though, RCA and RSCA values over the years has shown a slight decline during recent decade indicating marginal decline in comparative advantage, however, NRCA index values did not support this. The Netherlands, another major exporter of soymeal, though, has comparative advantage in export of soymeal, the RCA values near unity and RCSA values towards zero indicated that the country's soymeal export is more towards comparative advantage neutral level. NRCA index values indicated that Argentina and Brazil have higher comparative advantage compared to other exporters, and India enjoys higher CA compared to USA and Netherlands.

India, Argentina and Brazil had competitive advantage in soy meal exports (Nordin *et. al.,* 2008). Most of the countries showed either a consistently decreasing trend or slight fluctuating movement due to increasing competitiveness in the world oil meals market. Dohlman *et al*. (2001) found that during late 1980s, Brazil and Argentina maintained a competitive advantage over the United States in production costs of soybean, mainly due to higher land costs in the United States. The lower transportation and marketing costs in the United States partially offset the production cost disadvantage, but Brazil and Argentina have been reducing these costs in recent years. Huerta and Martin (2002) also noted that land values are lower in Brazil and Argentina, but these two countries face other issues that reduce their competitive advantage like economic instability and inadequate transportation infrastructure.

A study of US International Trade Commission (USITC, 2012) reported that rapid growth in world soymeal demand has allowed all exporters to ship higher volumes, limiting direct competition between the major exporters. Brazilian soybeans and soybean products (meal and oil) were cost-competitive with those produced anywhere in the world, including the United States—the world's largest producer. For the most part, soybeans from Brazil and the United States are highly substitutable commodities. However, direct competition between the two countries in third-country markets is limited.

Competitiveness and trade policies

Trade policies of the exporting and importing countries affect the competitiveness of a country's product. In the international trade, exports are regulated through export related taxes,

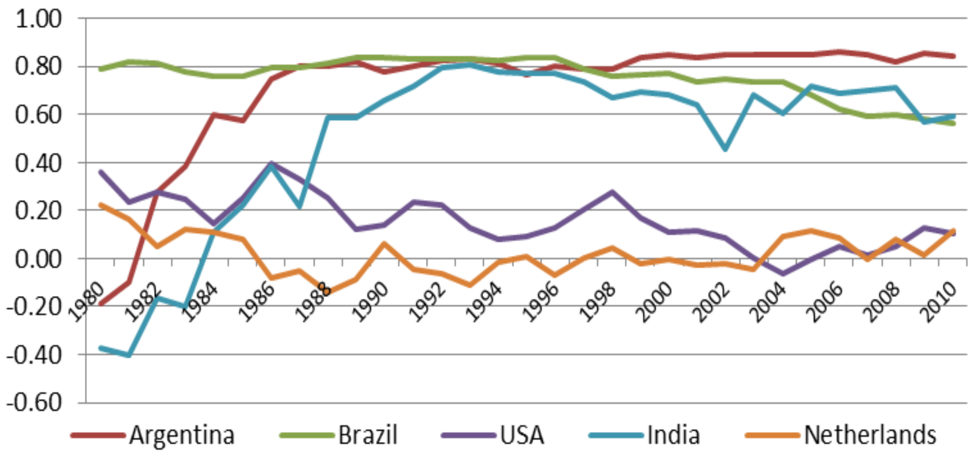

Fig. 1. RSCA of soy meal exports

export/ transport subsidies, while imports are regulated through import tariffs, value added tax (VAT), *etc*. With the according of WTO conventions by many countries tariffs rates are kept low. However, to regulate trade, many countries simply resort to technical barriers. Sanitary and phyto-sanitary (SPS) laws are frequently used as a way to regulate imports even from a preferred trading partner. Another frequently used way to regulate trade is the use of taxation, port charges or import fees and licenses to deny imports or to raise the price of imported goods to a price above the prevailing local price.

The government of Argentina maintains a tax on exports of soybeans and soybean products which incentivizes the production of beans into meal and oil. The differential export tax (DET) is higher on whole soybeans than it is on meal and oil, therefore making it more profitable to process soybean in Argentina for export and increasing country's competitiveness in exporting processed products (Costa *et al*., 2009; Bouet *et al.,* 2012) . Currently, the DET for soybeans is 35 per cent, while the DET for soymeal and oil is 32 per cent (Bouet *et al*., 2012; USB, 2012). The 3 per cent differential between the two taxes is enough to cover the variable cost of crushing. Argentina's DETs have helped to encourage large processing companies to invest in crushing facilities there. Crushing plants in Argentina are located strategically along a waterway, facilitating exports. Large processing plants also create economies of scale, making each processed bean marginally less expensive. Argentina has also got another advantage as there is little domestic demand for these products in Argentina (USITC, 2012). The United States competes directly with Brazil and Argentina for exports of soy meal to the EU-27. Both the United States and Brazil are at a competitive disadvantage with Argentina for EU-27 market share mainly due to Argentina's differential export tax on soybean products.

Trade policies for major importing countries have been changing. Some countries impose import duties on oilseed products. United States and European Union apply tariff escalation with zero import tariff on seeds and positive import duties on oils (Bouet *et al*., 2012). There is a dynamic relationship between oilseed, meal, and oil with regard to international trade (Mattson *et al*., 2004). In 1995, China lifted their value-added tax on soymeal to encourage growth in their livestock sector, and as a result, imports of soymeal increased (Hsu, 2001). However, China re-imposed the value-added tax on soymeal in 1999 resulting in rapid increase in soybean imports and a decline in imports of oils and meals.

Chinese policy has encouraged the importation of whole soybeans for crushing within its borders to capture the value-added processing activity (USITC, 2011). China is not a large import market for soymeal because it is largely self-sufficient. China maintains a 3 per cent import tariff on whole soybeans, a 5 per cent import tariff on soymeal, and a 9 per cent import tariff on soybean oil (*Commodity Online*, 2011). China is a major processor of soybean oil and meal from domestic and imported raw soybeans. In recent years, China is also net exporter of soymeal. As a result of cost competitiveness and the tremendous potential for growth in output, the production and processing of soymeal for export has been rapidly shifting from North to South America (Earley *et al.*, 2005). Low land costs and the devaluations of the Argentine and Brazilian currencies have contributed to large production cost advantage of South American producers compared to North American soybean producers. It is evident from Figure 2 that countries like India, Venezuela and Turkey impose higher import tariffs on soybeans, meals and oil. Like China, India needs to impose zero tariffs on import of soybeans to increase the capacity utilization of soybean crushing industry and realize food security in terms of edible oil availability. This will give a big boost to the export earnings of soy meal to the country. As discussed earlier, Chinese policy of importing beans has encouraged the crushing within its borders to capture the value-added processing activity and decline in imports of oils and meals.

The analysis of competitiveness revealed that Argentina, Brazil and India have significant comparative advantage in export of soymeal as indicated by the larger than unity RCA index value, higher positive RSCA and NRCA index values. The comparative advantage was found to be increasing in case of Argentina and India, while this is declining for countries such as Brazil and United States. NRCA index values indicated that Argentina and Brazil have higher comparative advantage compared to other exporters, and India enjoys higher CA compared to USA and Netherlands.

Cost involved in clearing a cargo for export (including cost for documents preparation, customs clearance and technical control, port and terminal handling, and inland transportation and handling) was highest in Brazil (US$ 2215/container of 20 ft) followed by Argentina (US$ 1650), India (US$ 1120). Cost of internal transportation and handling was highest in Brazil (US$ 990), and almost double than Argentina (US$ 500). The charges for documents preparation were highest in Argentina (US$ 450) and India (US$ 415). The government of Argentina maintains differential export tax (DET) on whole soybeans and products, which increases country's competitiveness in exporting processed products. The United States competes directly with Brazil and Argentina for exports of soy meal to the EU-27. Both the United States and Brazil are at a competitive disadvantage with Argentina for EU-27 market share, owing to Argentina's differential export tax on soybean products.

United States and European Union apply tariff escalation with zero import tariff on soybean and positive import duties on oils. China imposes higher import duty and value-added tax on import of oil and meals rather than on soybean ~~seed~~ which encourages the import of whole soybeans for crushing within its borders to capture the increasing edge in value-added processing activity. India, Venezuela and Turkey impose higher import tariffs on soybeans, meals and oil. Like China, India needs to impose zero tariffs on import of soybeans to increase the capacity utilization of soy

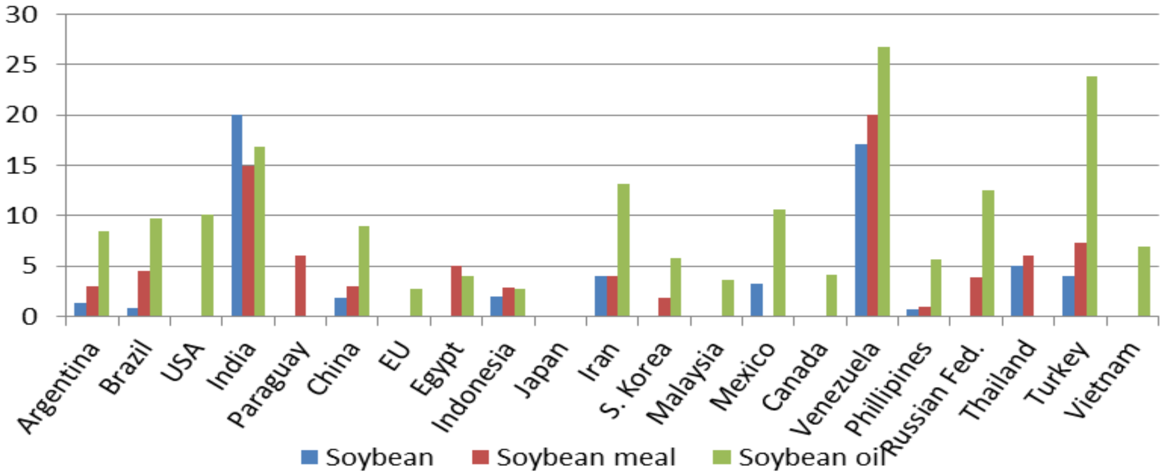

Fig. 2. Simple average applied tariffs on soybean and products by major players

crush industry and realize food security in terms of edible oil availability. The major factors significantly affecting soy meal export demand from major countries analysed were international prices of soy meal, prices of substitute commodity, volume of international soy meal trade, exchange rate and income of importing countries. Though, there was country-wise difference in the factors and their effect.

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Dynamics of Profitability from Soybean in Central India

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ABSTRACT

The soybean is an important commercial crop of the central India in terms of acreage and income generation. Therefore, economic parameters are examined using secondary data on cost and prices for the period of 1990-91 to 2009-10. The data on cost and returns aspects of soybean cultivation for Madhya Pradesh were collected from published reports of Commission for Agricultural Cost and Prices, Department of Agriculture and Cooperation, Government of India for assessing long-term sustainability of soybean production. The results revealed that use of seed by the sample farmers recorded positive (1.35 %) and significant growth, indicating that farmers are still inclined towards use of higher seed rate. Highly significant negative growth in use of fertilizers (- 8.32 %) reflected towards farmer's response to increased fertilizer prices. But at the same time, the enhanced productivity of soybean, despite of reduction in use of fertilizer, reflected in proper placement of fertilizer followed by introduction of high yielding varieties. The use of mechanical power for various operations had replaced use of human and bullock labour significantly. The growth in total cost over time (31.41 %) was lower than growth in gross income (33.20 %), revealing that the net income from soybean production increased over time due to growth in prices (26.72%) and productivity of soybean (15.23%). The widening positive gap between break-even and actual yield signifies the increasing profitability of soybean over time. Although, the minimum support prices (MSP) has grown faster than market prices, the market prices were higher as compared to MSP revealing that there is no market failure in case of soybean. The analysis showed that there is scope for enhancing the profitability from soybean on a sustainable manner through enhancement in productivity, as the growth in cost of production was lower than the cost of cultivation.

Key words: Cost structure, break-even point, profitability

India is the fifth largest soybean producer in the world contributing about 4.67% of world soybean production, whereas the largest producer, United States is credited to contribute about 32 per cent. It is expected that the world of soybean will continue to be dynamic with intensive utilization of food, oil, feed, industrial raw material and as nutraceuticals. Reducing under-nutrition is one of the Millennium Development Goal (MDG) set by the United Nations (Copenhagen Consensus, 2008). Soybean plays a greater role in the "biofortification" of the food and thus offers prospects for alleviation of wide- spread protein

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malnutrition among poor people. India stands at first position considering the growth rate (Table 1) with annual production growth rate of 6.36 % (2005 to 2011). The global average growth rate during the period was 3.54 % and it was 3.99 % in USA, 6.09 % in Brazil, 3.24 % in Argentina and -1.00 % in China. This reflects towards the positive response of Indian farmers to enhance profitability from soybean over other competing crops (Kajale 2002, Jaiswal; Hugar, 2011). Soybean (*Glycine max* (L.) Merrill) ranks first among the oilseed crops in the world and in India too. Soybean crop has exhibited unprecedented expansion in India by registering 15-20 per cent annual growth rate. It has emerged very fast since early eighty's and occupied vital place in agriculture, edible oil economy, foreign exchange earnings and witnessed to enhancement in the social status of farmers cultivating soybean. In India during 2011-12 soybean has established itself as the first oilseed crop (Table 2) followed by groundnut and mustard. Soybean crop accounted for 38.50 per cent of area and 40.92 per cent of the total production of nine oilseeds in the country. This gradual change in the position of soybean crops from second (2005-06) to first (2011-12) amongst nine oilseeds grown in the country again reflects towards higher profitability from this crop as compared to other *kharif* oilseeds (Gautam *et al.,* 1992).

The cultivation of soybean is concentrated in Central India ~~niche~~ predominantly in Madhya Pradesh, Maharashtra and Rajasthan, around a latitude 16^o to 26^o N and longitude range about 73^0 to 84^0 E, which constituted 55.70 per cent, 30.16 per cent and 8.84 per cent, respectively. These three states accounted for 94.70 per cent of the national acreage of soybean during 2011-12. In terms of production, these three states contributed more than 95 per cent. Contribution of Madhya Pradesh has always been the largest and substantial in respect of area and production of national total production. This fact has established Madhya Pradesh as synonym of "***SOY-STATE*"**.

Source of growth in soybean supply can primarily from the expansion of area harvested (Nahatkar *et al.*, 2005), which increased by almost 59 per cent during 2000-01 to 2011-12, while production increased by almost 132 per cent during the same period. The corresponding increase in productivity was rather low (47 % only). At the onset of sowing season during *kharif*, soybean was mostly preferred by the farmers. Higher price of soybean was lucrative as it was likely to fetch higher profit compared to other crops (Gautam and Nahatkar, 1993). In addition to the material benefits derived from soybean production, farmers underlined the important role of soybean income in human capital development, as it relates to children's school fees, health care, hospital bills, and other social obligations.

The profitability of producing soybeans varies greatly from year to year due to changing cost and price structure as well as variability in productivity. To track this variability, the analysis on dynamics of soybean profitability over the years is workout in this paper. This analysis will

Table 1. Status of soybean production (million tonnes) in the world

Year	USA	Brazil	Argentina	China	India	World
2005	83.50	51.18	38.29	16.35	8.27	214.56
2006	57.00	52.46	40.54	15.50	8.86	221.96
2007	72.86	57.86	47.48	12.72	10.96	219.72
2008	80.75	59.83	46.24	15.54	9.90	231.24
2009	91.42	57.34	30.99	14.98	9.96	223.26
2010	90.60	68.75	52.68	15.08	12.73	265.05
2011	84.19	74.81	48.88	14.48	12.21	262.04
LGR %	3.92	6.09	3.24	-1.00	**6.36**	3.54

Source: faostat.fao.org

Table 2. Status of soybean in oilseed production in India

Crops	Years	Area		Production		Productivity	
		Million ha	% to total	Million tonnes	% to total	kg/ha	% to average
Soybean	2000-01	6.42	28.19	5.28	28.63	823	101.60
	2005-06	7.71	27.67	8.27	29.56	1073	106.87
	2011-12	10.18	38.50	12.28	40.92	1207	106.34
Mustard	2000-01	4.48	19.67	4.19	22.72	936	115.55
	2005-06	7.28	26.13	8.13	29.06	1117	111.25
	2011-12	5.92	22.39	6.78	22.59	1145	100.88
Groundnut	2000-01	6.55	28.75	6.41	34.76	977	120.61
	2005-06	6.74	24.19	7.99	28.56	1187	118.23
	2011-12	5.31	20.08	6.93	23.09	1305	114.98
Other	2000-01	5.33	23.40	2.56	13.88	480	59.26
	2005-06	6.13	22.00	3.59	12.83	586	58.37
	2011-12	5.03	19.02	4.02	13.39	800	70.48
Nine oilseeds	2000-01	22.77	100	18.44	100	810	100
	2005-06	27.86	100	27.98	100	1004	100
	2011-12	26.44	100	30.01	100	1135	100

Source: Agriculture Statistics at a Glance 2012, GOI Publication

also help in assessing the reasons of stagnating productivity of soybean especially in during recent decade in Madhya Pradesh. Soybean which emerged as golden crop in the one year turns bitter in another crop year on low realization due to vagaries of nature. Higher cost of production of soybean cuts down the incremental profit of the farmers in case of low productivity.

