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Soybean: Morphology, Different Growth and Development Stages

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ABSTRACT

Soybean is an important oil seed and pulse crop in addition to source of food, feed and nutrition. It contains high quality protein, edible oil, carbohydrates, minerals, fiber, large amount of Phosphorus, high level of amino acids such as lysine, Lucien and lecithin and vitamins. Soybean products are widely used for human consumption. It is an annual, leguminous plant, it is self-pollinated and short-day plant, and tap root system. Plant height varies from 40 to 100 cm; mature soybean plant has 18-24 nodes. The leaflets of trifoliate vary 4-20 cm in length and 3-10 cm in width. Inflorescences are axillary or terminal racemes, purple or white in colour, Bearing 30-35 flowers/cluster. Soybean fruit is called pod, each plant produces a number of small pods averagely 400 pods/plant. Seed coat colours are yellow, Black, green and several shades of brown. Soybean growth stages, vegetative stages; first VE: stage Plant emerge from the soil, VC: Hypocotyl straightens and cotyledons unfold, V1: First node fully developed leaves at unifoliolate node, V2: second node fully developed trifoliolate at second node, V3-V5 fully developed trifoliolate at third node to six node. Reproductive stage; the appearance of the first open flower on the main stem, termed the R1 growth stage, to signal the beginning of the reproductive phase of development. They categorized reproductive development based on flowering, pod development, seed development and plant maturation stages. The first two stages R1 and R2 refer to flowering stages. The next two stages R3 and R4 refer to pod development. Seed development begins when the pod nears its maximum size. The R5 and R6 stages refer to seed development phases, whereas the R7 and R8 stages refer to phases of plant maturation.

Keywords: Soybean, Vegetative, Reproductive, and Maturity stages.

Soybean (*Glycine max* L.) belongs to the family *Fabaceae* (Leguminosae), and considered as a 'wonder crop', 'Miracle crop' and 'Golden Bean' of 21st century which is the top oil seed in the world production. It is also instrumental in bringing the yellow revolution in the country.

Out of nine oilseeds grown, soybean alone contributes nearly 20% to domestic vegetable oil production. It is an important oil seed and pulse crop in addition to source of food, feed and nutrition. Being the rich source of protein, it is also called "poor man's meat". It contains about 40-42% high quality protein, 20-22%, edible oil, 20-30% carbohydrates, 4.5% minerals, 3.7% fiber, 8.1% water, large amount of Phosphorus, high level of amino acids such as lysine, lucien, lecithin and vitamins (Barik and chandel, 2001). Soybean products are widely used for human consumption. Common soybean products include; for seed making food - soy milk, soy beverage, soy curd, soy ice-cream, soy candy, weany foods (Protein+), soy nuts, cheese, soy snakes, nutria nuggets-50% protein. (Gahukar *et al*., 1997). For oil prepare products; varnish, paint, soap, painting ink, glycerine, soya lecithin is some of the important products of soybean.

Morphology of Soybean

The soybean grown for seed production is an annual, leguminous plant, self-pollinated and short day plant, normally bushy and erect; it has an upright growth habit. At first, soybeans were described as having a tap root with numerous branches that extended to a depth of 150 cm, with the majority of its main portion happening in the upper 60 cm (Mitchell and Russell, 1971). Usual plant height varies from 40 to 100 cm, and may be sparsely or densely branched, depending on cultivation, management and growing conditions. The mature soybean plant has 18-24 nodes. The lower most nodes are the point of attachment of cotyledons. The next nodes produce single trifoliate leaves alternately arranged on the stem. The leaflets of trifoliate vary 4-20 cm in length and 3-10 cm in width. Leaves, stem, and pods in most varieties are covered with numerous fine tan-colored hairs. Stomata occur on both sides of leaf; lower leaf surface has three times more stomata than upper leaf surface of the soybean plant. (Badole and Rangari, 2015). The inflorescences are axillary or terminal racemes, purple or white in colour, bearing 30-35 flowers/cluster. The flowering period and the time of overlap of vegetative and reproductive growth is greater for indeterminate than determinate type (Leggett *et al*., 1973). Soybean fruit is called pod; each plant produces a number of small pods averagely 400 pods/plant. The mature pod contains 1-4 seeds; soybean seeds is generally oval-shaped. The average seed weight is 120-180 mg. of which seed coat contributes 10%. Cotyledons are generally yellow, Seed coat colours are yellow, Black, green and several shades of brown. Soybean can be cultivated successfully on a variety of soil (Vertisols, Alfisols, Entisols), but a well-drained, sandy loam soil to clay with medium water holding capacity, reasonable depth, comparatively rich in organic carbon and leveled fields with near neutral ph (6.5-7.5) is ideal for maximum soybean yield. Soybean require moist and warm climate. The optimum temperature for rapid germination of soybean is 30°C, whereas the minimum is 5°C and the maximum is 40°C (Lawn and

Hume, 1985). Soybean required 450-900 mm rainfall for better yield and seed quality, depending on growth conditions. It fixes atmospheric nitrogen by symbiotic relationship with *Bradyrhizobium japonicum*. It is able to leave residual nitrogen effect for succeeding crop equivalent to 35-40 kg N/ha. It can tolerate mild drought as well as floods. Due to this quality, soybeans are a good fit for sustainable agriculture. With so many uses, soybean is aptly referred to be humanity's "Golden Gift" from nature.

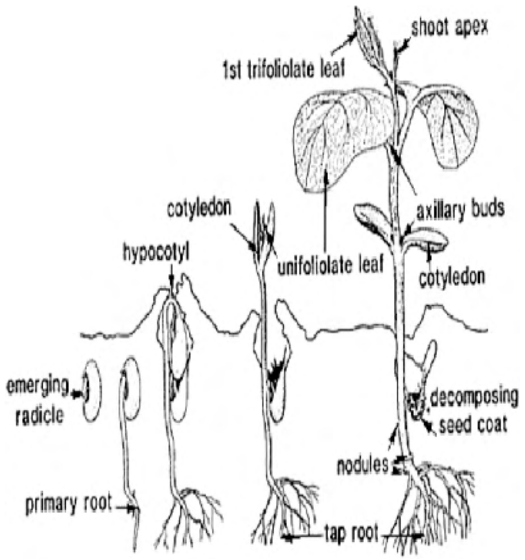

Fig. 1 Morphology of Soybean plant

Growth Stages of Soybean

<u>Vegetative stages</u>

VE – Emergence
V2 – Second trifoliolate
VC – Cotyledon
V3 – Third trifoliolate
V1 – First trifoliolate

Emergence stage (VE)

The soybean seed begins to germinate by absorbing water that is around 50% of its weight. The first root to develop from the inflated seed is the radical or primary root, which extends downward to anchor in the soil. Soon after, the cotyledons (seed leaves) are pulled upwards together with the hypocotyl (stem), which is growing toward the soil's surface. Emergence usually happens one to two weeks after planting, depending on factors like temperature, moisture, variety, and planting depth.