Farmers preferred to sow soybean crop amid expectation of higher profit.

Table 3. Soybean producing states of India (2011-12*)

States	Area		Production		Productivity	
	Million ha	% to total	Million tonnes	% to total	kg/ha	% to average
Madhya Pradesh	5.67	55.70	6.28	51.14	1108	91.80
Maharashtra	3.07	30.16	4.03	32.82	1312	108.70
Rajasthan	0.90	8.84	1.39	11.32	1544	127.92
Other States	0.54	5.30	0.58	4.72	1074	88.98
India	10.18	100	12.28	100	1207	100

**Based on fourth advance estimates published in Agriculture Statistics at a Glance 2012, GOI Publication*

Looking to overall importance of this crop in economy of the central India and as deciding factor for demand of input and consumer products in the market due to additional income generation due to this crop, the present study was carried out on changing behaviour of cost and profitability of soybean over the years. Within this context, it is expected that present study can shed light on the discussion of policy, production, research and development issues concerning the national soybean industry. The objective of present paper is to assess its changing economic efficiency over the years, specifically; it intends to find out profitability from soybean production in Central India that remained efficient for the period.

MATERIAL AND METHODS

The secondary data were collected from various reports of the Commission for Agricultural Costs and Prices, Department of Agriculture and Cooperation, Government of India for the period of 1990-91 to 2009-10. The collected data related to cost estimation of soybean crop for Madhya Pradesh were analysed. The growth in parameters was worked out to ascertain the pattern of change over the years.

Growth rate: The trend analysis was carried out using least square method. The following linear regression equation was fitted to different parameters for the study periods.
Linear growth rate (%) = (b/y)*100; Where, b = trend value, Y = average

Break-even analysis: The break-even analysis was carried to assess the extent of profitability over the break-even point. The following methodology was used to work out break-even point.

***Break-even point**:* Breakeven point is the point of intersection between revenue and cost.

***Break-even yield**:* It is the yield level at which cost and revenue lines intersect each other

Estimation of break-even point

BEP = FC / (AR-AVC); Where, FC = fixed cost (Rs/ha), AR = average revenue (price/q), AVC = average variable cost (cost Rs/q)

RESULTS AND DISCUSSIONS

Use of critical inputs

The seed, fertilizers and manures are considered as the critical inputs for the soybean growers along with supporting operational and managerial inputs like human and bullock labour and therefore the information on use of these inputs in physical form over the years is given (Table 4).

Table 4. Level of use of critical inputs in cultivation of soybean

Parameters	1990-91	1996-97	2003-04	2007-08	2009-10	LGR (%)
Seed (kg/ha)	88.48	98.49	92.67	88.91	87.12	1.35*
Fertilizers (kg nutrients/ha)	58.00	50.10	40.40	42.43	42.41	-8.32**
Manure (t/ha)	0.65	0.60	0.62	0.65	0.60	-0.68
Human labour (man h/ha)	379.64	431.36	336.25	334.03	327.57	-5.57**
Bullock labour (pair h/ha)	89.71	60.27	45.98	43.89	34.20	-23.24**

*** and * indicates significant at 5 and 10 per cent level of probability, respectively*

Source: Commission for Agricultural Costs and Prices (various published & unpublished reports). DAC, GOI, India

The use of soybean seed was around 90 kg per ha and the same level of its use was observed during 2009-10, although it is higher than recommended rate of 80 kg per ha for JS 335, the most dominating variety in central part of the country, and this might be due to poor germination rate of farm saved seed, narrow row spacing (22 cm) due to use of wheat seed drill for sowing soybean and practice of keeping dense plant population for suppressing weeds. The growth in its use over the years was significant (1.35 %) revealed that the use of soybean seed by the farmers over the last one decade increased marginally. With the increase in acreage of soybean in the State, the nutrient use per hectare decreased from 58 to 42.43 kg per hectare on sample farms while the recommended dose of nutrient is 100 kg per ha (20N:60P_2O_5:20K_2O kg/ha) revealing that the application of nutrient is less than 50 per cent of the recommended rate along with imbalanced use and negligible application of potash, zinc and sulphur. Over the years, the decreasing trend with negatively significant growth rate of 8.32 per cent in application of plant nutrients is an alarming situation. There was no change is observed in application of manure over period of time.

The use of human labour decreases marginally while use of bullock labour decreases substantially. The significantly decreasing trend in use of human labour (-5.57 %) and bullock labour (-23.24 %) revealed that the energy component was substituted by mechanical power over the years due to time and availability constraint.

Cost structure

The estimates on operational cost of soybean cultivation for different years showed that there was a gradual increase in cost of cultivation from Rs 2,542.20 per ha (1990-91) to Rs 13,066.87 per ha (2009-10) showing an increase of 414.00 per cent (Table 5). The enhancement in cost was mainly on account of escalation of input prices and substitution of animal power by machine power since use of seeds, fertilizers and manures was identical over time.

Table 5. Changes in operational cost of soybean cultivation

Cost items	Cost (Rs/ha)				
	1990-91	**1996-97**	**2003-04**	**2007-08**	**2009-10**
Human labour	808.13	2169.80	2544.20	3152.36	4774.86
Bullock labour	342.00	692.90	957.03	1159.39	1132.62
Machine power	243.07	634.50	1069.43	1631.36	2534.13
Seed	616.11	1277.22	1476.60	1517.69	2396.53
Fertilizers	322.68	651.99	607.32	653.30	651.43
Manures	122.20	223.67	290.68	427.80	509.87
Insecticides	17.96	92.19	178.62	453.15	730.65
Irrigation charges	0.63	13.80	24.79	33.87	0.00
Miscellaneous	00.00	0.55	3.43	11.37	17.90
Interest on working capital	69.42	140.65	180.30	230.31	318.88
Total operational cost	**2542.2**	**5897.27**	**7332.40**	**9270.6**	**13066.87**

Source: Commission for Agricultural Costs and Prices (various published & unpublished reports).DAC, GOI, India

The major components of operational cost are expenditure on human labour, machine power, seed, bullock labour, fertilizer and insecticides. The data on changes in fixed cost over the time are given (Table 6).

The estimates of fixed cost indicated that it increased from Rs 2,022.90 per ha in 1990-91 to Rs 8,423.86 per ha in 2009-10. The rental value of owned land, which is calculated as 1/6 of the gross income from the produce has increased mainly due to enhancement in prices of soybean over time. Land revenue, depreciation on farm assets, interest on fixed capital are the minor cost items of the fixed cost. The proportionate expenditure on human labour, machine power and insecticides increased over time; while, it decreased on important inputs *viz*, seed from 24.24 per cent in 1990-91 to 18.34 per cent in 2009-10 and fertilizer from 12.69 per cent in 1990-91 to 4.98 per cent in 2009-10. It indicates that over the period of time the soybean production becomes more energy intensive due to increase in cost of human labour and substitution of bullock labour by machine power for cultivation of soybean (Sharma *et al.*, 1997), on the contrary proportionate decline in expenditure on precious inputs like seed and fertilizes were observed. It may be attributed as the reason for stagnating productivity of soybean in the State.

The operational cost was categorized in to two components, one as

Table 6. Changes in fixed cost structure of soybean cultivation

Cost items	Cost (Rs/ha)				
	1990-91	1996-97	2003-04	2007-08	2009-10
Rental value of owned land	1499.15	2807.11	4172.38	4864.94	7249.24
Land revenue	6.56	4.93	4.47	5.22	3.88
Depreciation on farm assets	181.67	184.78	287.17	378.11	366.48
Interest on fixed capital	335.52	491.62	652.13	623.04	804.26
Total fixed cost	**2022.90**	**3488.44**	**5116.13**	**5871.31**	**8423.86**

Source: Commission for Agricultural Costs and Prices (various published & unpublished reports).DAC, GOI, India

operational and managerial input and another as productive and protective input and data presented on the same depicted that over the time, the percentage expenditure on operational and managerial inputs increased nearly by 10 per cent (Table 8). The percentage expenditure on productive and protective inputs decreases by about 10 per cent. It reflected towards ~~more~~ rise of cost of operational inputs due to increase in wage rates, hiring charges of tractor and hike in diesel prices and this leads to curtail in expenditure on productive and protective inputs and more dependency of farmers on farm saved inputs (especially seeds) due to poor resource base of majority of small and marginal farmers which resulted in only marginal increase in productivity of soybean on sample holdings during last two decades.

Considering above operational and fixed cost in the cultivation of soybean over the period of time the profitability was worked out (Table 9). The productivity levels (yield/ha) showed moderate increase from 10.37 q per ha during 1990-91 to 14.09 q per ha during 2009-10 on sample holdings showing the percentage change of about 35.87 per cent with annual growth rate of 7.61 per cent which is highly significant. On the other hand the market price of the product enhanced by 262.13 per cent from Rs 538.86 to Rs 1,951.37 per q with highly significant growth rate of 262.21 per cent. The growth in minimum support prices was higher (27.45 %) as compared to open market prices (26.72 %) revealing that the government support to soybean growers in terms of minimum support prices is higher.

On account of enhancement of prices followed by enhancement of productivity of soybean, the gross income from soybean increased by 392.03 per cent on the other side the operational cost increased by 414 per cent over the time and therefore the net income was increased only by 373.69 per cent. Input output ratio

Table 7. Expenditure on different items of the operational cost in cultivation of soybean

Cost items	Per cent of total operational cost				
	1990-91	1996-97	2003-04	2007-08	2009-10
Human labour	31.79	36.79	35.22	34.00	26.54
Bullock labour	13.45	11.75	12.95	12.51	8.67
Machine power	9.56	10.76	14.47	17.60	19.39
Seed	24.24	21.66	19.98	16.37	18.34
Fertilizers	12.69	11.06	8.22	7.05	4.98
Manures	4.81	3.79	3.93	4.61	3.90
Insecticides	0.71	1.56	2.42	4.89	5.59
Irrigation charges	0.02	0.23	0.34	0.37	0.00
Miscellaneous	0.00	0.01	0.05	0.12	0.13
Interest on working capital	2.73	2.39	2.44	2.48	2.44
Total operational cost	100.00	100.00	100.00	100.00	100.00

Table 8. Expenditure on basic inputs in soybean cultivation (%)

Cost items	1990-91	1996-97	2003-04	2007-08	2009-10
Operational and managerial inputs	57.53	61.70	65.13	66.71	67.17
Productive and protective inputs	42.47	38.30	34.87	33.29	32.83
Productivity of soybean (kg/ha)	1037	1065	1261	1236	1409

(Operational inputs include human labour, bullock labour, machine power and interest on working capital. Productive & protective inputs includes seed, fertilizer, manure, irrigation, insecticides)

has decreased by 10 paisa per rupee of investment in soybean cultivation at operational cost due to higher percentage increase in operational cost as compared to increase in gross income. The increase in fixed cost was lower (316.42 %) as compared to operational cost (414 %). The input output ratio at total cost was enhanced marginally from 1.22 in 1990-91 to 1.28 in 2009-10 despite of many new technological development and extensions efforts made by State and Central government under various programmes. Tawale and Pawar (2011) also recorded input output ratio of 1:1.15 in soybean cultivation in Maharashtra.

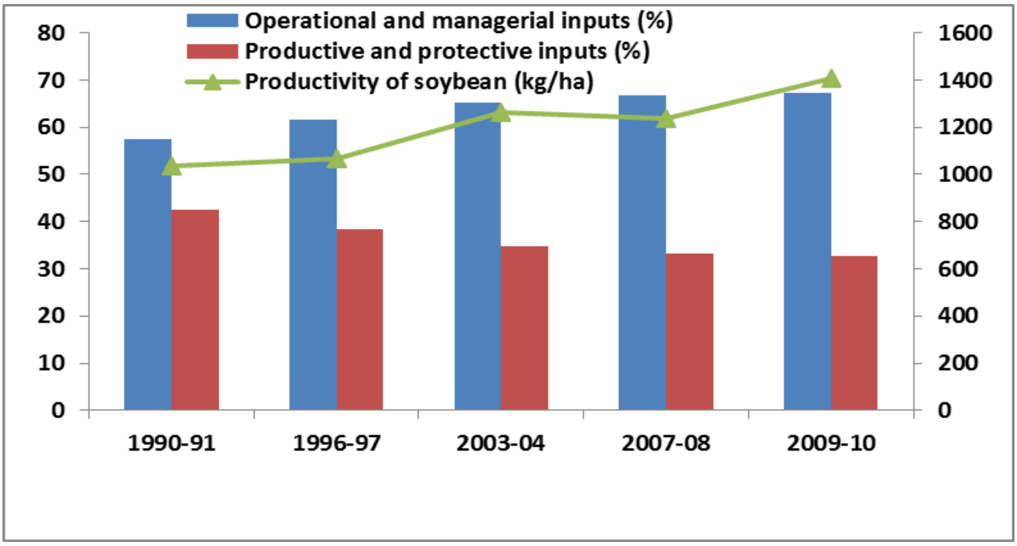

Fig. 1. Proportionate changes in use of basic inputs and productivity of soybean

The operational cost per quintal was Rs 245.15 during the year 1990-91 which increased to Rs 927.38 per quintal during the year 2009-10 (Table 10) showing an enhancement of 278 per cent which is lower than per hectare enhancement of operational cost (414 %). The net income per quintal at operational cost was Rs 293.71 and Rs 1,024.00, respectively during 1990-91 and 2009-10. The net income per quintal at total cost was Rs 98.64 during 1990-91 which increased to Rs 426.13 during 2009-10. From 1990-91 to 2009-10 the average cost of production data for soybean showed that farmers were able to cover not only their total variable cost but also fixed costs in soybean production.

Break-even analysis

Breakeven analysis is carried out using cost and price data presented under different heads. The Breakeven analysis is used to analyze the potential profitability of expenditure in a market-based agri-business. Break-even analysis is a type of cost-volume-profit analysis and break-even point for a product is the point where total revenue received equals the total costs associated with the sale of that product. The break-even analysis for soybean production during different period of time is given in table 11.
The break-even yield of soybean production in the State of Madhya Pradesh with the given cost and price structure shows that the farmers of the state are operating soybean production business above the breakeven point. This revealed that they are operating in profit zone in the cultivation of soybean. But the farmers, for whom the yield levels of soybean are less than 8 q per hectare, are running their soybean production business in loss if they are incurring the same cost structure. It is interesting to note that the difference between actual yield and breakeven yield is widening over the period of time revealing that the profitability from soybean is increasing in due course of time.

Table 9. Productivity and profitability of soybean crop in Central India

Cost items	1990-91	1996-97	2003-04	2007-08	2009-10	LGR (%)
Seed yield (kg/ha)	1037	1065	1261	1236	1409	7.61**
Farmers price (Rs/q)	538.86	989.85	1253.58	1491.47	1951.37	26.72**
Minimum support price (Rs/q)	400.00	620.00	930.00	1050.00	1390.00	27.45**
Gross income (Rs/ha)	5588.02	10541.90	15807.66	18434.52	27494.80	33.20**
Operational cost (Rs/ha)	2542.20	5897.27	7332.40	9270.60	13066.87	32.04**
Net income at operational cost (Rs/ha)	3045.82	4644.63	8475.26	9163.92	14427.93	34.31**
Input output ratio at operational cost	2.20	1.79	2.15	2.00	2.10	0.03
Fixed cost (Rs/ha)	2022.90	3488.44	5116.13	5871.31	8423.86	30.45**
Total cost (Operational + fixed costs) (Rs/ha)	4565.10	9385.71	12448.53	15141.91	21490.73	31.41**
Net income at total cost (Rs/ha)	1022.92	1156.19	3359.13	3292.61	6004.07	40.75**
Input output ratio at total cost	1.22	1.12	1.27	1.22	1.28	0.05

*** and * indicates significant at 5 and 10 per cent level of probability respectively; q- 100 kg (Estimated on the basis of cost items given in table 5 and 6, and data on the yield and prices received by the farmers were taken from the same source)*

Table 10. Production cost and profitability of soybean in Central India

Cost items	1990-91	1996-97	2003-04	2007-08	2009-10
Yield (kg/ha)	1037	1065	1261	1236	1409
Farmers Price (Rs/q)	538.86	989.85	1253.58	1491.47	1957.37
Minimum support price (Rs/q)	400.00	620.00	930.00	1050.00	1390.00
Operational Cost (Rs/q)	245.15	553.73	581.47	750.05	927.38
Net income at operational cost (Rs/q)	293.71	436.12	672.11	741.42	1024.00
Total cost (Rs/q)	440.22	881.29	987.19	1225.07	1525.24
Net income at total cost (Rs/q)	98.64	108.56	266.39	266.40	426.13

q = 100 kg

Table 11. Break-even analysis of soybean production

Particulars	1990-91	1996-97	2003-04	2007-08	2009-10
Average variable cost (Rs/q)	245.15	553.73	581.47	750.05	927.38
Average revenue (Rs/q)	538.86	989.85	1253.58	1491.47	1951.37
Fixed cost (Rs/ha)	2022.90	3488.44	5118.13	5871.31	8423.86
Break-even yield (kg/ha)	689	800	772	792	822
Actual yield (kg/ha)	1037	1065	1261	1236	1409
Difference between break-even yield and actual yield (kg/ha)	3.48 (50.51)*	2.65 (33.12)	4.89 (63.34)	4.44 (56.06)	5.87 (71.41)

**Parenthesis indicates percentage deviation from break-even yield; q = 100 kg*

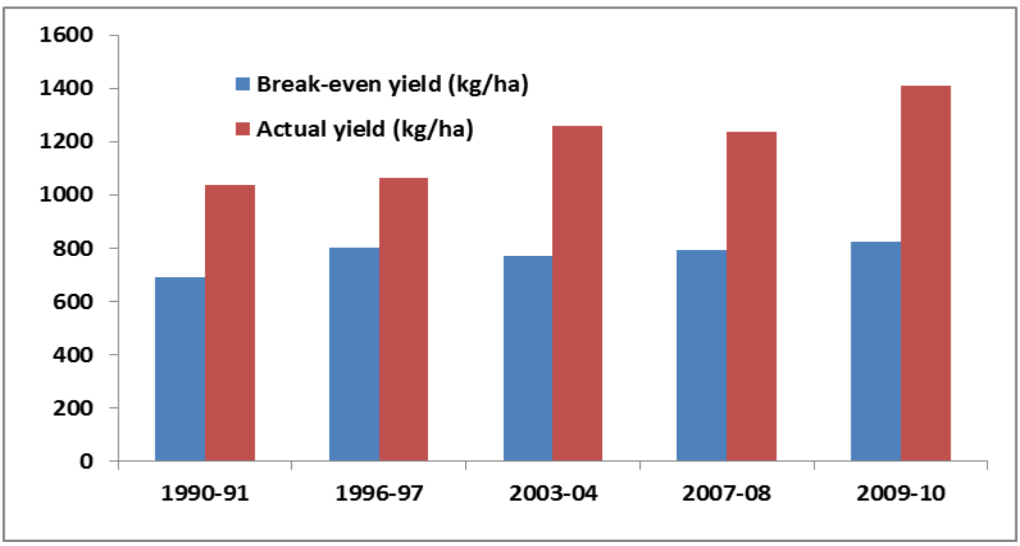

Fig. 2. Break-even and actual yield of soybean

Conclusions

* The profitability of soybean production exhibited historical positive change from 1990-91 to 2009-10, since the gap between break-even yield and actual yield is widening.
* The proportionate increase in expenditure on operational and managerial inputs as compared to productive and protective inputs and corresponding marginally increase in yield of soybean call for strategic action for long term sustainability of soybean yield.
* The breakthrough in productivity of soybean in the state can be achieved through increasing seed replacement rate, enhancing use of balance plant nutrient and judicious use of IPM technology and reduce expenditure on operational inputs through effective management practices, this will help in reducing cost of production of soybean.

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Soybean Research (Special Issue): 156-162: 2014

Arrivals and Price Behaviour of Soybean in Major Markets of Marathwada Region of Maharashtra

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ABSTRACT

Fluctuations in market arrivals largely contribute to the price instability of major agricultural commodities. So there is need to have a perfect understanding about the arrivals and price behaviour. In recent years (from 2000 onwards) after cotton, soybean become farmers prime choice crop in Marathwada region of Maharashtra. Hence, the present study was undertaken to gain insight in to behavior of market arrivals and prices of soybean. Time series (monthly) data on arrivals and prices of soybean crop were collected for twenty years (1990-91 to 2009-10) from sixteen major markets (Aurangabad, Lasur, Jalna, Ambad, Parbhani, Manwat, Nanded, Hadgaon, Hingoli, Basmat, Beed, Ambejogai, Latur, Udgir, Osmanabad and Kalab] of the region. Peak and slack period of arrivals and prices was measured by calculating monthly seasonal indices using moving average method. Instability was measured by estimating the coefficient of variation. Results revealed that, arrivals of soybean in all selected markets have seasonal effect. Arrivals of soybean in market start in the months of October and continued up to March, but peak arrivals of soybean were notices in the month of October to December. Within all selected markets, Latur market was found to be major soybean market in terms of quantum of arrivals and better prices in the region. In contrast to general price rule, price of soybean was observed above normal during peak arrivals period of soybean, i.e, *October to February. This may be because traders want to attract soybean stock of farmers by giving strong price signals. In all selected markets arrivals of soybean was more instable (both intra and inter year) compared to price.*

Key words: Price behaviour, seasonal index, soybean

Indian agriculture is characterized by wider fluctuations in output of principle agricultural crops, which lead to wider fluctuation in market arrivals. Fluctuations in market arrivals largely contribute to the price instability of major agricultural commodities (Khunt *et al*., 2006; Virender Kumar, 2006). There is need to have a perfect understanding about the behavior of prices of different agricultural commodities and the responsiveness of market arrivals in movements over a period of time. The empirical knowledge of the relationship between prices and

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market arrivals of different agricultural products for accessing the degree of responsiveness of market arrivals to price movement is repeatedly required over a period of time. Hence, the present study was undertaken to gain insight in to behavior of market arrivals and prices of important oilseed crop of the Marathwada region. The specific objectives of the study were to examine the pattern of market arrivals and prices of soybean and to identify the peak and slack period of arrivals and prices of soybean.

MATERIAL AND METHODS

In order to examine arrivals and prices pattern, soybean crop was purposively selected mainly because, in recent years (from 2000 onwards) after cotton, soybean become farmers prime choice crop in the region and area of the crop in *kharif* oilseed is predominant in Maharashtra state as well as in Marathwada region. For present study, all eight districts of Marathwada region namely, Aurangabad, Jalna, Parbhani, Nanded, Hingoli, Beed, Latur and Osmanabad were selected to give proper representation to the region. By considering the triennium average arrivals figures of soybean, two Agricultural Produce Market Committees [APMC] were selected for the study from each selected district (Table 1).

The study was based on time series data on arrivals and prices of selected oilseeds crop, *i.e*. soybean. The data on monthly arrivals and prices were collected for twenty years (1991 to 2010) from the office record of selected APMC. The monthly averages and coefficient of variation (CV) were estimated to know the fluctuations in arrivals and prices. To know the peak and slack periods, monthly seasonal indices were worked out by moving average method (Agarwal *et al.*, 1994).

Table 1. Districts selected for the study

Name of district	Market -01	Market -02	Name of district	Market -01	Market -02
Aurangabad	Aurangabad	Lasur	Hingoli	Hingoli	Basmat
Jalna	Jalna	Ambad	Beed	Beed	Ambejogai
Parbhani	Parbhani	Manwat	Latur	Latur	Udgir
Nanded	Nanded	Hadgaon	Osmanabad	Osmanabad	Kalam

RESULTS AND DISCUSSION

The calculated arrivals and prices seasonal indices (Table 2 and 3) revealed that the arrival of soybean starts in the month of October in all districts of Marathwada regions. The arrival index was more than 100 for the months of October, November and December, implying maximum arrivals of soybean in these months than monthly average. The arrival index was considerably lower than 100 during the months of March to September. The coefficient of variation of mean arrivals ranged from 18 per cent to 135 per cent, the price index was more than 100 for the months of October, November, December, January and February, implying that the prices of soybean were higher in these months than monthly average. Among all sixteen markets under study, maximum arrivals of soybean were found in Latur market followed by Hingoli and Nanded markets. Least arrivals were observed in Beed market followed by Lasur and Manwat markets. Maximum prices of soybean were realized by farmers in Latur market followed by Osmanabad and Jalna markets. Minimum prices of soybean were observed in Basmat market followed by Lasur and Nanded markets, among all sixteen markets under study (Table 4).

Seasonal indices of arrivals and prices and coefficient of variation of soybean in Marathwada region (Table 5) revealed that arrivals of soybean in Marathwada region was highest in the month October followed by November and December. The arrival was considerably lower during the months of February to of soybean were seasonal for the period of three months only, starting from October to December. The coefficient of variation for arrivals ranged in-between 81 to 117. Monthly price index showed that prices of soybean were also seasonal (Mehta *et al.*, 2000). A price of soybean was observed maximum in the month of December followed by January, February and March. The price index was less that 100 from the month of May to September. The coefficient of variation for prices of soybean is ranged in between 29 to 49 per cent.

Table 4. Top and bottom three markets of soybean in Marathwada region

	Arrivals	Prices
Top		
1	Latur	Latur
2	Hingoli	Osmanabad
3	Nanded	Jalna
Bottom		
1	Beed	Basmat
2	Lasur	Lasur
3	Manwat	Nanded

Top months of arrivals and prices of soybean in different district of Marathwada region were identified and presented (Table 05). In Marathwada region, maximum arrivals and maximum prices of soybean was observed in the month of October (402 %) and December (122 %), respectively. Farmer secured 18 per cent below average prices, when the arrivals of soybean are maximum, *i.e.* in the month of October. In the month of December, prices of soybean are highest. In this month, soybean grower secured 22 per cent higher price than average soybean prices.

Table 2. Seasonal indices of arrivals of soybean in different districts of Marathwada region

Month	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed	Osmanabad	Latur
September	12 (106)*	25 (90)	11 (78)	6 (18)	2 (101)	22 (72)	37 (120)	16 (97)
October	581 (115)	325 (64)	535 (85)	540 (67)	605 (109)	368 (80)	497 (109)	342 (89)
November	431 (108)	447 (61)	388 (111)	532 (97)	353 (64)	384 (100)	345 (106)	372 (96)
December	104 (100)	179 (67)	161 (117)	56 (48)	98 (66)	224 (111)	143 (111)	181 (98)
January	37 (103)	75 (70)	57 (95)	21 (41)	49 (115)	69 (115)	63 (103)	99 (103)
February	13 (102)	38 (89)	17 (92)	15 (43)	31 (84)	41 (122)	32 (105)	47 (114)
March	7 (116)	28 (98)	11 (100)	13 (14)	24 (111)	25 (122)	26 (09)	38 (105)
April	7 (74)	21 (106)	9 (105)	5 (33)	10 (52)	18 (118)	17 (113)	31 (106)
May	5 (66)	23 (96)	4 (116)	3 (43)	11 (58)	14 (19)	13 (100)	29 (128)
June	1 (98)	22 (103)	4 (71)	5 (31)	10 (33)	19 (112)	11 (113)	20 (127)
July	2 (104)	12 (93)	1 (38)	3 (39)	4 (135)	11 (102)	7 (111)	13 (126)
August	1 (121)	4 (116)	1 (68)	2 (45)	3 (119)	6 (110)	9 (104)	12 (124)
Total	**1200**	**1200**	**1200**	**1200**	**1200**	**1200**	**1200**	**1200**

* *Figures in parenthesis indicate per cent coefficient of variation*

Table 3. Seasonal indices of prices of soybean in different districts of Marathwada region

Month	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed	Osmanabad	Latur
September	62 (80)*	96 (43)	94 (46)	86 (48)	38 (113)	86 (45)	86 (45)	92 (46)
October	109 (51)	107 (37)	110 (32)	108 (21)	116 (31)	104 (48)	108 (19)	96 (31)
November	123 (45)	123 (37)	125 (27)	117 (19)	113 (34)	115 (36)	116 (17)	110 (16)
December	128 (47)	110 (35)	119 (26)	121 (19)	120 (31)	116 (37)	120 (14)	123 (27)
January	123 (48)	108 (37)	127 (30)	119 (23)	119 (32)	116 (41)	121 (20)	109 (24)
February	115 (59)	109 (48)	116 (33)	107 (25)	98 (39)	109 (40)	104 (35)	106 (31)
March	91 (77)	125 (52)	106 (32)	96 (32)	110 (54)	98 (48)	99 (31)	99 (39)
April	80 (87)	86 (29)	105 (34)	82 (42)	99 (69)	92 (48)	84 (51)	100 (46)
May	116 (55)	85 (22)	65 (76)	96 (41)	112 (59)	85 (45)	98 (26)	98 (48)
June	88 (56)	84 (29)	95 (22)	85 (55)	102 (51)	92 (57)	87 (51)	99 (41)
July	97 (70)	84 (21)	73 (14)	92 (47)	86 (27)	100 (62)	94 (45)	83 (66)
August	67 (80)	82 (24)	65 (28)	84 (38)	86 (132)	87 (57)	84 (47)	83 (64)
Total	**1200**	**1200**	**1200**	**1200**	**1200**	**1200**	**1200**	**1200**

* *Figures in parenthesis indicate per cent coefficient of variation*September. This proves that the arrivals

Arrivals and prices of soybean in all selected market were seasonal. The arrivals and price indices of soybean (Table 6, Fig. 1 and 2) were highest in the month of October and December, respectively with modest CV value (29 %) indicating sureties of highest prices during this month. Among all selected market, Maximum arrivals were observed in Latur market and maximum price was also observed in Latur market. Hence farmer should store the soybean for few days after harvest and sell in the months of December–January to get maximum price in market.