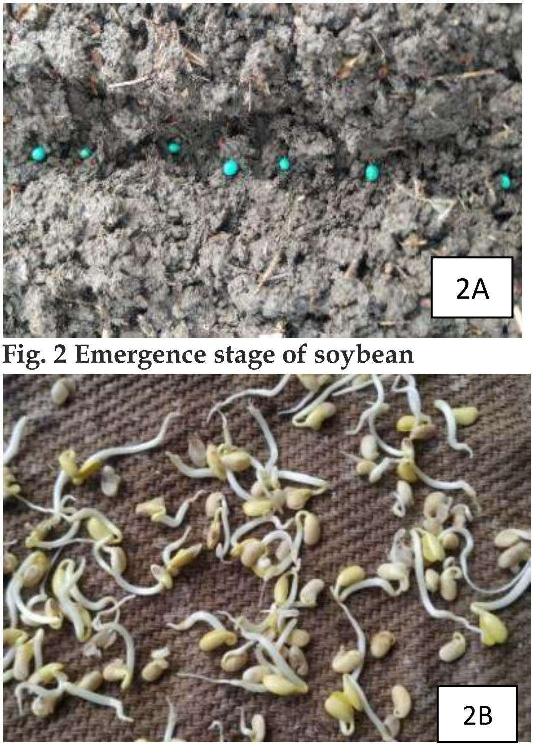

Fig. 2 Emergence stage of soybean

Cotyledon stage (VC)

After emergence, the cotyledons start to unfold, and the hypocotyl straightens out and stops growing. At this stage, the epicotyl is visible, which consists of the immature leaves, stem, and growth point that is situated just above the cotyledonary node. For roughly seven to ten days following emergence, the cotyledons provide the young plant's nutritional requirements. During this phase, the weight of the cotyledons decreases by roughly 70%. The impact of cotyledon loss during this period is negligible if only one is lost, but if both are lost at VE or VC, seedlings become stunted, which can eventually lower yields by 8–9%.

Fig. 3 Cotyledon stage of soybean

First trifoliate (V1) stage

When the first trifoliate is fully emerged and unfolded, the V1 stage has reached. The higher, fully grown trifoliate leaves on the main stem serve as a marker and a number for the vegetative growth phases following VC. When evaluating vegetative growth stages, trifoliate leaves on branches are not taken into account. For indeterminate cultivars, when the greatest number of nodes are formed, new V stages arise around every five days from VC through V5, and then every three days from V5 until shortly after R5.

Fig.4 Soybean initial trifoliate (V1) stage.

Second node (V2) stage

Soybean plants are 15-20 cm tall and have two completely developed trifoliate leaf nodes in the V2 growth stage. The majority of the nitrogen needed by the soybean plant is made available through the N-fixation. However, active N2 fixation does not start until the V2 to V3 stages, when nodules are first evident shortly after the VE stage. After that, until about the R5 stage, the quantity of N2 fixed and the number of nodules created both grow over time. Pink or red nodules have a healthy interior that is actively fixing nitrogen.

Fig. 5 Soybean second node (V2) stage

Third to fifth nodes (V3 through V5) stage

The height of soybean plants ranges from 18 to 23 cm, and they have three fully developed trifoliate leaf nodes at the V3 growth stage. When a plant is in the V4 growth stage, it is 20–27 cm tall with four fully grown trifoliate leaf nodes, whereas a plant in the V5 growth stage is 25–30 cm tall with five fully developed trifoliate leaf nodes. With broader row widths and fewer plants per square foot, the majority of cultivars develop more branches. At the V5 stage, the soybean plant often bears axillary buds in the upper stem that will eventually give rise to racemes, which are flower clusters.

Fig. 6 Stage of the soybean from the third to the fifth nodes.

Reproductive stages

R1 – Beginning flowering
R2 – Full Bloom
R3 – Beginning pod
R4 – Full pod
R5 – Beginning seed
R6 – Full seed
R7 – Beginning maturity
R8 – Full maturity

Beginning flowering (R1) stage

During this stage of the soybean's development, the main stem's nodes each have one open bloom. Indeterminate plants begin to bloom at the low or mid canopy and continue to bloom higher. Determined plants begin flowering at one of the top four nodes, and then the flowering process moves up and down the stem.

Fig. 7 Soybean at the R1 stage of blooming

Full Bloom (R2) stage

The soybean plant has one open blossom at each of the two top nodes on the main stem at this point, and at least one of the two upper nodes has a leaf that is completely formed. 43–56 cm is the height range for plants. The soybean plant has grown to about 50% of its mature height, 25% of its total dry weight, and about 50% of its complete mature node count. The R2 stage also denotes the start of the extremely quick accumulation of nutrients and dry matter, which lasts until the R6 Growth stage.

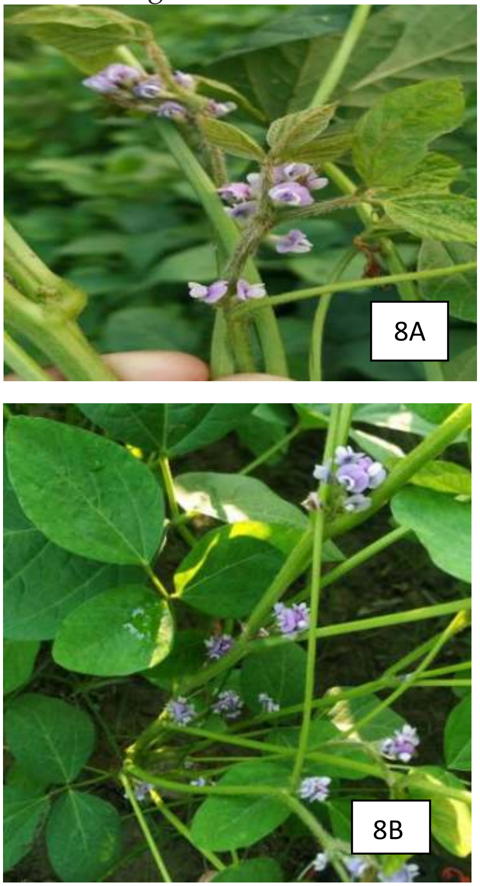

Fig. 8 Soybean in the full bloom (R2) stage

Beginning pod (R3) stage

The height of soybean plants ranges from 58 to 81 cm. A pod measuring 3/16 inch (0.5 cm) in length is seen in one of the topmost nodes. A plant has growing pods, open flowers, decaying flowers, and flower buds at this stage. On lower nodes, where blooming first started, developing pods are found.

Fig. 9 Beginning pod (R3) stage of soybean.