Table 5. Arrivals and prices seasonal indices and coefficient of variation of soybean in Marathwada region

Month	Arrival Index (%)	CV (%)	Price Index (%)	CV (%)
October	402	86	82	47
November	401	94	107	34
December	169	95	122	29
January	76	95	120	29
February	36	106	118	31
March	27	104	109	39
April	21	107	104	44
May	19	117	94	49
June	15	112	89	43
July	9	108	92	41
August	7	118	88	43
September	17	81	75	47
Mean	**1200**	**92**	**1200**	**39**

Table 6. Top months of arrivals and prices of soybean in different districts of Marathwada region

District	Arrivals	Arrival Index	Prices	Price Index
Parbhani	October	581	December	128
Hingoli	November	447	November	123
Nanded	October	535	January	127
Jalna	October	540	December	121
Aurangabad	October	605	December	120
Beed	October	384	December	116
Osmanabad	October	497	January	121
Latur	November	372	December	123
Marathwada	**October**	**402**	**December**	**122**

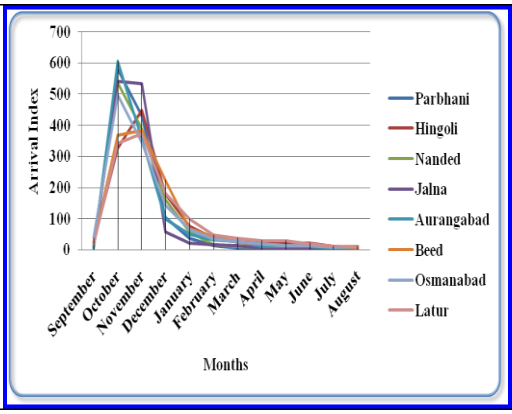

Fig. 1. Seasonal index of arrivals of soybean in different markets

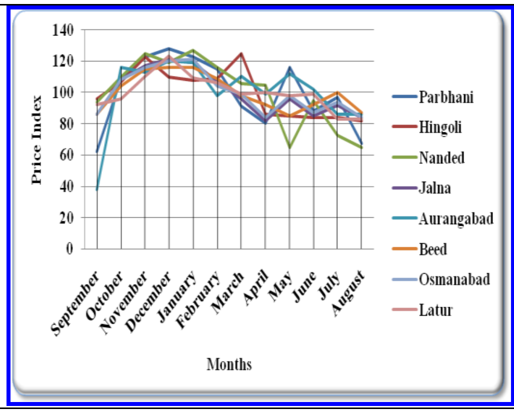

Fig. 2. Seasonal index of prices of soybean in different markets

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Influence of Different Row Proportion of Pigeonpea on Productivity and Economics in Soybean + Pigeonpea Intercropping System

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Key words: Intercropping, row proportion, soybean, pigeonpea

Vidarbha region of Maharashtra is consistently showing an increase in area under soybean crop. Presently, it is cultivated in 1.79 million ha producing 2.62 million tonnes with a productivity of 1,328 kg per ha (Anonymous, 2013). The intercropping systems are well known and have been recognized as a common practice throughout the tropical countries as these aim at increasing the production potential per unit area and insuring against total crop failure under aberrant weather conditions. Intercropping system can improve and maintain soil fertility and partial nutrient requirement of crop particularly when legume is included. It has established itself as an advantageous system over sole cropping. Intercropping of pulses and oilseeds has been reported as more advantageous than growing them as sole crops (Singh and Rajput, 1996). Utilization of natural resources like, soil, space, moisture and light through intercropping of short duration pulses, namely urdbean /mungbean in between the row of pigeonpea is the promising way to boost total productivity of pulses. Recently agronomists have concentrated their efforts in developing the feasible and remunerative intercropping system suitable for different agro-climatic zones (Ginnis, 1997).

Soybean + pigeonpea intercropping is being adopted on large scale in Vidarbha region of Maharashtra. The farmers are adopting the different row proportion of soybean and pigeonpea crops in intercropping system rather than the recomm-endation of the Agricultural Universities. Hence, in order to study the productivity and economics of this system under rainfed conditions and to minimize the risk, it was thought worth to test these row proportions, so that systems should be

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less susceptible to aberrant weather condition of the region and able to utilize the natural resources more efficiently.

An experiment was conducted at research field of AICRP for Dryland Agriculture, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif* 2011. The experiment was laid out in randomised block design with three replications. It comprised of ten treatments which included the sole soybean and pigeonpea crops and eight treatments of soybean and pigeonpea in intercropping with different row proportion. The varieties utilized were JS 335 and C-11 of soybean and pigeonpea, respectively. The sole soybean was sown in 45 cm x 5 cm in row to row and plant to plant spacing and pigeonpea in 60 cm x 20 cm. All the intercropping systems were sown in 45 cm row spacing and plant to plant distance (5 cm for soybean and 20 cm for pigeonpea) maintained as per the crops. The recommended dose of fertilizers (30: 75: 0 kg $N:P_2O_5:K_2O$/ha) applied to sole cropping of soybean and all intercropping systems, and to sole pigeonpea (25: 50: 0 kg:: $N:P_2O_5:K_2O$/ha). The fertilizers were applied at the time of sowing to all the treatments. The experiment was conducted on Vertisols which was slightly alkaline in reaction (pH 7.95), low in available N (198 kg N/ha) and available P (9.3 kg P_2O_5/ha) and high in available K (325.8 kg K_2O/ha), respectively. The crops were sown on July 9, 2011. Rainfall received during the crop growing season was 515.3 mm. Soybean equivalent yield was calculated by converting the seed of pigeonpea into soybean seed equivalent yield on the basis of selling prices.

Seed yield of crops: Soybean seed yield (Table 1) was observed to be maximum in sole cropping (1,937 kg/ha) and minimum in intercropping system of 1:1 (975 kg/ha). The sole soybean seed yield was at par with intercropping treatments with row ratios of 4:1, 6:1 and 8:1. The reduction in the soybean seed yield in intercropping systems as compared to sole cropping ranged from 6.35 to 49.66 per cent. Minimum reduction of soybean seed yield was observed in soybean + pigeonpea inter-cropping system (4:1). This reduction of the seed yield is due to the reduction in plant population of the soybean crop in intercropping system as well as due to the competition effect. Similar results were reported by Tomar *et al.* (1987), Holkar *et al.* (1991), Halvankar *et al.* (2000) and Sree Rekha and Dhurua (2009).

The highest pigeonpea seed yield was found in sole pigeonpea (1,669 kg/ha). Minimum reduction of pigeonpea seed yield (10.73 %) was observed in intercropping system 1:1 row proportion and maximum reduction in soybean + pigeonpea (8:1) intercropping system (72.13 %).

Soybean seed equivalent yield: Results revealed that soybean + pigeonpea (2:1) intercropping system recorded significantly highest soybean seed equivalent yield of 3,351 kg per ha, which was on par with intercropping systems with row ratios of 1:1 (3,280 kg/ha) and 4:2 (3,162 kg/ha) (Table 1). Joshi *et al*. (1997) also reported that higher soybean equivalent yield with soybean and pigeonpea in 2:1 and 3:1 row proportion. Tomar *et al. (*1987) also reported that

Table 1. Effect of different row proportion on crop productivity and soybean seed equivalent yield

Treatments	Yield (kg/ha)				
	Soybean		Pigeonpea		Soybean seed equivalent yield
	Seed	Straw	Grain	Stalk	
Sole soybean	1937	2673	-	-	1937
Sole pigeonpea	-	-	1669	5952	2512
Soybean + pigeonpea (1:1)	975	1235	1490	4530	3280
Soybean + pigeonpea (2:1)	1274	1850	1379	3345	3351
Soybean + pigeonpea (3:1)	1478	1913	998	2279	2981
Soybean + pigeonpea (4:1)	1814	2073	575	1787	2680
Soybean + pigeonpea (4:2)	1281	1843	1250	3437	3162
Soybean + pigeonpea (5:1)	1439	1800	613	1406	2362
Soybean + pigeonpea (6:1)	1638	2286	469	1055	2344
Soybean + pigeonpea (8:1)	1745	2218	465	1440	2444
SEm (±)	127	189.69	95	296.32	202
C D (P = 0.05)	**380**	**568.72**	**285**	**888.41**	**602**
CV (%)	14.57	16.53	16.67	18.31	13.01

highest pigeonpea equivalent yield was recorded in 1:2 row ratio planting pattern which was at par with 1:4 and 1:1 row ratio planting pattern of pigeonpea and soybean.

Land equivalent ratio: Land equivalent ratio ranged from 1.10 to 1.53 in different row proportion of soybean + pigeonpea intercropping systems. All intercropping pattern of soybean with pigeonpea exhibited LER values > 1 which indicated that these treatments were more efficient in utilizing available resources than sole cropping of either soybean or pigeonpea resulting in higher productivity per unit of space (Table 2). Land equivalent ratio was significantly higher in soybean + pigeonpea (2:1) intercropping system (1.53) and was on par with the soybean + pigeonpea planted at 4:2 and 1:1 row ratios. These results are similar to the findings of Tomar *et al*. (1987), Joshi *et al*. (1997) and Halvankar *et al.* (2000).

Economics: The data on economics of the cropping systems (Table 2) revealed that significantly highest gross and net monetary returns of Rs 74,802 and Rs 56,877 were recorded in soybean + pigeonpea (2:1) intercropping system, which was at par with soybean + pigeonpea (1:1) and soybean + pigeonpea (4:2) intercropping systems Dubey *et al*. (1991) reported 32 per cent more net returns due to planting of pigeonpea and soybean compared to sole pigeonpea. Similar results were also observed by Joshi *et al*. (1997). Halvankar *et al*. (2000) who also reported that planting of soybean and pigeonpea in 3:1 row proportion gave the maximum gross as well as net returns. Maximum B:C ratio of 4.17 was observed in soybean + pigeonpea (2:1) intercropping system which was more remunerative and followed by treatment of soybean + pigeonpea (1:1) intercropping system (4.11) and soybean + pigeonpea (4:2) intercropping system (3.99). Similar results were reported by Tomar *et al*. (1987).

Table 2. Effect of different row proportion on land equivalent yield and economics

Treatments	**Land equivalent ratio**	**Gross monetary returns (Rs/ha)**	**Net monetary returns (Rs/ha)**	**B:C**
Sole soybean	1.00	43083	23154	2.16
Sole pigeonpea	1.00	57116	39120	3.17
Soybean + pigeonpea (1:1)	1.40	72234	54662	4.11
Soybean + pigeonpea (2:1)	1.53	74802	56877	4.17
Soybean + pigeonpea (3:1)	1.36	66341	48434	3.70
Soybean + pigeonpea (4:1)	1.29	59680	41733	2.65
Soybean + pigeonpea (4:2)	1.43	70780	53043	3.99
Soybean + pigeonpea (5:1)	1.11	52510	34473	2.91
Soybean + pigeonpea (6:1)	1.15	52183	34111	2.89
Soybean + pigeonpea (8:1)	1.18	54517	36170	2.97
SEm (±)	0.096	6380	6380	-
C D (P = 0.05)	**0.28**	**13404**	**13404**	**-**
CV	13.42	12.95	18.52	-

Market value of soybean seed: Rs 21.55/kg and straw: Rs 0.50/kg; pigeonpea grain: Rs 32.44/kg and stalk: Rs 0.50/kg

Hence, the results of the experiment suggested that to achieve maximum total yield and monetary advantage from the system, soybean intercropping with pegeonpea in the row ratio of 2:1 is advisable under dryland conditions of Vidarbha region of Maharashtra.

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Soybean Research (Special Issue): 168-171: 2014

Evaluation of Soybean Genotypes under Excessive Moisture Stress in Madhya Pradesh

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Key words: **E**xcess moisture stress, Madhya Pradesh, seed productivity, soybean genotypes

Soybean is one of the most important oil seed crops in India. Madhya Pradesh accounts for more than 50 per cent soybean production and cultivation areas in India. Low soybean yield in Madhya Pradesh is frequently caused by excess rainfall during soybean-growing season (rainy season between June and September). Though soybean plants can tolerate to 48 hours of water logging, flooding for 4 to 6 days significantly reduces their stands, vigor, and eventually yield (Scott *et al*, 1989). A study on water logging tolerance on soybean cultivars indicated that excess water stress at early vegetative and early reproductive stages are primary factors to cause low yield (Lee *et al.*, 2004).

In Madhya Pradesh, plenty of soybean genotypes have been developed and utilized. However, detailed yield evaluations of these soybean genotypes by focusing on excess moisture stress tolerance have not been conducted. In this study, we exposed soybean genotypes under excess moisture condition in an experiment field at seedling, vegetative and reproductive stages and evaluated
their seed yields. Based on the results, we discussed following two points; (1) yield correlation between excess moisture and control conditions (2) promising soybean genotypes for cultivation in excess moisture condition.

The field experiment was conducted on a clay loam soil belonging to Vertisol in the Jawaharlal Nehru Krishi Vishwa Vidyalaya farm in the 2012 rainy season. During the season, the average minimum temperature ranged between 12.6 and 23.8 °C, while the average maximum temperature ranged between 29.5 and 38.6 °C. The total rainfall of the study area during the time was 1,317 mm. A total of 25 soybean genotypes (Table 1) were exposed to excessive moisture condition at seedling stage, 15-20 days

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after sowing (DAS), vegetative stage 35-40 DAS and reproductive stage 55-60 DAS in addition to natural rainfall. The excessive moisture plots were bounded by field soil ridges to ensure uniform high moisture condition. In case of control, the same set of soybean genotypes were grown in plots with drain furrows under natural rainfall. In each plot, 25 genotypes were grown as sub-plots. The sub-plot size for each genotype was 3.6 m^2 (2.0 m x 1.8 m). The inter-row and plant distances were 45 cm and 6.25 cm, respectively. Thirty two plants were maintained per 2-m row length. Randomized block design with three replications was adopted. Sowing was done on 6th July 2012. As the yield and yield components, following parameters were measured; number of pods per plant, number of seed per plant, biological yield per plot, hundred seed weight (test weight), seed yield per plant and seed yield per plot. Harvest index (%) was calculated by following the formula of Pedersen and Lauer (2004).

Yield correlation between control and excess moisture conditions

The seed yields of 25 genotypes tested decreased with excess moisture condition, relative to control condition (Table 1). A significant correlation (R^2 = 0.718, P < 0.01) was observed in seed yields between the excess moisture and control conditions over 25 genotypes (Fig. 1). This result illustrated that the genotypes of high seed yield in control condition tend to show high yields in excess moisture condition, though an inter-genotype variation was also observed in yield response to excess moisture.

Soybean genotypes for cultivation in excess moisture condition

The rate of yield reduction by excess moisture ranged from 21 to 71 per cent among the 25 genotypes (Table 1). Low reduction rates of less than 30 per cent were observed for genotypes *viz.,* JS 20-59 (21 %), JS 97-52 (23 %), JS 20-80 (23 %), JS 335 (24 %), JS 93- 05 (24%), RVS 2001 4 (28 %), JS 20 50 (29 %), and JS 20-53 (29 %). Among these 8 genotypes, 6 genotypes were developed in Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur; where the annual rainfall generally measures 1200-1500 mm; and 2 genotypes were released from College of Agriculture, Sehore (Rajmata Vijayaraje Sindia Krishi Vishwa Vidyalaya) with the annual rainfall of 800-900 mm. This result may implicate that a genotype selection pressure to improving moisture tolerance inherently existed in soybean breeding programs in Jabalpur. Adverse high yield reduction rates of more than 40 per cent were observed for genotypes JS 20-73 (71 %), RVS 2007-5 (51 %), NRC 7 (46 %), RVS 2007-4 (45 %), JS 20-79 (44 %), and JS 20-86 (41 %). For use of these 6 genotypes, a potential yield reduction by excess moisture has to be taken into account regardless of their yield level, since further severe excess moisture condition may occur depending on monsoon.

Genotypes, JS 20-71, JS 20- 87, Bragg, RVS 2001-4, JS 20-50, and JS 97-52 recorded more than 1,800 kg per ha in seed yields in both control and excess moisture conditions (Table 1). These six genotypes can be useful for soybean cultivation in excess rainfall regions, especially in

Table 1. Seed productivity of the 25 soybean genotypes under excess moisture and control conditions

Genotype	Origin	Seed yield (kg/ha)		Yield reduction by excess moisture (kg/ha)*	Yield reduction rate (%)**
		Control	Excessive moisture		
JS 20-71	Jabalpur	3120	1935	1,185	38
JS 20-87	Jabalpur	2991	2056	935	31
JS 20-79	Jabalpur	2759	1546	1,213	44
Bragg	USA	2759	1935	824	30
RVS 2001-4	Sehore	2602	1861	741	28
JS 20-50	Jabalpur	2583	1833	750	29
JS 20-73	Jabalpur	2426	704	1,722	71
JS 97-52	Jabalpur	2407	1861	546	23
NRC 37	Indore	2398	1648	750	31
RVS 2007-4	Sehore	2287	1269	1,019	45
JS20-69	Jabalpur	2231	1370	861	39
JS 20-86	Jabalpur	2213	1296	917	41
RVS 2007-6	Sehore	2157	1315	843	39
JS 20-53	Jabalpur	2139	1509	630	29
RVS 2007-1	Sehore	2102	1426	676	32
JS 20-59	Jabalpur	1981	1565	417	21
JS 20-80	Jabalpur	1843	1426	417	23
RVS 2007-2	Sehore	1843	1130	713	39
RVS 2007-3	Sehore	1843	1204	639	35
RVS 2007-7	Sehore	1750	1093	657	38
JS 335	Sehore	1306	991	315	24
RVS 2007-5	Sehore	1259	620	639	51
JS 95-60	Jabalpur	1222	852	370	30
JS 93-05	Jabalpur	1074	815	259	24
NRC 7	Indore	833	454	380	46
S Em (±)		192	107		
C D (p = 0.05))		**613**	**342**		

**Yield reduction on the kg per ha basis was calculated by control yield minus excess moisture yield; **Yield reduction rate (%) was calculated as the yield reduction divided by control yield times 100*

eastern Madhya Pradesh. Among these genotypes, JS 97-52, RVS 2001-4, and JS 20-50 further showed a low yield reduction rate by excess moisture and shall be promising for genetic improvement of moisture stress tolerance in Madhya Pradesh.

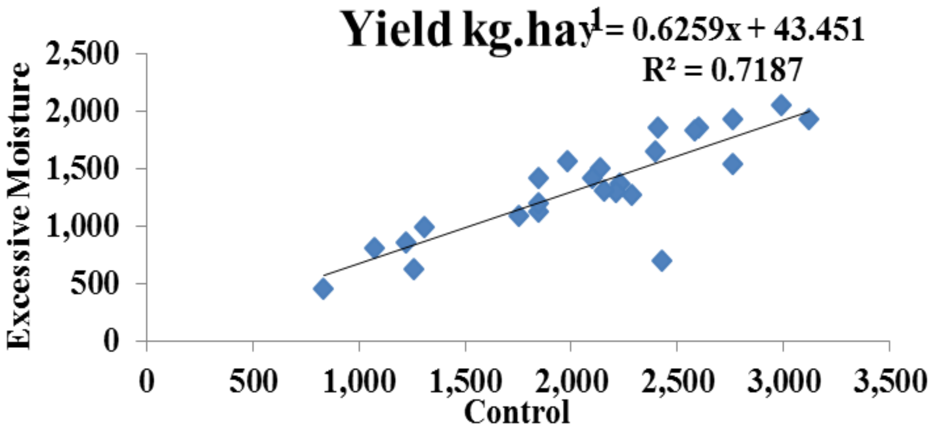

Fig. 1. Correlation in seed yield between control and excess moisture conditions over 25 soybean genotypes

Further genotype evaluation and analyses are required in order to confirm the current results and to select promising soybean genotypes for cultivation in excess moisture condition.

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Impact of Planting Time on the Performance of Soybean (G*lycine max* L. Merrill) Genotypes under Punjab Conditions

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Key words: Planting time, Punjab, soybean genotype, seed yield

Despite the positive benefits created from the rice-wheat system, the state of Punjab presently faces a number of problems threatening its sustaina-bility. The most important is the over-exploitation of its ground water resources due to excess of paddy cultivation. Soybean is most viable option, which requires less number of irrigations and inputs as compared to paddy. Soybean is an important legume crop contains 20 per cent edible oil and 40 per cent of protein. It has medicinal value and provides protection against heart disease, cancer and other diseases. Soybean is short day plant and is most sensitive to photoperiod.

The soybean growth and development can be affected on account of environmental factors, temperature, photoperiod and planting date. Planting at appropriate time of a crop leads to optimum yield. Reduced yields consequent upon late plantings during vegetative and reproductive periods mainly result from shorter day lengths (Board and Settimi, 1986) and decreases the growth period from emergence to R5 (Fehr and Caviness, 1977) resulting in too little vegetative growth for optimum yield (Egli *et al*., 1987). On the other hand, genotype adaptability to a region influences soybean physiology which can be affected by growth habit and planting date (Pedersen and Lauer, 2004). Early planting of soybean genotypes results in more nodes and a greater number of pods, higher seeds weight (Woong and Takeo, 2006; Boquet and Clawson, 2007). These yield component changes are linked to extended growth periods during R1 (Bastidas *et al*., 2008) through R8 soybean stages in early as compared to late planted soybean. A shorter day length can also decrease the length of growth stage (Calvin and Brent, 2001) and increase seed mass. The decreases in life cycle of soybean plant due to late planting between 13-25 days in comparison with early planting date and it may leads to decrease the biomass of plant. Reduction in seed yield at non-optimal sowing dates resulted from reduced pod set and smaller seed size. The objective of this study was to examine the effect of sowing dates on yield and yield

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attributes of fifteen diverse genotypes of soybean under Punjab conditions.

The experiment was laid out in randomized block design with three replications in Punjab Agricultural Ludhiana, Punjab, (30^o 54′ N 75^o 48′ E), India in 2012 on the sandy loam soil to investigate the impact of planting date on yield traits of fifteen soybean genotypes. Experiment consisted of two planting dates (first fortnight of June and July) and fifteen genotypes (SL 688, SL 778, SL 795, EC 457161, EC457286, SL 525, SL 744, SL 955, SL 983, SL1123, SL 900, SL 958, DS 12-5, DS 26-13 and DS 26-14). Each plot consisted of 4 rows, 45 cm apart and 5 m long. Randomly ten plants were taken from each plot to measure plant height (cm), number of pods per plant, 100-seed weight (g), seed weight per plant (g) and seed yield per plot. All the data collected were subjected to statistical analysis to obtain the mean effects of sowing dates and their interaction with genotypes according to analysis of variance (ANOVA) and mean values were compared with least square difference.

Plant height (cm): Analysis of variance in (Table 1) showed that the significant effect of planting time on plant height. Of the soybean genotypes sown in first fortnight of June, SL 958 had attained maximum plant height followed by genotype DS 12-5 and minimum plant height was recorded by genotype SL 688 (Fig. 1). While in early July sowing, the same genotype SL 958 recorded maximum plant height, but was less as compared to early June sowing and significantly lowest plant height recorded in genotype SL 688. It appears that genotypes planted in early June better utilises the water and nutrients, which might have led to higher plant height than those planted in early July. Therefore, we expect that the results of this experiment corresponded to lower yields in late planting. Also, the results of analysis of variance showed that there was significant affect regarding to interaction effect between planting time and genotypes on plant height at 5 per cent probability level (Table 2).

Table 1. Results of analysis of variance of mean squares for different traits in soybean genotypes pooled over planting dates

Source of variation	df	Plant height	pods/ plant	100-seed weight	Harvest index	Yield/ plant
Replication (in env.)	4	92.61^{ns}	8.661^{ns}	0.042^{ns}	2.46^{ns}	10.19^{ns}
Sowing time (D)	1	520.75*	8128.18*	85.88*	224.72*	78.12*
Genotypes (G)	14	436.67*	602.55*	3.17*	98.28*	25.66*
Interaction (G x D)	14	49.70*	154.57*	1.12*	46.99*	8.28*
Error	56	20.60	6.50	0.32	4.42	2.48

*Ns=Non-significant,*Significant at 5%*

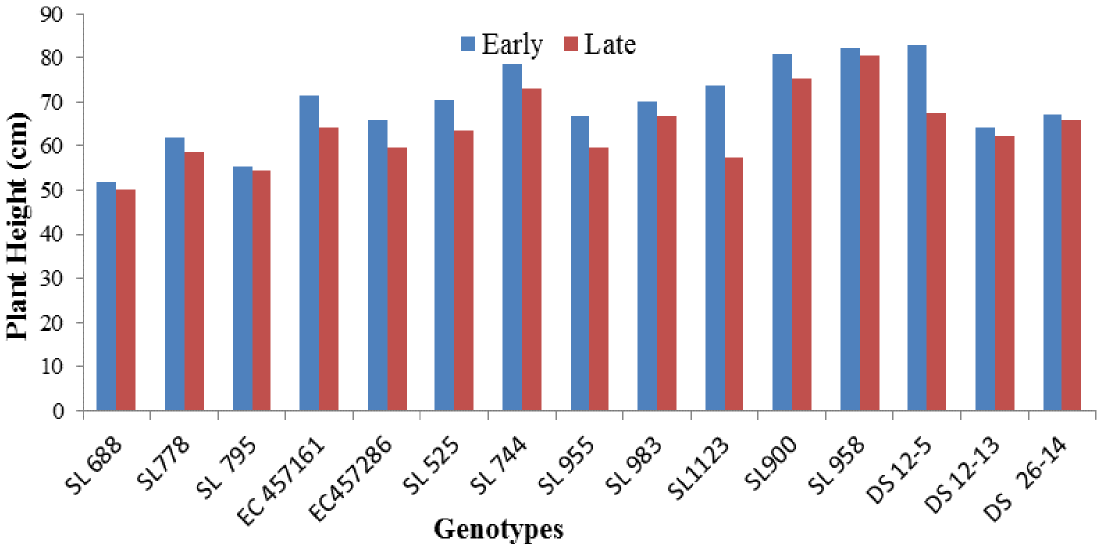

Fig. 1. Interactive effect of planting date and genotypes on plant height (cm) of diverse soybean genotypes

***Number of pods per plant*:** Highly significant variation among the number of pods per plant between genotypes at both the sowing was noted (Table 1). Variance due to interaction between genotypes and sowing dates was also significant. The mean pod number per plant, in case of early June sowing was 89.35 which varied from range 57.01 to 108.71 pods (Table 2). The genotype SL 958 had the highest number of pods per plant, which was statistically at par with genotype EC 457161 followed by genotype SL 744 and SL 983. Significantly lower number of pods per plant recorded in genotypes SL 900. In early July sowing, highest number of pods per plant was produced by EC 457161 followed by genotype EC 457286 and SL 983. Bello (2000) stated that experiment in the Southern Guinea earlier sowings increase the number of pods per plant, number of branches and ultimately increase yield. Also, significantly minimum number of pods per plant was produced by genotype SL 525. These results are in accordance with the finding of Batwal *et al.* (2004) and Kantolic and Slafer (2007).

100-seed weight (g): Plating date, genotypes and their interactions significantly affected 100-seed weight (Table 1). In general, the planting in early July decreased the 100-seed weight as compared to early June planting. This can be accounted for better partitioning of photosynthate to seeds, and shortening of seed fill period and environmental temperature inclement and attitude of plant. In early June planted genotypes, SL 983 produced highest 100-seed weight followed by genotype SL 958, which was at par with genotype EC 457161. Significantly lower value of 100-seed weight was recorded in genotype SL 688. While in early July planted genotypes, SL 958 produced highest value of 100-seed weight followed by genotype DS 26-14 and lower value was recorded in genotype SL 955 (Table 2). So, planting date of June was with suitable conditions for vegetative and reproductive growth of plants and100-seed weight was greater than late sown. The results are in line with those observed by Moosavi *et al*. (2011).

***Harvest index* :** Large variations for harvest index were observed within and between the environments (Table 1).The mean harvest index value increased from early June to early July planting (Table 2).Among genotypes sown in early June SL 958 had maximum value of harvest index followed by SL 983 and minimum value was recorded by genotype SL 900. However, in early July sowing, the genotypes EC 457161 had obtained maximum value of harvest index followed by genotype EC 457286 and minimum was recorded by genotype SL 1123. Most of the genotypes had high harvest index in late sowing as compare to normal sowing in June. The genotypes in normal sowing produced high biomass that could not be converted into high grain yield thus resulting in low value of harvest index. The genotypes with high harvest index were different in different sowing dates indicating G X E interaction for harvest index (Table 1). Similar results were obtained by Oad *et al.* (2002) and Pederson and Lauer (2004).

Seed yield (g/plant): The effect of sowing time on seed yield was found to be highly significant (Table 1). Interaction between genotypes and sowing time was also significant. In case of early June sowing, highest mean (Table 2) seed yield per plant was recorded by genotype SL 958 and followed by SL 983. The lowest seed yield per plant was recorded by genotype DS 12-13. However in early July sowing, the genotype SL 958 had maximum seed yield followed by genotype SL 983 and significantly minimum seed yield per plant recorded by genotype SL 688. The trend recorded in seed yield per plant was similar as was in case of pods per plant. Thus, grain yield was highest in the optimal sowing date which confirms to the results of Parvez *et al.* (1989), Shishodia and Singh (1995) and Oad *et al.* (2002). Kumar *et al* (2008), Bastidas *et al.* (2008) and Ngalamu *et al.* (2012) also reported decrease in yield with late sowing. In the late planting date crop growing with shorter days and earlier onset of flowering and reproductive competition with the growing consumption of photosynthesis, amount of yield affected.

Seed yield (kg/ha): Significant differences in seed yield on account of sowing time were observed (Table 1). In early June sowing, the genotype SL 958 produced more seed yield (Fig. 2) followed by genotype SL 983 and lowest seed yield was recorded by genotype SL 1123. While in early July sowing, the genotype SL 958 had attained maximum seed yield followed by genotypes SL 983 and EC 457161. Significantly lower seed yield was recorded by genotype SL 688. Such behaviour can be accounted for reduced vegetative phase limiting accumulations

Table 2. Comparison of mean performance of diverse soybean genotypes sown at two planting dates for number of pods, 100-seed weight, harvest index and grain yield

Genotypes	Pods (No/plant)		100-Seed weight (g)		Harvest index (%)		Seed yield (g/plant)	
	Early June planting	Early July planting	Early June planting	Early July planting	Early June planting	Early July planting	Early June planting	Early July planting
SL 688	79.34	63.97	9.98	8.09	30.87	38.66	11.06	8.09
SL778	99.41	79.07	11.53	9.26	37.37	42.36	13.78	13.51
SL 795	79.81	68.97	11.67	9.20	30.04	35.91	14.31	10.91
EC457161	105.71	81.84	12.07	9.74	37.67	52.51	15.91	14.21
EC457286	92.51	81.27	11.38	9.41	38.37	43.07	15.11	13.20
SL 525	74.24	52.17	11.89	8.56	33.11	40.95	15.44	11.04
SL 744	101.64	71.07	11.56	9.95	38.77	41.22	16.03	12.13
SL 955	92.67	69.04	10.67	7.99	35.11	32.26	15.34	11.03
SL 983	100.67	79.07	12.59	10.30	39.04	42.61	16.22	14.83
SL1123	81.54	70.07	10.97	8.83	35.44	29.43	11.03	9.71
SL900	63.01	57.97	11.39	9.82	27.11	34.39	10.94	9.31
SL 958	108.17	72.91	12.32	11.36	42.34	38.12	17.24	15.04
DS 12-5	96.77	67.27	11.48	10.24	35.44	36.35	15.34	14.46
DS 12-13	82.37	64.34	11.04	9.83	32.53	37.43	10.63	10.71
DS 26-14	88.41	70.11	11.21	11.08	36.84	32.22	13.38	11.76
Mean	89.35	70.34	11.52	9.58	35.34	38.50	14.12	12.28
LSD (P = 5%)	**3.95**	**4.57**	**1.09**	**0.78**	**3.18**	**3.84**	**2.89**	**2.34**
CV (%)	2.64	3.88	4.90	4.91	5.37	5.96	12.25	11.45

of photosynthetes and their translocation to seed due to late planting. As a result, the total amount of assimilates produced in comparison with the number of leaves per plant, will be reduced. In other hand because of the reduction in plant height and number of branches, leading to the lower production number of pods per plant. Also, due to the short duration of grain effecting period, seed reserve amount is also reduced, which will result in reduced 100-seed weight. Other studies researchers stated yield loss due to delay in planting date. Also, Johnson *et al.* (1995) showed that delayed in planting date leading to decrease seed yield. Reduce the size of the canopy than desirable size, and shorten the growth period of vegetative stated as one of the main reasons for reduced seed yield history of late sowing (Hocking and Stapper, 2001). Egli and Bruening, (2000) in their study reported a decrease in yield with delayed sowing.

The results of this study showed that significant effect on seed yield and its attributes due to planting dates. The increase in these traits at early planting date may be due to the prevailing of favourable temperature and day length leading to greater of these attributes of soybean plants. The genotypes EC 457161, SL 983 and SL 958 produced higher numbers of pods per plant, more 100-seed weight and maximum seed yield than other because of their better genotypic records. Finally, genotype SL-958 and early planting seem to be more effective in getting higher seed yields.