Full pod (R4) stage

At this stage pods are ¾ inch long at one of the four uppermost nodes on the main stem. At this stage, rapid pod growth occurs and seeds starts to develop. Flowers are still present on the upper branch nodes.

Fig. 10 Full pod formation stage of soybean

Beginning seed (R5) stage

At this stage plants are 76 to 100 cm tall. The plant has seeds at least 1/8 inch (3 mm) long in a pod at one of the four top nodes on the main stem. The R5 stage is characterized by rapid seed growth and redistribution of dry weight and nutrients within the plant. Root growth slows down when seed development begins.

Fig. 11 R5 stage, beginning of the seed formation

Full seed (R6) stage

This stage is initiated when plants have a pod containing a green seed that fills the pod cavity on at least one of the four top nodes on the main stem. Total pod weight maximizes at this stage. Growth rates of the seeds and the whole plant are still very rapid, but will begin to slow down in the whole plant shortly after R6.

Fig. 12 Full seed formation (R6) stage

Beginning maturity (R7) stage

At this stage, the soybean plant has one normal pod on the main stem that has reached mature color (tan or brown). Dry matter accumulation for individual seeds peaks at this stage. The soybean plant is visually yellow as all green color is lost from seeds and pods. Soybean seeds contain about 60% moisture at maturity.

Fig. 13 Soybean at the beginning of maturity (R7) stage

Full maturity (R8) stage

At this stage, 95% of pods reach their mature color (tan or brown). Five to ten days of dry weather is required after R8 for soybean seeds to have less than 15% moisture. Timely harvest is very important for soybean.

Fig. 14 Stage of soybeans at full maturity (R8)

CONCLUSION

Soybean has different stages from seed germination to harvesting. Its different stages require different nutrient management and other agricultural practices. If nutrient management, disease, pest management and agricultural activities are done properly at critical stage, crop production can be increased with reduction in additional cost. The knowledge of plant morphology and different stages of soybean will be helpful for the producers in understanding the important stages of the soybean crop.

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Assessment of Genetic Parameters and Estimates of Genetic Variation in Soybean [*Glycine max* (L.) Merrill] Germplasm

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ABSTRACT

Estimation of variability, heritability, and genetic advance were carried out for eleven characters in hundred diverse genotypes of soybean. Analysis of variance revealed that mean squares due to genotype were found significant for all the traits under study, indicated that enormous phenotypic variability was present among the genetic materials studied. The highest genotypic and phenotypic coefficient of variances were observed for number of seeds per plant recorded the highest PCV (48.88%) and GCV (40.91%), followed by seed yield per plant (44.85% and 30.17%), number of primary branches per plant (37.17% and 36.39%), biological yield per plant (35.30% and 35.28%). High heritability, genetic advance and genetic advance as per cent mean were observed for biological yield, followed by plant height (98.82%) and 100 seed weight (98.51%). The studies suggest that for improvement in high yielding genotypes of soybean make selection for biological yield per plant, number of seeds per plant, number of primary branches per plant and 100 seed weight.

Key words: *Genetic variability, GCV, Heritability, PCV, Soybean, Augmented Block Design.*

Soybean (*Glycine max* (L.) Merrill), due to its high protein content and beneficial oil for human and animal nutrition, is regarded as one of the most important legumes in the world for the production of grains (Lima *et al.,* 2015). Soybean serves as an excellent source of vegetable oil and protein for human use as well as animal feed (USDA, 2009). Unlike most of the vegetable proteins which are deficient in supplying most of the essential amino acids (EAAs), the quality protein of soybean stands exclusive in comparison to other protein-rich crops by way of supplying all the ten EAAs including lysine. Soybean having cardio friendly oil that satisfies around 30% of world vegetable oil necessity. Apart from quality protein and oil, soybean also has many therapeutic constituents *viz.*, lactose-free fatty acids, antioxidants like vitamins C, D, and K and folic acid, vitamins of B complex group viz., nicotinic acid- B_3 (23pg./g), pantothenic acid- B_5 (15g), thiamine- B_1 (12pg./g), pyridoxine- B_6 (8pg./g), riboflavin- B_2 (3.5 pg./g) and biotin-

B_7 (0.7g), and isoflavones like genistein and daidzein (Mathur,2004).

Genetic resources play a key role in developing new cultivars. For the genetic improvement of soybeans, a vast collection of soybean germplasm (1,70,000 accessions) is present in the world, with some duplicated accessions (Nelson, 2009). China has the largest collection of germplasm (>23000 cultivated and 7000 wild accessions), and this germplasm has been preserved and maintained at the Chinese National Soybean Gene Bank (Dong *et al.,* 2004; Wang *et al.,* 2006; Limei *et al.,* 2005). The USDA-Agricultural Research Service has the second-largest soybean germplasm collection, which is comprised of >20000 accessions of the genus *Glycine* with a wide range of natural variations (Carter *et al.,* 2004).

Due to the crop's economic importance, soybean has been the focus of research, especially in the area of genetic improvement. To obtain improved cultivars carrying genes capable of expressing broad adaptation and tolerance to biotic and abiotic factors, representing significant contributions to the Productive Sector (Soares *et al.,* 2015). The selection of superior soybean genotypes is a complex process. The agronomic traits of economic importance are quantitatively correlated with each other and their low heritability (Nogueira *et al.,* 2012). The possibility of improvement in any crop is dependent on variability available in the crop, wider the genetic variability in a trait, better the chances of improvement through selection. An evaluation to detect the extent of variability available for the yield attributes and their heritability values is of immense help to the breeders to select the breeding methods for improvement of yield attributing traits. But heritability alone does not give a true picture of genetic improvement through selection, therefore, the study of genetic advance coupled with heritability is more useful. Improvement through selection depends upon the variability in the available genotypes, which may be either due to different genetic constitutions of cultivars or variations in the growing environments. Since most of the characters influencing yield are polygenic, plant breeders need to estimate the type of variation available in the germplasm. Heritability estimates give a measure of transmission of characters from one generation to the other, as consistency in the performance of the selection depends on the heritable portion of the variability. Thus, enabling the plant breeder for the variation and the estimates of the heritability and genetic advance are the crucial parameters for the success of selection lines. Promising genotypes should simultaneously unite some desirable attributes aiming at high yields to meet the demand of the productive sector (Cruz, 2013). From this perspective, the objective of this study was to estimate genetic parameters for agronomic traits to carry out the practical selection of soybean lineages.