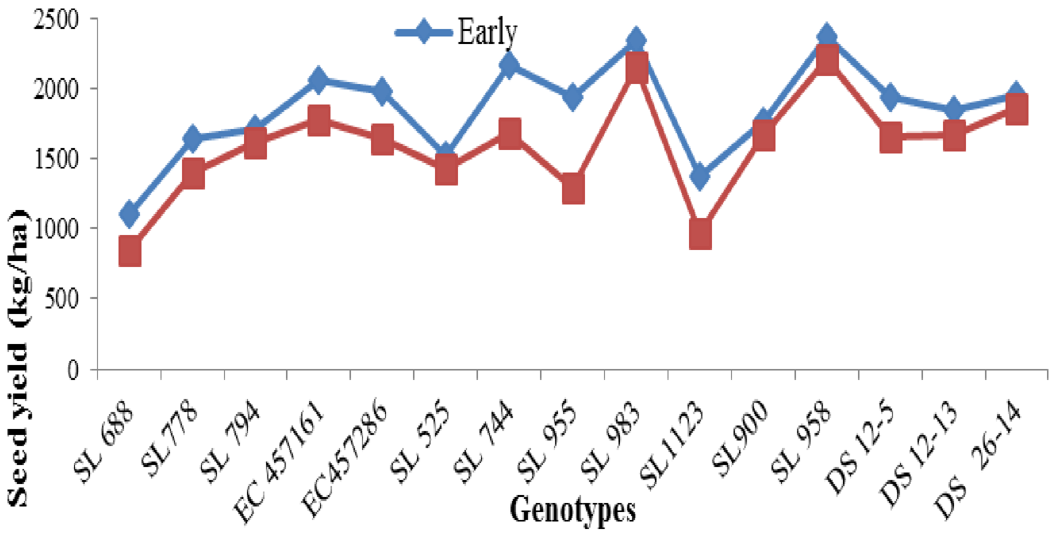

Fig 2. Interactive effect of planting date and genotypes on seed yield (kg/ha) of diverse soybean genotypes

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Impact of Sowing Dates on Quality Estimation in Different Soybean [*Glycine max* (L.) Merrill] Varieties

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Key words: Chlorophyll, soybean, proline, varieties

Soybean is called a miracle golden bean because of its nutritive value, especially as a substitute or complement of protein. Soybean seed contains approximately 40-45 per cent high valued protein and 20-22 per cent high valued oil and can be considered to be a concentrated protein food. The protein of soybean is called a complete protein because it supplies sufficient amount of various kinds of amino acids. Chlorophyll is vital for photosynthesis, which allows plants to absorb energy from light. Chlorophyll content is an index of organic matter production and plant growth (Lahai *et al*, 2003). The increased photosynthesis has been linked to increased chlorophyll content in plants. As a result, chlorophyll content is a measurement of physiological activities in plants. Proline plays an important role in flowering and development both as a metabolite and as a single molecule. Although there is a growing consensus that proline is of special importance throughout the reproductive phase (from flower transition to seed development). Recently, a conceptual model that relates remotely sensed reflectance with pigment content in different media (leaves, crop canopy and phytoplankton) was developed and used for the non-destructive estimation of chlorophyll, carotenoids and anthocyanins in higher plant leaves. Abiotic stress is a major factor around the world in limiting plant growth and productivity (Osakabe *et al*., 2011; Jamil *et al*., 2011). Exposure of plants to a stressful environment during various developmental stages appears to induce various physiological and developmental changes.

The field study was conducted at the Research Farm, Department of Physics and Agrometerology, College of Agricultural Engineering, JNKVV, Jabalpur during *kharif* 2010-11 to find out the effect of sowing date and variety on the soybean yield and quality. During the experimental period, the maximum temperature ranged from 29.3 to 37.4 ^{0}C and the minimum temperature ranged from 15.3 to 25.4 ^{0}C with a range of average temperature from 22.3 to 31.4 ^{0}C. The

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maximum and minimum air humidity was from 59 to 82 per cent. Three sowing dates (1st, 15th and 30th July) and three soybean varieties (JS 93-05, JS 97-52 and JS 335) were included in the experiment laid out in a split-plot design with three replications. The sowing dates were allocated in the main plot and varieties in the sub-plots. Quality parameters in seed (chlorophyll, protein, fat and proline contents) were analyzed in the laboratory.

The plant parts were analyzed for the biochemical constituents, namely chlorophyll content and total in nodal leaves at pod initiation stage (Yoshida *et al*., 1972), and protein (AOAC, 1965), fat (AOAC 1980) and prolin (Bates *et al*., 1973) in matured seeds.

Chlorophyll content: All the three sowing dates influenced the chlorophyll content of leaves at pod initiation stage of soybean (Table 1). It was maximum (0.56 mg/g) for crop sown on 15th July. Chlorophyll content of crop sown on 1st July (0.18 mg/g) and on 30th July (0.14 mg/g) also differed significantly from each other. Soybean varieties also differed significantly from each other in chlorophyll content; the maximum being with JS 335 (0.53 mg/g) and minimum with JS 97 52 (0.16 mg/g). The interaction effect showed highest value of chlorophyll content (0.82 mg/g) when JS 335 was planted on 15th July. Other combinations showed the value of chlorophyll content between 0.09 mg per g (JS 97 52 planted on 30th July) and 0.23 mg per g (JS 93 05 planted on 30th July). Although 1st July sowing did not reveal higher chlorophyll, but it was maximum in 15th July planting and more than 30th July planting, it corroborates the findings of Yazied (2011), who reported that early sowing date in case of snap bean increased the total chlorophyll contents in leaves.

Seed protein: Seed protein was significantly influenced by different sowing date and it was found to be maximum (39.41 %) in 15th July planting of soybean. Planting of the crop on 30th July revealed lowest protein content (38.23 %). Due to the effect of Variety the seed protein (%) was affected significantly (Table 1). Among varieties, JS 97-52 (38.96 %) revealed the highest protein content followed by JS 335 (38.70 %) and JS 93-05 (38.62 %) Interaction effect between sowing dates and varieties showed that JS 97-52 planted on 15th July had maximum protein content of 39.64 per cent. Values of protein contents for other combinations ranged between 38.15 per cent (JS 93-05 planted on 30th July) and 39.30 per cent (JS 335 planted on 15th July). Like chlorophyll content in leaf, the protein content was also higher in 15th July planting as compared to 30th July planting and corroborates the findings of Yazied (2011), who reported higher protein content in green pods of snap bean due to early planting.

Seed proline: The highest seed proline (34.71 μmol/g) was found 30th July sowing followed by 1st July (33.09 μmol/g) and 15th July (27.92 μmol/g) plantings, and all the three differed significantly. Due to the effect of variety the seed proline (μmol/g) was affected significantly (Table 1). In case of varieties also, JS 97-52 (36.76 μmol/g) showed highest content of proline followed by JS 335 (29.85 μmol/g) and JS 93-05

Table 1. Impact of staggered sowing dates and varieties on chlorophyll content, protein, proline and fat contents

	Chlorophyll content (mg/g)*	Seed protein** (%)	Proline** content (μmol/g)	Fat content** (%)
Main treatment sowing date (D)				
1st July	0.18	38.63	33.09	17.53
15st July	0.56	39.41	27.92	18.01
30th July	0.14	38.23	34.71	17.49
SEm (±)	0.00006	0.0020	0.0741	0.0034
CD (P = 0.05)	**0.00024**	**0.0082**	**0.29**	**0.013**
Sub treatment variety (V)				
JS 93-05	0.19	38.62	29.12	17.37
JS 97-52	0.16	38.96	36.76	18.36
JS 335	0.53	38.70	29.85	17.29
SEm (±)	0.000059	0.039	0.068	0.0046
CD (P = 0.05)	**0.000182**	**0.099**	**0.19**	**0.014**
Interaction (D x V)				
1st July x JS 93-05	0.13	38.41	22.04	17.15
1st July x JS 97-52	0.20	38.87	36.04	18.25
1st July x JS 335	0.20	38.62	41.18	17.20
15th July x JS 93-05	0.21	39.29	34.19	17.87
15th July x JS 97-52	0.18	39.64	25.40	18.62
15th July x JS 335	0.83	39.30	24.18	17.54
30th July x JS 93-05	0.23	38.15	31.13	17.14
30th July x JS 97-52	0.09	38.35	48.83	18.22
30th July x JS 335	0.10	38.17	24.18	17.09
SEm (±)	0.000102	0.050	0.11	0.0080
CD (P = 0.05)	**0.000136**	**0.17**	**0.38**	**0.024**

**Contents on leaf at pod initiation; ** contents in matured seeds*

(29.85 μmol/g) and the values differed significantly. The variety JS 335 planted on 31st July showed highest proline content (48.83 μmol/g), which was significantly different from other interactions (22.04 – 41.18 μmol/g). This finding is in corroboration with report of Pawar *et al.* (2009), wherein they found pegionpea genotypes planted on four dates influenced the proximate composition and limited amino acids.

Fat content: The influence of sowing dates on fat content revealed that the highest value (18.01 %) was associated with 15th July planting followed by 1st July (17.53 %) and 30th July (17.49 %) plantings, and the values differed significantly. Soybean varieties too differed significantly from each other in fat content; JS 97-52 showed highest content (18.36 %) and JS 335 the lowest (17.29 %). As far as the interactive effective is concerned, JS 97-52 planted on 15th July showed the significantly highest fat content (18.62 %) over other interactions (17.14 – 18.25 %). The results get support from the work of Mirshekari *et al*. 2012, who examined the effect of planting dates and water deficit on quantitative and qualitative traits of flax seed.

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Effect of Nitrogen and Plant Growth Regulators on Soybean [*Glycine max* (L.) Merrill] under Late Sown Conditions

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Key words: Cytokinin, growth regulators, methanol, NAA, nitrogen, soybean, triacontenol

Soybean [*Glycine max* (L.) Merrill] is one of the major leguminous and oilseed crops of India, particularly in central part of the country. It has two scarce quality that is protein and oil, which are not only the major component in the diet of vegetarian mass but a boon to the developing countries as well. Soybean plays a vital role in the agricultural economy of India. The optimum time of sowing of soybean is last week of June to first week of July. However, its sowing is sometimes delayed due to late onset of monsoon and insufficient initial rains. Sometimes long rainfall gap or heavy showers just after sowing have forced the farmers for re-sowing. The late sown soybean crop attains reduced growth, nodulation and low yield. There is possibility of improvement in growth and productivity of such crop by top-dressing of nitrogenous fertilizers and external application of plant growth regulators at optimum concentration and at proper stage. Use of fertilizers has brought about the remarkable increase in agricultural production. Jaypaul and Ganesaraja (1990) also observed that the application of 40 kg N per ha significantly increased seeds per pod by 9.2 and 14.2 per cent over 20 kg N per ha and no nitrogen, respectively in soybean. They also observed marked increase in seed yield of soybean by application of 40 kg N per ha over control, but it was comparable with 20 N per ha. Kang *et al*. (2004) reported that application of 120 kg N per ha in soybean significantly increased the 100-seed weight by 18.06 per cent over no nitrogen.

Vyas *et al*. (2000) reported that the hormonal effect of triacontenol and its role in growth promoting processes has led to increased yield of dry matter, total phosphorus utilization in soybean.

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Dwivedi *et al.* (2001) reported that foliar application of triacontanol (Vipul) @ 250 ml per ha at 30, 40 and 50 DAS produced the maximum growth and yield components in soybean with 25.8 per cent increase in seed yield over no PGR. The total N, P and K uptake was also highest up to 190.86, 17.40 and 72.38 kg per ha, respectively.

Albrecht *et al.* (1995) reported that the vegetative growth and yield of C_3 crops are enhanced by foliar methanol application and methanol sprays reduced that overall crop water use. Methanol may act as a carbon source for the plant and a photorespiration inhibitor. Dwivedi *et al.* (2001) reported that the application of methanol @ 20 per cent caused reduction in plant height and increased total and effective nodes, number of pods and pod weight per plant which ultimately led to maximum biological as well as economic yield.

The probable mechanism through which plant regulator work is considered to be one where by senescence is delayed after anthesis thus prolonging grain development and ripening period. This is of tropical importance to late sown conditions that may prevail in Malwa region due to late onset of monsoon, insufficient initial rains, and long rainfall gap after sowing. For this reason, it was considered worthwhile to explore the possibilities of augmenting the soybean yield through the use of nitrogenous fertilizers and growth regulators, namely triacontenol, NAA, cytokinin and methanol under late sown conditions during *kharif* 2007 at the College of Agriculture, Indore situated at an altitude of 555.7 m above mean sea level and geographical bearing of 22°43′N latitude and 75°66′E longitude.

A field trial was conducted in a randomized block design with ten treatments replicated thrice. A spacing of 30 cm x 10 cm was maintained between and within the rows. The ten treatments were comprised of three levels of basal application of nitrogen (20, 30 and 40 kg/ha), two foliar sprays of nitrogen (10 kg and 20 kg/ha) at 20 days after sowing (DAS) in combination with basal application of 20 kg N per ha, foliar sprays of four growth regulators (methanol 20 % @ 30 l/ha, triacontenol 0.1 % EW @ 325 ml/ha, NAA 4.5 % SL @ 13 g CP/ha and cytokinin @ 975 ml CP/ha) in combination with foliar spray of 20 kg N per ha at 20 DAS and 35 DAS and an absolute control (without nitrogen and plant growth regulator). For foliar sprays 650 litres of water per ha was utilized. The test variety of soybean was JS 93-05 sown on July 17, 2007. All the plants from one meter square were harvested at maturity to record data on the yield attributes, namely number of seeds per pod and number of pods per plant. After threshing, cleaning and drying, seed and stover yields from one m^2 area from each treatment was recorded and reported as kg per ha after conversion.

Effect on growth parameters: Maximum number of pods (27.48 pods/plant) was recorded in triacontenol @ 0.1 per cent along with basal application of nitrogen @ 20 kg per ha, which was significantly superior to other treatments. Minimum pods (22.45/plant) were recorded in 20 kg N per ha as basal treatment (Table 1).

Table 1. Effect of nitrogen and plant growth regulators on yield and yield attributes in *kharif* soybean

Treatments	**Pods (No/ plant)**	**Seeds (No/ plant)**	**Seed yield (kg/ha)**	**Stover yield (kg/ha)**
20 kg N/ ha as basal (Recommended)	22.45	1.9	1951	4233
30 kg N/ ha as basal (Regional recommendation)	23.63	2	1671	4296
40 kg N/ ha as basal (Dryland recommendation)	25.3	1.77	1680	4364
20 kg N/ ha as basal + 10 kg N/ ha at 20 DAS	25.03	1.9	1751	4049
20 kg N/ ha as basal + 20 kg N/ ha at 20 DAS	25.63	1.9	1831	4227
20 kg N/ ha as basal + methanol AR grade, 20 % solution 130 l/650 L water/ha at 20 and 35 DAS	25.18	1.8	1998	4287
20 kg N/ ha as basal + triacontenol 0.1% EW @ 325 ml CP/650 l water/ha at 20 and 35 DAS	27.48	2.8	2380	4736
20 kg N/ ha as basal + NAA 4.5 % SL @ 13 g CP/650 L water/ha at 20 and 35 DAS	25.93	2	1691	4409
20 kg N/ ha as basal + cytokinin @ 975 ml CP/650 l water/ha at 20 and 35 DAS	25.91	2	1800	4236
Without nitrogen and plant growth regulator application	24.41	2	1767	3836
SEm (±)	0.43	0.15	113.3	96.25
C D (P = 0.05)	**1.28**	**0.44**	**337**	**286**

Number of seeds per pod reflects the yield of soybean directly. Foliar application triacontenol @ 1 per cent at 20 and 35 DAS along with basal application of nitrogen @ 20 kg per ha resulted in the highest number of seeds per pod (2.8). Rest of the treatments containing foliar application of NAA and cytokinin at 20 and 35 DAS and basal application of nitrogen @ 20 kg per ha also registered higher number of seed per pod as compared to other treatments. Minimum number of seed per pod was found in 40 kg N per ha as basal (1.77) treatment (Table 1). This result showed that foliar application of plant growth regulators (tricontenol, NAA and cytokinin) and basal application of nitrogen @ 20 kg per ha had positive effect on seeds per pod under late sown conditions.

Effect on seed yield: Among the treatments, application of triacontenol 0.1 per cent EW along with basal application of nitrogen @ 20 kg per ha had recorded the maximum seed yield (2,380 kg/ha), which was significantly higher over other treatments. Those treatments which involve foliar application of methanol (20 %) in combination with basal application of nitrogen @ 20 kg per ha also registered significantly higher seed yield (1,998 kg/ha and 1,951 kg/ha, respectively) over absolute control treatment (Table 1). These findings showed that application of nitrogen and growth regulator enhanced yield of soybean under late sown conditions. The differences in yield among treatments can be on account of number of pods per plant and number of seeds per pod. These results are similar to the findings reported by Vyas *et al*. (1999), Dwivedi and Tiwari (2001) and Dwivedi *et al*. (2001). A possible explanation for the low yield in control is that the plants could not attend normal growth and vigor in the absence of application of nitrogen and growth regulator. Hence, it would be advantageous to apply nitrogen and plant growth regulator (triacontenol and methanol) to harness higher seed yield in late sown soybean.

Effect on stover yield: All the treatment increased the stover yield of soybean as compared to absolute control treatment. Highest stover yield per hectare was obtained under the triacontenol 0.1 per cent EW in combination with 20 kg N per ha as basal (4,736 kg/ha) and minimum stover yield per hectare was recorded in absolute control (3,836 kg/ha). The increase in stover yield might be due to the foliar application of triacontenol due to which plants could attend the normal growth and vigor.

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Effect of Anti-Transpirant and Mulches on Growth and Yield of Soybean [*Glycine max* (L.) Merrill] under Manipur Conditions

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Key words: Anti-transpirant, mulching, soybean, yield

Soybean is one of the five major crops in the world with high-quality protein (35-45 %) and edible oil (18-22 %) for mankind (Javor *et al.,* 2001) and thereby lifted the socio-economic status of soybean farmers. Its cultivation also improves soil health because of its atmospheric nitrogen fixing ability and deep root system. Manipur has a great potential for production and domestic utilization of soybean and its derivatives as health foods. Mulching with plant materials reduces soil loss up to 17 times compared to cropped soil without mulches. It also reduces runoff and nutrient losses. By increasing the amount of mulch, sediment present in runoff water can be reduced as it covers more soil surface and protects it from rain drop impact (Reddy and Reddy, 2010). Straw mulch ameliorates environment stresses (Macilwan, 2004) and improves the food quality and safety. Pawar *et al.* (2004) also reported that surface applied mulches provide several benefits to crop production by controlling evaporation from the soil. Not only this, it also provides benefits to heat energy and nutrient status in soil, buffering drastic changes in soil temperature (Naoini and Cook, 2000). Using of mulching in combination with anti-transpirant will reduce the transpiration rate and moisture loss from the soil. The present experiment was done to identify the best anti-transpirant in combination with mulches for obtaining maximum yield of soybean under Manipur conditions.

A field experiment was carried out at Agricultural Research Farm, Andro, Central Agricultural University, Imphal, Manipur during the *kharif* 2012. The area is located at 24°45.89´ N latitude, 94°03.45´ E longitude with an elevation of 808-940 m above mean sea level. The soil is clay loam in texture with a soil pH of 5.7 containing 229 kg per ha available nitrogen, 12.0 kg per ha available phosphorus and 59.4 kg per ha available potassium with an organic

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carbon content of 0.80 per cent. The experiment was laid out in factorial randomized block design and the treatment were comprised of four anti-transpirant *viz.,* $MgCO_3$ at 5 per cent, glycerol at 5 per cent, Na_2CO_3 at 5 per cent, KNO_3 at 1 per cent and water spray with straw mulching and without mulching which were replicated thrice. The anti-transpirant were spray 15 days after the flower initiation. The genotype used in the experiment was RKS 18 with a spacing of 45 cm x 10 cm. The fertilizers were applied as basal @ 20:60:40 kg per ha of N, P_2O_5 and K_2O in the form urea, single super phosphate and muriate of potash, respectively with 2 tonnes per ha of FYM. After sowing, mulching with rice straw was done @ 5 t per ha at the respective plots as per the treatment leaving the rows open. No irrigation was applied. The mean maximum temperature was 32.3^{o} C during July, 2012 and the total rainfall was 647 mm during cropping period.

Effect on growth attributes: Mulching had significant effect on dry matter production, crop growth rate (CGR) and relative growth rate (RGR) in all the dates of observation except CGR at 45-60 days after sowing (DAS) and RGR 30-45 DAS (Table 1). Dry matter production increased with the age of the crop and the maximum dry matter production, CGR and RGR was observed in mulching treatment in all the date of observation except RGR at 45-60 DAS. This may be due to reduction of crop weed competition thereby producing greater leaf area which helps in production of higher dry matter. Tolk *et al*. (1999) reported that leaf area was greater in the mulched treatments when compared with the bare soil treatments. Furthermore, Qin *et al*. (2006) also reported the increased in leaf area per plant by application of rice straw mulch. The considerable enhancement in soybean growth was the result of soil water being used for crop growth and yield rather than evaporation of soil water (Xue *et al.*, 2013). The greater soil profile moisture under mulch has important implications in the utilization of water by crop and in soil reactions that control the availability of nutrients and biological nitrogen fixation (Surya *et al*., 2000) that leads to improve growth. These results are in agreement with that of Ahmed *et al*. (2007).

Spraying of anti-transpirant had no significant influenced on growth attributes *viz*., dry matter production, CGR and RGR in all the dates of observation except dry matter production on 30 DAS (Table 1) as the anti-transpirant were sprayed 15 days after flower initiation *i.e.*, after taking the observation on growth attributes. However, the highest dry matter production in all the dates of observation was observed in spraying of glycerol at 5 per cent and spraying of KNO_3 produced maximum CGR and RGR at 45-60 DAS, while control treatment produced maximum CGR and RGR at 30-45 DAS.

Effects on yield components and yield: Mulching and anti-transpirant spray had no significant effect on pods per plant, seed index and harvest index. However, mulching with rice straw produced maximum number of pods per plant (47.19) and seed index (9.79 g) in comparison with unmulch treatment and

Table 1. Effect of anti-transpirant with mulching on dry matter, mean CGR and RGR at 30, 45 and 60 DAS

Treatment	Dry matter (g/plant)			Mean crop growth rate ($g/m^2/day$)		Mean relative growth rate (g/g/day)	
	30 DAS*	45 DAS	60 DAS	30-45 DAS	45-60 DAS	30-45 DAS	45-60 DAS
Mulch							
Mulch	2.90	7.70	14.36	9.60	13.33	0.064	0.043
Without mulch	2.36	6.04	12.62	7.35	13.17	0.062	0.050
SEm (±)	0.05	0.25	0.34	0.48	0.51	0.002	0.002
C D (P = 0.05)	**0.16**	**0.75**	**1.01**	**1.43**	**NS**	**NS**	**0.005**
Anti-transpirant							
$MgCO_3$ at 5%	2.57	6.90	13.34	8.66	12.89	0.0623	0.047
Glycerol at 5%	2.84	7.47	13.99	9.26	13.05	0.062	0.044
Na_2CO_3 at 5%	2.80	6.58	13.25	7.56	13.32	0.058	0.047
KNO_3 at 1%	2.38	6.17	13.23	7.59	14.12	0.064	0.051
Water spray	2.55	7.21	13.65	9.30	12.88	0.069	0.043
SEm (±)	0.09	0.40	0.54	0.76	0.81	0.004	0.003
C D (P = 0.05)	**0.25**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

**Days after sowing*

maximum HI (33.3 %) was observed under unmulch (Table 2). Straw mulching provides proper moisture in the root zone which helped in nutrient translocation resulting in maximum number of pod per plant and seed index. Mulching improves soybean nodulation and N-fixation (Siczek and Lipiec, 2009) thereby helps in increasing yield attributes. Liang *et al*. (1999) who reported that mulching treatment could effectively retain soil moisture and improve nutrient transformations and availability, thus ultimately results in improving yield. Seed and straw yield was significantly influenced by mulching and the maximum seed yield (2,507 kg/ha) and straw yield (5,559 kg/ha) was recorded under mulching treatment. Greater seed yield under mulching treatment might be due to higher number of pod per plant and seed index and higher straw yield might be due to increase in dry matter production. Better development of roots and proliferation depending on soil moisture under mulching helps in producing yield and yield attributes. Bonfil *et al*., 1999 also reported that wheat grain yield under mulching was higher due to longer rooting and higher moisture content in the upper soil layers. The findings were in conformity with Xue *et al.* (2011).

In case of anti-transpirant treatments, spraying of $MgCO_3$ at 5 per cent produced maximum pods per plant (52.2) and seed index (9.83 g), while the

Table 2. Effect of anti-transpirant with mulching on pods/plant, seed index, straw yield, seed yield, harvest index and economics

Treatment	Pods (No/ Plant)	Seed index (g/100 seeds)	Straw yield (kg/ha)	Seed yield (kg/ha)	HI (%)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Mulch									
Mulch	47.19	9.79	5559	2507	31.06	65044	125367	60322	1.93
Without mulch	43.57	9.53	4147	2046	33.30	46280	102333	56053	2.21
SEm (±)	1.62	0.25	167.0	106.06	1.21	-	5303	5303	-
C D (p = 0.05)	**NS**	**NS**	**496.2**	**315.13**	**NS**	**-**	**15757**	**NS**	**-**
Anti-transpirant									
$MgCO_3$ at 5 %	52.2	9.83	4990	2660	34.93	64339	133000	68661	2.07
Glycerol at 5%	45.3	9.58	4658	2483	35.04	64493	124167	59674	1.93
Na_2CO_3 at 5 %	44.8	9.75	5033	2308	31.47	61185	115417	54232	1.89
KNO_3 at 1 %	43.2	9.71	4567	1867	30.46	47032	93333	46301	1.98
Water spray	41.5	9.43	5017	2067	29.00	41262	103333	62071	2.50
SEm (±)	2.57	0.40	264.1	167.70	1.91	-	8385.2	8385.2	-
C D (P = 0.05)	**NS**	**NS**	**NS**	**498.27**	**NS**	**-**	**24914**	**NS**	**-**

maximum HI (35.04 %) was observed under spraying of glycerol at 5 per cent (Table 2). Spraying of anti-transpirant had no effect on straw yield and the highest straw yield (5,033 kg/ha) was observed under spraying of Na_2CO_3 at 5 per cent. Seed yield was significantly influenced by spraying of anti-transpirant and spraying of $MgCO_3$ at 5 per cent produced highest seed yield (2,660 kg/ha), which was statistically at par with spraying of glycerol at 5 per cent and Na_2CO_3 at 5 per cent (Table 2). Use of anti-transpirant reduces the plant water loss and transpiration rate that might help in increasing the yield. Moftah (1997) reported that use of anti-transpirants increased yield of soybean. Moreover, spraying of $MgCO_3$ at 5 per cent and 1g per litre gave higher yield of banana and barley respectively (Abd El-Kader *et al*., 2006 and El-Kholy *et al*., 2005). El-Kholy and Gaballah (2005) also proved that use of $MgCO_3$ increased wheat yield under water stress condition. The lowest seed yield was observed under spraying of KNO_3 at 1 per cent (1,867 kg/ha). The per cent increase of seeds yield by spraying of $MgCO_3$ at 5 per cent over glycerol at 5 per cent, Na_2CO_3 at 5 per cent, water spray and KNO_3 at 1 per cent were to the tune of 7.12, 15.25, 28 and 42.4 per cent, respectively.

Effects on economics: Higher cost of cultivation, gross returns and net returns were recorded under mulch treatment. The higher cost of cultivation was mainly due to high cost of rice straw. However, unmulched treatment recorded maximum B:C ratio. In case of anti-transpirant, gross returns and net returns were maximum under spraying of $MgCO_3$ at 5 per cent, whereas spraying of glycerol at 5 per cent recorded maximum cost of cultivation. The higher B:C ratio was found in control treatment (2.50) closely followed by spraying of $MgCO_3$ at 5 per cent (2.07). This might be due to lower cost of cultivation under control treatment.

Based on the results discussed, it can be concluded that spraying of $MgCO_3$ at 5 per cent with mulching was found to produce better yield of soybean under Manipur condition.

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Effect of Drainage, Tillage and Land Configurations on Root, Nodules and Yield of Soybean in Vertisols

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Key words: Drainage, soybean, sowing method, tillage

Soybean (*Glycine max* L.) is an important oil seed crop of India. Soybean, a photoperiod sensitive plant (Yayock *et al*., 1988), has tremendous potential to reduce malnutrition (Adekayode, 2004) as it is a major source of protein and vegetable oil. India has 9.60 million hectares of land under soybean cultivation, producing 12.74 MT of soybean seeds with an average productivity of 1.33 t per ha. Madhya Pradesh is the largest soybean-producing state in India, with 5.56 million hectares of cultivation area and 6.67 million tons of seed production with productivity of approximately 1.20 t per ha (Anonymous, 2012). The major command area for soybean lies on Vertisols that suffers from water stagnation and severe runoff during monsoon. Thus, soybean plants when cultivated under intensive rainfed condition and suffer from excess soil water stress. This growing environment results in poor development of root system, root nodulation, plant height and consequently lower crop yield. In such a condition, raised bed system with ridges and furrows helps to drain excess soil water from plant root zone. Previously, some works have been done on the effects of different tillage methods on the growth and yield of soybean. Ram *et al.* (2011) reported that the adoption of raised bed system resulted in 6.7 per cent and 5.3 per cent higher seed yields than ridge plus furrow and flat bed systems, respectively. Singh *et al*. (2011) further showed that the mortality rate of soybean plants sown with a tractor-drawn BBF seed drill on Vertisols was decreased by 14–19 per cent as compared with flat bed under the vagaries of monsoon, and subsequently resulting in 18.7 per cent yield increase. But, there is very scarce information available on the suitable combination of drainage, tillage and sowing methods for achieving optimum soybean production on the

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Vertisols of Madhya Pradesh. Each of the methods affects soybean growth, yield and will be of importance for better field management and soybean yield. This study, therefore, aims to evaluate the combination of different drainage, tillage and sowing technologies for increasing soybean productivity in Madhya Pradesh.

A field trail was conducted on a clay loam soil belonging to Vertisols in the JNKVV farm with the collaboration of Japan International Corporation Agency (JICA) in 2012. The soil was neutral in reaction (pH 7.6), rich in potassium (370 kg K_2O/ha), medium in nitrogen (254 kg N/ha) and deficient in phosphorus (14.0 kg P_2O_5/ha). The minimum temperature ranged between 12.6 and 23.8 °C, while the maximum temperature between 29.5 and 38.6 °C. The mean annual rainfall of 1300.5 mm was received during the period of the study.

The trial was established with nine treatments, namely (i) no till + flat bed, (ii) no till + open drainage channel, (iii) no till + open drainage channel + sub-soiler, (iv) conventional tillage + flat bed, (v) conventional tillage + raised bed, (vi) conventional tillage + raised bed + open drainage channel, (vii) no tillage + flat bed, (viii) no till + open drainage channel and (ix) no till + open drainage channel + sub-soiler. There treatments were under early sowing (21st June) and three treatments (no till + flat bed, no till + open drainage channel and no till + open drainage channel + sub-soiler) under late sowing (10th July). The experiment design was randomized block with three replications. Conventional tillage consisted of the combination of one pass plough, 2 passes cultivator, and 2 pass disc harrow after wheat harvest. In no till plots sub-soiler was used at every 2m distance up to 45 cm depth across the slope for facilitation of sub-surface drainage. In no till plots, soybean was sown directly into dead wheat residue without field preparation by using a zero-till seed drill with inverted T-type furrow openers and manually opening slits. The variety JS 97-52 was sown @ 70 kg per ha with a spacing of 5 cm inter-plant and 45 cm inter-row distances. The recommended dose of fertilizers (20 kg N, 60 kg P_2O_5 and 20 kg K_2O/ha) was applied before sowing. The numbers of roots, root nodules, branches and plant height were recorded at 60 days after sowing (DAS) in five randomly selected plants in each replicated plot. To count the number of roots and nodule uprooted with the help of a fork by removing the entire root along with soil lump and it was kept as such in a bucket, filled with water for half an hour. The roots of each plant were then gently cleaned carefully so that roots and nodules may not be separated from the roots. Thereafter, the total number of roots and nodules per plant were counted and the mean was worked out. Seed and straw yields were recorded at harvest to calculate the economics of each treatment.