MATERIAL AND METHODS

The present investigation was conducted at Seed Breeding Farm, Department of Plant Breeding and Genetics, College of Agriculture, JNKVV, Jabalpur (M.P.) during *Kharif*, 2019. The experiment consisted of 96 accessions with four checks evaluated in Augmented Block Design (ABD). The entries were sown in a single row of 4 m in length, adopting inter-row spacing of 50 cm and intra-row spacing of 7 cm. The recommended package of practices was followed for raising a healthy crop. The data were recorded on five randomly selected competitive plants in each replication and each genotype for 11 characters, *viz.*, days to flower initiation, days to maturity, plant height (cm), number of primary branches per plant, number of nodes per plant, number of pods per plant, number of seeds per plant, biological yield per plant (g),100 seed weight (g), harvest index (%) and seed yield per plant (g). Observations of days to 50% flowering and days to maturity were recorded on a plot basis. The mean and standard errors were worked out as per traditional methods, and coefficients of variation were computed. Heritability (h^2) and genetic advance as a percentage of mean (G.A. %) were calculated as per the formula suggested by Hanson (1956) and Johnson (1955). The genotypic (GCV) and phenotypic (PCV) coefficients of variation were estimated according to the formula given byBurton (1952).

RESULTS AND DISCUSSION

The ANOVA indicated that the mean sum of squares due to genotypes were significant for all the traits under study present in table 1. The estimates of phenotypic (PCV) and genotypic (GCV) coefficients of variation (Table 2 and Fig 1) indicated that the values of PCV were higher than that of GCV. Still, the difference between these two estimates was closer for all the cases. These showed that the more significant role of genetic components and expression of characters under study was less influenced due to environmental factors. The number of seeds per plant recorded the highest PCV (48.88%) and GCV (40.91%), followed by seed yield per plant (44.85% and 30.17%), number of primary branches per plant (37.17% and 36.39%), biological yield per plant (35.30% and 35.28%). At the same time, days to maturity had low PCV and GCV (5.04% and 4.69%). Similar results have been reported by Jain et al. (2017) and Uikey*et al.,* (2021) for the number of pods per plant and harvest index, Neelima *et al*. (2018) for the number of pods per plant, number of seeds per plant, biological yield per plant and harvest index, Shruti et al. (2019) , Mehra *et al.,* (2020) for pod weight per plant and seed yield per plant, Bhairwa *et al.* (2020) and Verma *et al.,*(2021) for number of pods per plant, 100 seed weight, dry matter weight per plant, plant population per plot and harvest index. However, with the help of the genotypic coefficient of variation alone, it is impossible to determine the extent of variation that is heritable. Thus, the knowledge of heritability and genetic advance of a character helps the plant breeder predict the genetic advance for any quantitative characters and aids in exercising the necessary selection procedure.

The highest heritability (99.91%) was obtained for biological yield, followed by plant height (98.82%), 100 seed weight (98.51%), number of primary branches per plant (95.88%), days to maturity (86.57%), number of nodes per plant (85.11%), days to flower initiation (82.52%), number of pods per plant (80.43%), number of seeds per plant (70.05%) and harvest index (65.29%) was moderate, and seed yield per plant (45.23%) was having low heritability. The highest genetic advance as a percentage of (GA%) was recorded for a number of primary branches per plant (73.40%), followed by biological yield (72.64%), number of seeds per plant (70.54%), 100 seed weight (54.65%), number of pods per plant (52.48), plant height (47.42%), harvest index (42.57%), seed yield per plant (41.79%), number of nodes per plant (27.74%), days to flower initiation (25.06%) and days to maturity (8.99%) had low GA%. High heritability coupled with high genetic advance has also been reported by Adsul *et al.*(2016) for 100 seed weight, yield per plant and number of primary branches per plant, Akram *et al.* (2016) for plant height, yield per plant, number of pods per plant and number of seeds per plant, Mahbub and Shirazy (2016) for plant height, number of seeds per plant, number of pods per plant and 100-seed weight, Chandel *et al.* (2017) for biological yield per plant, pods per plant and harvest Index, Jain *et al.* (2017) for number of pods per plant, harvest index and plant height, Neelima *et al*. (2018) for plant height, number of branches per plant, number of pods per plant and seed yield per plant, Bhairwa *et al.* (2020) for plant height, number of pods per plant, dry matter weight per plant, plant population per plot and harvest index %., Upadhyay *et al.,* (2022) number of pods per plant, number of seeds per plant, seed yield per plant, biological yield per plant, plant height at maturity, number of primary branches per plant, harvest index, and 100 seed weight identified as important traits.

Based on heritability and genetic advance, the present investigation suggests that selection may be effective from an early generation for the improvement of traits, *viz.* biological yield per plant, number of primary branches per plant, 100 seed weight, plant height per plant, number of seeds per plant, number of nodes per plant, number of pods per plant and harvest index because these traits are governed by additive gene action. High or moderate heritability coupled with high or moderate genetic advance was observed for all the traits under study. This indicates the preponderance of additive gene action in the inheritance of these traits.

Fig. 1 Graphical representation of GCV, PCV, Heritability (%) and GA as % of mean

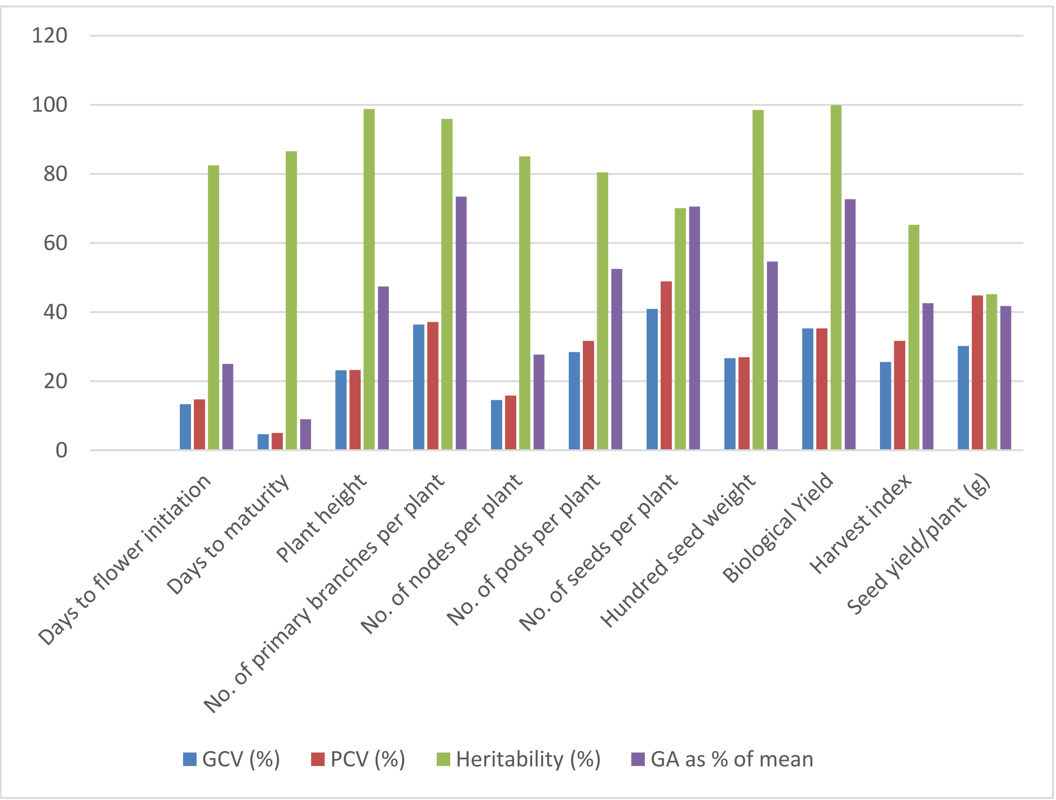

Table 1. Mean squares from analysis of variance of 11 quantitative traits in 100 soybean germplasm