The data showed that plant height, number of roots and nodules significantly changed with tillage, drainage and sowing methods (Table 1). The conventional tillage + raised bed + open drainage channel treatment recorded the highest plant height (80.47 cm) and number of branches per plant (8.03), followed by the conventional tillage + raised bed treatment. This indicated that the

Table 1. Seed yield, straw yield and economics of treatments of soybean crop

Treatments	Roots (No/ plant)	Nodules (No/ plant)	Branches (No/ plant)	Plant height (cm)	Seed Yield (t/ha)	Straw Yield (t/ha)	Net returns (Rs/ha)	B: C ratio
Early sowing (21st June 2012)								
No till + flat bed	30.87	27.93	5.77	58.90	1.93	4.71	27459	2.26
No till + open drainage channel	30.14	26.53	6.43	63.44	2.34	5.74	36655	2.60
No till + open drainage channel + sub-soiler	31.57	28.93	7.63	64.57	2.56	6.06	40559	2.66
Conventional tillage + flat bed	25.80	22.47	7.70	67.71	2.60	6.12	40055	2.54
Conventional tillage + raised bed	28.73	25.40	7.97	78.00	2.70	6.23	41492	2.54
Conventional tillage + raised bed + open drainage channel	29.33	26.93	8.03	80.47	3.14	7.19	50682	2.75
Late sowing (10th July 2012)								
No till + flat bed	22.83	21.47	3.40	39.47	1.16	3.41	8810	1.41
No till + open drainage channel	22.73	21.07	4.30	39.07	1.00	3.40	3706	1.16
No till + open drainage channel + sub-soiler	22.50	21.73	5.20	32.33	1.36	3.88	10855	1.44
SEm (±)	0.45	1.36	0.22	1.62	1.37	2.92	3450	0.13
CD (P=0.05)	**1.35**	**4.07**	**0.66**	**4.87**	**4.10**	**8.75**	**10343**	**0.40**

conventional tillage and raised bed with open drainage was helpful for soybean growth in the tested field environment. However, for early sowing, the no till treatments where sub-soiler was used recorded the highest number of roots (31.57) and root nodules (28.93) per plant. Effect of sub-soiler on numbers of roots and nodules were found pronounced in soybean because of soil loosening and proper aeration in soil. Similar results were also reported by Bishop and Grimes (1978), Ibrahim and Miller (1989) and Merrill *et al*, (1996). The number of roots and nodules tended to decrease with late sowing for all the treatments. The conventional tillage + raised bed + open drainage channel treatment recorded 29.33 and 26.93 for the numbers of root and nodules per plant, respectively and this, method combination resulted in a higher seed (3.14 t/ha) and straw yields (7.19 t/ha), followed by conventional tillage + raised bed (2.70 and 6.23 t/ha). The increased yield is probably attributable to improved field drain capacity and soil environments by adopted land configuration (Sharma et al., 2000), and is similar to the results of Singh et al. (2011) who reported a higher seed yield on broad bed furrow (1.31 t/ha) than flatbed (1.11 t/ha). Soybean plants in late sowing showed significantly lower values in plant height, number of branches, seed yield, and straw yield, relative to plants for early sowing. And, for early sowing, plant growth in no till treatments was also lower than conventional tillage treatments. Lasisi and Aluko (2009) also reported a similar trend that soybean growth and seed yield are much better in conventional tillage than conservation tillage. The current study also showed that the highest numbers of roots and nodules for the no till + open drainage channel + sub-soiler treatment and a clear trend to increase these numbers with no till relative to conventional tillage, indicating that the no till treatment combined with drainage methods improves soybean root growth. The overall economics calculated for each treatment revealed that the values of net returns (Rs 50,682/ha) and B:C ratio (2.75) were higher for the conventional tillage + raised bed + open drainage channel treatment than other method combinations. All the method combinations in late sowing showed minimum net returns and B:C ratio due to low seed and straw yields. Ram *et al*. (2011) also reported that the net returns and B:C ratio recorded highest in raised bed sowing relative to flat bed sowing. From results, it can be concluded that the conventional tillage + raised bed + open drainage channel treatment is a suitable combination for better seed and straw yields, and that the no till treatments combined with drainage methods can improve soybean root growth and nodule number.

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Response of *Kharif* Legumes to Soybean Girdle beetle, *Obereopsis brevis* (Swed.)

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Key words: Girdle beetle, incidence, *kharif* legumes, stem tunneling

India has the largest area under pulses in the world, but the average productivity is low (Anonymous, 2012).The legumes are rich source of protein, particularly in the essential amino acid, lysine, which rather deficit in cereals. In the Madhya Pradesh green gram (*Vigna radiata* L. Wilczek), black gram (*Vigna mungo* L. Hepper), cow pea (*Vigna unguiculata* (L.) Walp, cluster bean (*Cymopsis tetragocalobe* L. Taub), pigeon pea (*Cajanus cajan* L. Millsp), Indian bean (*Dolichos lablab* L.) and soybean (*Glycine max* L. Merrill) are cultivated as *kharif* legumes. Out of theses legumes soybean is also a major source of oil and protein. Soybean ranks first amongst oil seeds crops in the world. In international markets soybean oil trading is next only to palm oil. The crop contributes to nearly twenty five per cent of the world's total oil and fats production. The United State of America, Brazil, Argentina, China and India are the five major producer of soybean accounting for 90 per cent of world production. The world productivity of soybean is 2,384 kg per ha. Soybean is also number one oil seed crop in India currently occupying 9.67 million ha with production of 10.22 million tonnes. The Madhya Pradesh is having about 5.3 million ha in India (Anonymous, 2010). Girdle beetle is a predominant and major insect-pest (Singh *et al*., 1990 and Sharma 1999). The infestation of this insect pest is increasing year by year may be due to sole cropping (Anonymous, 2010). Keeping this back ground in view, the present study was undertaken in Vidhayan plateau of Madhya Pradesh to understand the response of diverse *kharif* legumes to girdle beetle.

A field experiment was conducted during *kharif* 2010 in a randomized block design with seven *kharif* legumes replicated thrice at Research farm of College of Agriculture, Ganjbasoda as well as in farmer's field nearby to evaluate the response of *kharif* legumes against girdle beetle, *Obereopsis brevis* (Swed.). The legumes were sown in the month of July,

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2012 in plot size 7.20 m^2. All the agronomic practices were followed except plant protection measures. The observations (incidence and stem tunnelling) were recorded on randomly selected five tagged plants in each plot of *kharif* legumes and three such observations were taken plot-wise from both experimental field and after the pooled data mean was worked out. The per cent plant incidence and stem tunnelling were transformed angularly for statistical analysis.

The data (Table 1) revealed that the per cent incidence varies from 0.50 to 60.75. The minimum 0.50 per cent incidence was recorded in *Vigna mungo,* but it was significantly less than rest of the *kharif* legumes except cluster bean, *Cymopsis tetragocalobe* (2.35 %). The black gram, *Vigna radiata* (23.20 %) was observed to be significantly less preferred crop over rest of the legumes apart from black gram, *Vigna mungo* and cluster bean, *Cymopsis tetragocalobe*. In cow pea, *Vigna unguiculata,* the incidence recorded was 37.43 per cent, which was on par with Indian bean, *Dolichos lablab* (43.12%). The significantly maximum per cent infestation was found in soybean, *Glycine max* (60.75 %) and it was on par with pigeon pea *Cajanus cajan* (55.25 %).

Table 1. Reaction of *kharif* legumes to girdle beetle, *Obereopsis brevis* (Swed.)

Name of legumes	**Per cent plant incidence**	**Per cent stem tunneling**
Green gram (*Vigna radiata)*	23.20 (28.18)	38.47(37.45)
Cow pea (*Vigna unguiculata)*	37.43 (37.57)	49.03 (44.88)
Cluster bean (*Cymopsis tetragocalobe)*	2.35 (8.04)	7.25 (15.49)
Pigeon pea *(Cajanus cajan)*	55.25 (48.00)	69.52 (56.51)
Indian Bean (*Dolichos lablab)*	43.12 (41.02)	61.22 (51.50)
Soybean (*Glycine max)*	60.75 (51.21)	85.50 (68.36)
SEm (±)	2.18	3.48
C D (P = 0.05)	**6.71**	**10.70**
CV (%)	12.15	15.12

The stem tunnelling data of girdle beetle ranged from 0.80 to 85.50 per cent (Table 1). Minimum stem tunnelling of 0.8 per cent was noticed in black gram, *Vigna mungo,* which was on par with cluster bean, *Cymopsis tetragocalobe* (7.25 %). The stem tunnelling in green gram, *Vigna radiata* recorded was 37.45 per cent, however, it was on par with cow pea, *Vigna unguiculata* (49.03 %). The Indian bean, *Dolichos lablab* recorded stem tunnelling of 61.22 per cent, while it was on par with pigeon pea, *Cajanus cajan* (69.52 %). The maximum stem tunnelling was found in soybean, *Glycine max* (85.50 %) indicating that it was most preferred as compared to other legumes under the study.

The results indicated that soybean is the most preferred crop by girdle beetle for feeding purpose in comparison to rest of *kharif* legumes. The further investigation is necessary to find out the host-plant preference of girdle beetle through different technique *i.e.,* morphological, biochemical and molecular.

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Observation Materials and Diagnostic Book on Soybean Insect Pests and Diseases for Farmers of Madhya Pradesh, India

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Key words: Diagnostic book, observation board, observation sheet, soybean disease, soybean insect pest

Soybean is a main rainy season crop in Madhya Pradesh state of India. The present area under soybean in Madhya Pradesh is 5.71 million ha producing 6.17 million tons with a productivity of 1,107 kg per ha (2011-2012). Productivity of soybean in Madhya Pradesh is less than the potential yield of recommended varieties. Insect-pests and diseases are one of the major biotic factors to reduce soybean yield in the state. About 130 insect-pests have been recorded on soybean in Madhya Pradesh (Singh and Verma, 1988; Singh *et al.,* 1990). At present, diseases like mungbean yellow mosaic virus (MYMV), charcoal rot and other foliar diseases are becoming more prevalent and injurious than earlier days.

In nature, natural enemies, *viz.* parasitoids, predators and insect pathogen influence the population of the insect pests (Sharma and Ansari, 2007). Efficiency of natural enemies is adversely affected by indiscriminate use of non-selective chemical insecticides. This led to a problem like outbreak or resurgence of unexpected soybean insect pests. Other side effects of agricultural chemicals such as health risk of human being and environmental pollution have often been reported. Therefore, it is important for famers to adopt Integrated Pest Management (IPM). To adopt the IPM, it is firstly prerequisite to know which insect pests and diseases appear in the fields; secondly, to understand its life cycle, ecology, tentative

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control threshold and control options.

In an international technical cooperation project "Project on Maximization of Soybean Production in Madhya Pradesh" between Government of Madhya Pradesh and Japan International Cooperation Agency (JICA), we are focusing to educate farmers for their adopting proper insect-pests and diseases management practices including integrated pest management (IPM). From the view of this focus, we developed (1) insect observation sheet, (2) insect-pests and diseases observation boards, and (3) diagnostic book on insect-pests and diseases by paying attention to acceptable format, volume and content based on education level of soybean farmers in Madhya Pradesh. These tools are expected to provide accurate information on insect-pests and diseases and their management to the farmers, accordingly to reduce unnecessary chemicals adoption and lead to IPM based insect-pests and diseases control. These three tools will be distributed to the farmers in a few selected villages, together with training programs. After several revisions through the trial uses in the selected villages, these tools will be finalized and distributed to farmers in whole regions in Madhya Pradesh. Details on these three tools are given as follows.

Observation sheet on insect pests and natural enemies

Insect observation sheet has been developed as a tool for farmers to count the target insect pests and natural enemies. A white flax sheet of 1 m x 0.5 m was used for the purpose (Fig. 1). Two persons between the lines hold the sheet and shake soybean plants from one side. The insects present on the plants along with natural enemies drop on this sheet. The sheet is gently removed by holding both the ends and fallen insects and natural enemies were counted in one meter row. Farmers can identify the fallen insects with the "Insect observation board" and consult the "diagnostic book" for its detailed description and management. Meantime, farmers can observe natural enemies and learn their role.

Observation boards on insect pests and diseases

In a handy A4 size paper two separate observation boards, *i.e.* one for identification of insects (Fig. 2) and another for identification of soybean diseases (Fig. 3), were developed. In this observation board, natural enemies are also included. Colored good quality photographs of major insect pests of soybean are printed using both side of paper and sheet was laminated to protect from rains.

Diagnostic book on insect pests and diseases

This diagnostic book is prepared for farmers and extension personnel to facilitate understanding of ecology and control of insect pests and diseases (Fig. 4). The book includes clear photographs and short description of important insect pests and diseases of soybean for their quick identification along with management options in English and Hindi. Information on marks of identification, damage symptoms, life cycle and management

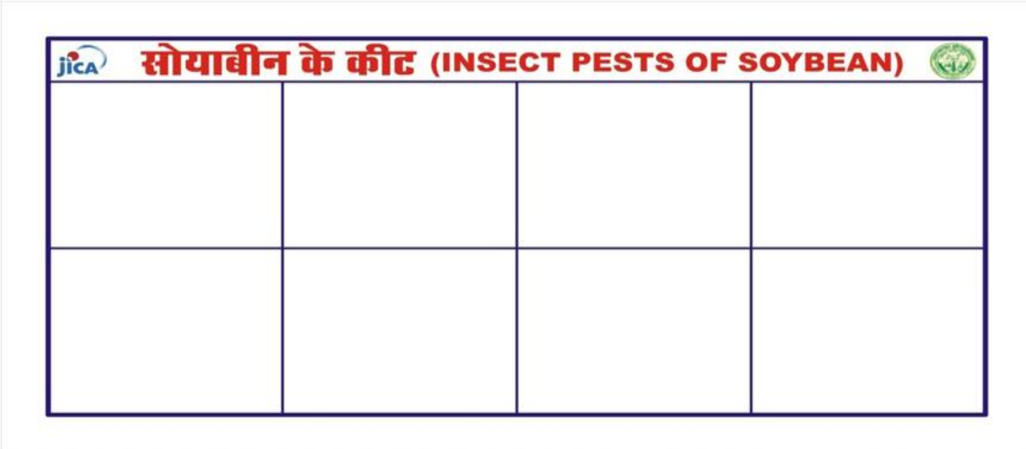

Fig. 1. Observation-sheet on insect pests and natural enemies (Sheet is divided into 8 portions by line for easy insect counting)

Fig. 2. Observation board on major soybean insect-pests in Madhya Pradesh

Fig. 3. Observation board on major soybean diseases in Madhya Pradesh

strategies were collected from domestic and foreign literature. It is expected that this diagnostic book will provide quite helpful information for reduction of unnecessary and indiscriminate chemicals and finally adopt IPM among soybean growers in Madhya Pradesh.

This diagnostic book consists of two chapters, *i.e.* Insect pests and Diseases. The chapter on Insect-pests includes (1) stem borers: stem fly and girdle beetle, (2) leaf feeders: green semilooper, brown semilooper, tobacco caterpillar, Bihar hairy caterpillar, gram pod borer, (3) sucking pests: white fly, red spider mites and (4) white grub. The Chapter on Diseases includes major diseases (1) Rhizoctonia aerial blight, (2) yellow mosaic virus, (3) Myrothecium leaf spot, (4) frogeye leaf spot, (5) charcoal rot, (6) bud blight, (7) bacterial pustule, (8) bacterial blight, (9) brown spot, (10) Alternaria leaf spot, (11) Fusarium blight, (12) collar rot, and (13) anthracnose / pod blight.

Fig. 4. Diagnostic book on major soybean insect pests and diseases in MP (Cover page of Hindi version)

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SOYBEAN RESEARCH

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References: References should be cited by authors and year: Ansari (2000) or Ansari and Sharma (2000) in the text. References should be arranged in alphabetical order and listed at the end of the paper as follows:

Ansari M M and Sharma A N. 2000. Compatibility of *Bacillus thuringiensis* with chemical insecticides used for insect control in soybean (*Glycine max*). *Indian Journal of Agricultural Sciences* **70**: 48-9. **(Journal)**

Joshi O P, Billore S D, Ramesh A and Bhardwaj Ch . 2002. Soybean-A remunerative crop for rainfed forming. *In*: Agro technology for dry land forming, pp 543-68. Dhopte AM (Eds.). Scientific Publishers (India), Jodhpur. **(Book chapter)**

Ansari M M and Gupta G K. 1999. Epidemiological studies of foliar diseases of soybean in Malwa plateau of India. Proceedings, World Soybean Research Conference VI, Aug 4-7, 1999, Chicago, Illinois, USA, 611p. **(Symposium/ Conf./Workshop)**

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