Source of variation	df	Mean sum of square										
		DFI	DM	HGT	NB	NN	NP	NS	100S	BY	HI	SY
Blocks	3	63.80	67.10	1054.50	1.02	9.80	1051.20	4769.28	1.01	175.20	93.20	28.12
Entries	99	57.10**	35.70**	336.14**	1.46*	5.40**	339.50**	1664.31**	5.20**	82.20**	402.61**	20.11**
Checks	3	521.60**	101.20**	1306.70**	4.96**	26.70**	2898.20**	15875.22**	15.80**	15.86**	220.34**	284.60**
Variety	95	41.20**	26.80**	293.90**	0.97*	4.70**	261.30**	1218.98**	4.70**	79.05**	91.68**	9.44**
Checks Vs varieties	1	174.10**	692.90**	1431.40**	37.94**	12.35**	96.02**	1338.44**	16.05**	581.59**	30487.5**	240.30**
Error	9	7.20	3.60	3.46	0.04	0.70	51.14	365.05	.70	.70	31.82	5.17

*Significant at probability level of 0.05 and **Significant at probability level 0.01.

Here:

Df= degree of freedom Dfi= Days to flowering Dm= Days to maturity

Nbp= number of primary brancher per plant Nnp= number of nodes per plant Hi= harvest index

Npp= number of pods per plant Nsp = number of seeds per plant Syp= seed yield per plant

100sw= hundred seed weight (g) By= Biological yield per plantPh= plant height (cm)

Table 2.- Genetic parameters of variability for yield and its component traits in soybean genotypes

Traits	Mean	Range		GCV (%)	PCV (%)	h^2b (%)	GA as % of mean 5%
		Mini	Maxi				
Days to flower initiation	43.54	28.00	67.00	13.39	14.74	82.52	25.06
Days to maturity	102.64	88.50	118.00	4.69	5.04	86.57	8.99
Plant height	73.60	32.90	146.00	23.16	23.29	98.82	47.42
No. of primary branches per plant	2.65	0.00	5.90	36.39	37.17	95.88	73.40
No. of nodes per plant	13.70	8.30	21.00	14.60	15.82	85.11	27.74
No. of pods per plant	51.03	18.76	114.70	28.41	31.68	80.43	52.48
No. of seeds per plant	71.43	16.00	223.00	40.91	48.88	70.05	70.54
Hundred seed weight	8.05	15.10	54.70	26.73	26.93	98.51	54.65
Biological Yield	25.19	7.50	79.93	35.28	35.30	99.91	72.64
Harvest index	30.25	1.90	23.00	25.58	31.65	65.29	42.57
Seed yield/plant (g)	6.85	2.20	15.20	30.17	44.85	45.23	41.79

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Hierarchical clustering of Edamame germplasm (G*lycine max* L. Merrill)

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ABSTRACT

The present study was carried out to determine the diversity of edamame germplasm, Cluster analysis was performed for 14 quantitative traits in 33 genotypes vegetable soybean using HC analysis. Based on the cluster analysis, the genotypes were grouped into 4 clusters of which cluster III contained maximum number of genotypes whereas the cluster with minimum number of genotypes was Cluster II. The highest average inter cluster distance values were observed between cluster II and IV (6.123783) and the minimum inter cluster distance values were observed between cluster II and III (5.063893). The inter cluster distance varied from 5.063893 to 6.123783. The maximum intra-cluster distance (5.067029) was shown by cluster IV and minimum intra-cluster distance (3.84744) was shown by cluster II. The intra cluster distance varied from 3.84744 to 5.063893. The fresh pod yield per plant is the parameter to be used as selection criteria to make plant selection.

Keywords: Diversity, Edamame, Hierarchical cluster analysis, Quantitative Inter and Intra cluster distances.

Glycine max (L.) Merrill (vegetable soybean) is a leguminous, self-pollinated crop with 2n = 40 chromosomes. It belongs to Fabaceae family. It's a young soybean that's eaten as a vegetable or a snack. Soybeans were first grown in China around 7000 years ago, and the term "edamame" was coined in Japan. It is a major crop worldwide due to its wide range of geographical tolerance, unique chemical composition, high nutritional content, practical health advantages, and a variety of end uses. Traditional food legumes (pulses) are high in protein but low in oil, while the soybean is higher in protein (40-42%) than other pulses and has a significantly higher quantity of edible oil (approximately 20%) than other pulses (Gopalan *et al.,* 1994). Farmers in Asia, where edamame is a popular vegetable, harvest stems with fresh green pods before they reach full maturity, when pods are fully filled, approximately 80% matured, and just before turning yellow (Shanmugasundaram *et al*., 1991). This stage of soybean development corresponds to the immature R6 (completely expanded seed) stage (Fehr *et al*., 1971). Protein, vitamins A, C, and E, unsaturated fats, phosphorus, thiamine, and riboflavin are all abundant in vegetable soybean. It is well-liked in Japan and China due to its scent and sweet flavour (Masuda, 1991). The size of a dry vegetable soybean seed (usually over 30gm/100 seeds) is greater. It has more soluble sugars and fewer chemical components linked to off-flavors than grain soybeans. Soybean is one of the few natural sources of isoflavones (78 to 220 µg/g dried seed depending on isoflavone type) and tocopherols (vitamin E) (84 to 128 µg/g dried seed depending on tocopherol type). Ascorbic acid is abundant in vegetable soybeans, while niacin levels are minimal (Masuda, 1991). Protease inhibitors, for example, are found in soybean seed. The trypsin inhibitor (TI) activity in vegetable soybean is one-third lower than in grain soybean, making vegetable soybean more nutritious.

Hierarchical clustering is a cluster analysis method that aims to create a hierarchy of clusters. The concept of hierarchical clustering is based solely on the creation and analysis of a dendrogram. A dendrogram is a tree-like structure that explains the relationship between all of the system's data points. Cluster analysis and Principal Component Analysis (PCA) are tools for summarising and describing crop genotype genetic variation. This technique aids in the identification of traits that aid in the differentiation of selected genotypes based on similarities in one or more traits and the classification of genotypes into separate groups (Ariyo, 1987 and Nair *et al*., 1998).

MATERIALS AND METHODS

The field experiment on edamame was Andro research farm, Central agricultural university, Imphal East during kharif 2021. The genotypes were collected from IISR, Indore. A total of 33 genotypes were collected and seeds were sown in the main field under Augmented design, with 30 lines and 3 checks. Biometrical observations for 33 genotypes were recorded for fourteen traits *viz.,* Days to 50% flowering, Plant height (cm), Days to maturity, Pod length (g), Number of seeds per pod, Number of pods per plant, Fresh pod yield per plant (g), 100 Fresh pods weight (g) , 100 Fresh seeds weight (g) , 100 Dry seeds weight (g) , Crude sugar content, Crude protein content, Hydration rate and cooking time (min). Hierarchical clustering was done by R studio with R version 4.2.1.

RESULT AND DISCUSSION

Cluster analysis is commonly used to investigate genetic diversity and to create a core subset for grouping accessions with similar characteristics into a single homogeneous category. Any plant researcher's primary goal is to identify an optimal number of plant traits that are sufficient to explain the maximum variability in the crop growth from sowing to harvest.

A cluster analysis of 33 edmame genotypes was performed, and their clustering pattern based on quantitative characters is shown in Table 1 and Figure 1. Cluster III contained the highest number of genotypes, which included 12 genotypes namely EC 915895, EC 915900, EC 915903, EC 915909, EC 915913, EC 915926, EC 915949, EC 915959, EC 915983, EC 915993, EC 916000, EC 916039. Cluster I identified as the second highest number of genotypes, which included 9 genotypes namely AGS-ACC, EC915902, EC 915908, EC 915910, EC 915919, EC 915924, EC 915945, EC 916009, EC 916022.

The third group which had highest number of genotypes appeared in cluster IV, which included 7 genotypes namely EC 915898, EC 915974, EC 915975, EC 915978, EC 915989, EC 916025, EC 916032. The group with the lowest number of genotypes appeared in cluster II, which included 5 genotypes namely, Karune, NRC 105, EC 915923, EC 915933, EC 915937. A more or less same trend was observed by Vart *et al.,* (2002), Singh *et al.,* (2007), Reni and Rao (2013).

Table 1: Genotypes included in different clusters based on cluster analysis for fresh pod yield and its contributing traits of edamame genotypes

Cluster number	Frequencies	Name of Genotypes
I	9	AGS-ACC, EC915902, EC 915908, EC 915910, EC 915919, EC 915924, EC 915945, EC 916009, EC 916022.
II	5	Karune, NRC 105, EC 915923, EC 915933, EC 915937
III	12	EC 915895, EC 915900, EC 915903, EC 915909, EC 915913, EC 915926, EC 915949, EC 915959, EC 915983, EC 915993, EC 916000, EC 916039
IV	7	EC 915898, EC 915974, EC 915975, EC 915978, EC 915989, EC 916025, EC 916032

Intra and Inter-cluster distances

The estimate of average intra and inter-cluster distances are represented in Table 2. At intra-cluster level maximum values were recorded for cluster IV (5.067029) followed by cluster I (4.708981), cluster III (4.240809) and cluster II

(3.84744). The average inter-cluster values were minimum between cluster II and III (5.063893) and maximum between cluster II and IV (6.123783). The average inter cluster distance were maximum between Cluster II and IV (6.123783), followed by Cluster I and IV (6.059602), Cluster III and IV (5.317615), Cluster I and II (5.284150), Cluster III and I (5.159227) and Cluster II and III (5.063893). Crossing genotypes from the same cluster is not expected to produce superior hybrids or desirable segregants because they share common biochemical pathways.

Table 2: Average Intra (BOLD) and Inter cluster values in 33 Genotypes of edamame.

	Cluster I	Cluster II	Cluster III	Cluster IV
Cluster I	**4.708981**	5.28415	5.159227	6.059602
Cluster II	5.28415	**3.84744**	5.063893	6.123783
Cluster III	5.159227	5.063893	**4.240809**	5.317615
Cluster IV	6.059602	6.123783	5.317615	**5.067029**

Cluster means:

Cluster means of different characters indicated in tabulated form (Table 3.). Cluster IV had maximum cluster means for six traits *viz.,* Days to maturity (0.5334794), Number of seeds per pod (0.46039929), Number of pods per plant (1.2801679), Fresh pod yield per plant (1.4259769), 100 Fresh seed weight (0.8170593), 100 Dry seed weight (0.7601971). Cluster I had Maximum cluster mean value for traits Crude sugar content (0.2014263), Hydration rate (0.1725467) and cooking time (0.5123471). Cluster II had maximum cluster mean for Days to 50% flowering (1.3096301), Plant height (1.12291905), Crude protein content (0.6084579) and Cluster III had maximum cluster mean for Pod length (0.4425834) and 100 Fresh pod weight (0.710154).

Days to 50% flowering: In case of Days to 50% flowering had maximum cluster mean in Cluster II (1.3096301) followed by Cluster III (-0.0167859), Cluster I (-0.3431639) and minimum cluster mean in Cluster IV (-0.465464).

Plant Height (cm): Plant height had maximum cluster mean in Cluster II (1.12291905) followed by Cluster IV (0.02092484), Cluster I (-0.27194093) and minimum cluster mean in Cluster III (-0.2761334).

Days to maturity: Days to maturity had maximum cluster mean in Cluster IV (0.5334794) followed by Cluster III (0.1361846), Cluster II (-0.2295651) and minimum cluster mean in Cluster I (-0.468972).

Pod length (cm): Pod length had maximum cluster mean in Cluster III (0.4425834) followed by Cluster IV (0.1260163), Cluster I (-0.346436) and minimum cluster mean in Cluster II (-0.6150382).

Number of seeds per pod: Number of seeds per pod had maximum cluster mean in Cluster IV (0.46039929) followed by Cluster III (-0.07687267), Cluster II (-0.15257394) and minimum cluster mean in Cluster I (-0.17082815).

Number of pods per plant: Number of pods per plant had maximum cluster mean in Cluster IV (1.2801679) followed by Cluster II (0.4776313), Cluster III (-0.5155137) and minimum cluster mean in Cluster I (-0.573685).

Fresh pod yield per plant: Fresh pod yield per plant had maximum cluster mean in Cluster IV (1.4259769) followed by Cluster II (-0.2173821), Cluster III (-0.2195624) and minimum cluster mean in Cluster I (-0.695576).

100 Fresh pod weight (g): 100 Fresh pod weight had maximum cluster mean in Cluster III (0.710154) followed by Cluster IV (0.7003706), Cluster II (-0.765379) and minimum cluster mean in Cluster I (-1.066394).

100 Fresh seed weight (g): 100 Fresh seed weight had maximum cluster mean in Cluster IV (0.8170593) followed by Cluster III (0.5263776), Cluster II (-0.63799144) and minimum cluster mean in Cluster I (-0.9828876).

100 dry seed weight (g): 100 Dry seed weight had maximum cluster mean in Cluster IV (0.7601971) followed by Cluster I (0.1037428), Cluster III (-0.1500697) and minimum cluster mean in Cluster II (-0.890846).

Crude sugar content: Crude sugar content had maximum cluster mean in Cluster I (0.2014263) followed by Cluster IV (0.1832553), Cluster III (-0.1663166) and minimum cluster mean in Cluster II (-0.219965).

Crude protein content: Crude protein content had maximum cluster mean in Cluster II (0.6084579) followed by Cluster IV (0.4501881), Cluster I (-0.4652864) and minimum cluster mean in Cluster IV (-0.608139).

Hydration rate: Hydration rate had maximum cluster mean in Cluster I (0.1725467) followed by Cluster IV (0.1086047), Cluster III (0.1219666) and minimum cluster mean in Cluster II (-0.741989).

Cooking time (min): Cooking time had maximum cluster mean in Cluster I (0.5123471) followed by Cluster IV (0.4931658), Cluster III (-0.2363937) and minimum cluster mean in Cluster II (-1.045312).

Mean Performance of different clusters for characters revealed that Cluster I showed high mean for traits like crude sugar content, Hydration rate, Cooking time; Medium mean for traits like Days to 50% flowering, Plant height, Pod length, 100 dry seed weight, Crude protein content; Low mean for Days to maturity, Number of seeds per pod, Number of pods per plant, Fresh pod yield per plant, 100 Fresh pod weight, 100 fresh seed weight. Mean performance of Cluster II revealed a high performance for days to 50% flowering, plant height, High protein content; medium performance for Days to maturity, number of seeds per pod, Number of pods per plant, Fresh pod yield per plant, 100 fresh pod weight, 100 fresh seed weight; Low performance for pod length, 100 dry seed weight, Crude sugar content, Hydration rate, Cooking time. Mean performance of Cluster III revealed a high performance for pod length, 100 fresh pod weight; medium performance for days to 50% flowering, days to maturity, Number of seeds per pod, Number of pods per plant, Fresh pod yield per plant, 100 Fresh seed weight, 100 Dry seed weight, Crude sugar content, crude protein content, Hydration rate and cooking time; low performance for Plant height. Mean performance of Cluster IV revealed a high performance for Days to maturity, Number of pods per plant, number of seeds per pod, Fresh pod yield per plant, 100 Fresh seed weight, 100 dry seed weight; medium performance for Plant height, Pod length,100 fresh pod weight, Crude sugar content, hydration rate and cooking time; low performance for Days to 50% flowering and Crude protein content. From the above studies we can conclude that Cluster IV is containing the best genotypes. Maximum inter cluster distance was noticed between Cluster II and IV. Similar findings were shown by Tyagi and sethi (2011).

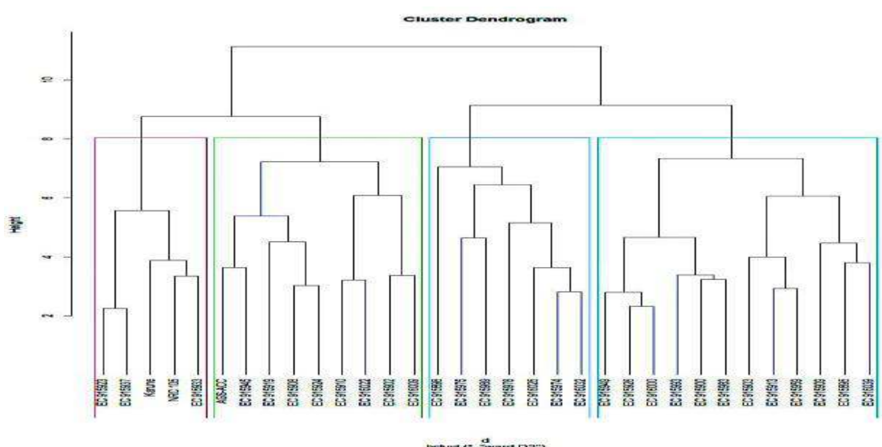

Fig 1. Hierarchical clustering

Table 3: Cluster wise Mean Values for Pod Yield & its Contributing Traits

S.No	Cluster Number No. of Genotypes	Cluster I 9	Cluster II 5	Cluster III 12	Cluster Iv 7
1.	Days to 50% flowering	-0.3432	**1.30963**	-0.0168	-0.4655
2.	Plant height(cm)	-0.2719	**1.12292**	-0.2761	0.02092
3.	Days to maturity	-0.469	-0.2296	0.13618	**0.53348**
4.	Pod length(cm)	-0.3464	-0.615	**0.44258**	0.12602
5.	Number of seeds per pod	-0.1708	-0.1526	-0.0769	**0.4604**
6.	Number of pods per plant	-0.5737	0.47763	-0.5155	**1.28017**
7.	Fresh pod yield per plant(g)	-0.6956	-0.2174	-0.2196	**1.42598**
8.	100 Fresh pod weight(g)	-1.0664	-0.7654	**0.71015**	0.70037
9.	100 Fresh seed weight(g)	-0.9829	-0.638	0.52638	**0.81706**
10.	100 Dry seed weight(g)	0.10374	-0.8908	-0.1501	**0.7602**
11.	Crude sugar content	**0.20143**	-0.22	-0.1663	0.18326
12.	Crude protein content	-0.4653	**0.60846**	0.45019	-0.6081
13.	Hydration rate	**0.17255**	-0.742	0.1086	0.12197
14.	Cooking time(min)	**0.51235**	-1.0453	-0.2364	0.49317

Fig 2: Field picture

CONCLUSION

Thirty-three Edamame genotypes were clustered into four groups. Genotypes in cluster II are more divergent to genotypes in cluster IV due to more inter cluster distance between cluster II and IV (6.123783). Whereas genotypes in cluster III are less divergent to genotypes in cluster II due to less inter cluster distance between II and III (5.063893). The selection of genotypes from distant clusters was expected to result in maximum heterosis in crossing and to be used in a hybridization programme to improve quality traits.

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Impact of Front Line Demonstrations in Soybean [*Glycine max* (L.) Merrill] under North Western Himalayan Hills

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ABSTRACT

Front line demonstrations are conducted on farmer's fields for effective transmission of crop production and protection technologies generated under the close supervision of the researchers. For effective transfer of technology, it is pertinent to study the various constraints observed during demonstration of technology in the farmer's fields. The present study aims to assess the impact of improved technology, identify various constraints causing yield gaps and propose potential strategies to increase soybean production under North Western Himalayan hills. The study was carried out in 3.52-hectare area by involving 34 farmers of Kangra, Mandi and Chamba districts, 3.52 hectare by involving 32 farmers of Kangra and Mandi districts and 3.64 hectare with 33 farmers of Kangra, Mandi, Hamirpur and Bilaspur districts during kharif 2017, 2018 and 2019, respectively. Results revealed that by using improved variety of soybean and scientific recommendations, the net returns may be increased up to 67-68 % by increasing cost of cultivation about 21% only in the form of interventions. Among the varieties, Him Soya appeared to be more profitable compared to Hara Soya as the farmers prefer yellow seeded varieties for use as soya milk, tofu, dal, flour and other preparations. Green-seeded varieties need popularization among farmers by creating awareness and motivation to adopt appropriate recent production and protection technologies in the state. Results suggested that by adoption of improved package of practices, the farmers can realize higher yields and net profit in soybean cultivation under North Western Himalayas.

Key words: Improved Technology, Farmer's Practice, Economics, Soybean

Soybean [*Glycine max* (L.) Merrill] is one of the oldest crops of the world, grown across diverse environments in tropical, subtropical and temperate climates. It has a prominent place among modern agricultural commodities as the world's most important seed legume and contributes about 25% to the global edible oil production, 65% of the world's protein concentrate for livestock feeding (Anonymous, 2020). It is a good source of vitamins and minerals like calcium, phosphorous, iron, molybdenum, vitamin K_1, copper, manganese, etc. It contains antioxidants and phytonutrients that are linked to various health benefits. Food uses of soybean include beverages, fermented products like *soya* sauce and cheese, baked goods, biscuits and snacks. The amount of protein produced by soybean per unit land area is higher than any other crop and therefore, it is also called as 'golden bean', 'yellow jewel', 'nature's miracle protein' and 'meat of the field'. Soybean also contains numerous antioxidative compounds which are beneficial to human health as they reduce the risk of diabetes, cardiovascular diseases, breast cancer, osteoporosis, neurodegenerative disorders and menopausal symptoms. Soybean provides cholesterol free oil (20%) and high-quality protein (40%). Its protein is rich in lysine (4-6%) and the oil is edible one (Katare *et al*., 2013). Soybean is crop of food and nutritional security as it is consumed as a pulse as well as an oilseed. In India, large portion of the population being vegetarians, the crop like soybean has become an important crop due to its high protein content and yield potential. India is fifth largest producer with area, production and productivity after Brazil, USA, Argentina and China. In India, soybean has emerged as a major oilseed crop starting with a meager area of 0.03 m ha in 1970, the crop has touched the figure of 11.13 m ha area with an estimated production of 13.26 m tons and productivity of 1191 kg/ha (http://eands.dacnet.nic.in). The crop is grown under rainfed conditions in diverse agro-ecological zones ranging from northern hill, northern plain, north eastern, central and southern zones and among them, the agro-climatic conditions in hills are the most challenging and highly variable (Bhartiya and Aditya, 2016).

In Himachal Pradesh, soybean is grown as a major *kharif* oilseed crop in mid hills under rainfed conditions in an area of 600 ha with the production of 1006.2 tons and productivity of 1680 kg/ha (http://www.fao.org/faostat/en/#data/QC). The crop is primarily used as pulse, oil as well as a vegetable by the hill farmers. The main reasons for low productivity of soybean include the poor extension of improved technology, high cost of inputs, improper nutrient management, poor plant protection measures, erratic behavior of rainfall and cultivation on marginal and sub-marginal lands under rain fed conditions in the state. Hills represent most challenging agro-climatic conditions and differences in altitude and sunshine hours render significant impact on genotype × environment interaction in determining crop yields. Earlier, Bhartiya *et al*., 2018 suggested that locations contributed maximum variation for days to maturity followed by grain yield and days to flowering.

At present, the existing gap in the production and requirement of soybean is a great threat to the nutritional and livelihood security of resource poor masses in hills. Although, soybean has emerged as a main oilseed crop and gained a vital status in the oil economy of the country still, a vast gap exists between potential yield and yield under real farming situations in all the soybean growing agro ecological zones (Bhatia *et al*., 2006). To revamp this gap with limited land holdings and resources in hilly region is a great challenge. The quantification of existing yield gaps could be a key strategy to understand their causes which can be helpful in focusing research and policy on areas where improvement can be made. The potential to increase production in a given area and an insight into yield limiting/reducing factors can be determined by estimating yield gaps, which in turn, will help in prioritization of research strategies (Stuart *et al*., 2016).

Front line demonstration programme is a useful outcome of 'Technology Mission on Oilseeds'. The demonstrations are conducted on farmer's fields for effective transmission of technology generated under the close supervision of the scientists. It is pertinent to study the various factors contributing higher crop yield and constraints in field production observed while demonstrating the technologies in the farmer's fields.

Keeping this in view, the present study aims to assess the impact of improved technology, identify various constraints causing yield gaps and propose potential strategies to increase soybean production under North Western Himalayan hills.

MATERIAL AND METHODS

The present study was carried out during *kharif* seasons of 2017, 2018 and 2019 in different districts of Himachal Pradesh under All India Coordinated Research Project on soybean. Front line demonstrations were planned in the farmer's fields to demonstrate the genetic worth of improved soybean varieties *viz*., Hara Soya and Him Soya. Recommended package of practices were followed to raise the crop in comparison to farmer's practice as control to aware farmers in terms of overall higher yields, cost-benefit ratio and net returns in their own real farming situations. Before conducting the demonstrations, information about farmers and their farming systems, available resources, present cropping systems, use of inputs and productivity of major crops of the area was gathered through interaction (Table 1). Demonstration site was selected based on its easy accessibility, farm size and layout of the field in order to have better impact of the demonstrated technology. The demonstrated area was scattered due to small land holdings in the state.

The present study was carried out in 3.52 ha area by involving 34 farmers of Kangra, Mandi and Chamba districts, 3.52 ha by involving 32 farmers of Kangra and Mandi districts and 3.64 ha with 33 farmers of Kangra, Mandi, Hamirpur and Bilaspur districts during *kharif* 2017, 2018 and 2019, respectively. Crucial farm operations *viz*., sowing, fertilizer application, weeding, draining of excess water due to high rainfall, plant protection measures, harvesting and post-harvest operations were ensured through time-to-time interactions with farmers. The crop was sown during last week of May to first fortnight of June or onset of monsoonal rains in all villages.

Estimation of technology gap, extension gap and technology index

In front line demonstrations, full package of practices were adopted whereas in the farmer's practice, existing practices being used by the farmers of the area were followed. The yield data were collected from the demonstrated plot and farmer's practice through personal interaction. The yield increase in demonstration plot over farmer's practice was calculated by using the following formula:

Yield increase over farmer's practice (%) = {(Demonstration plot yield–Farmer's plot yield)/Farmer's plot yield)} x 100

The data obtained were analyzed to estimate the technology gap, extension gap and technology index as per following formulae (Samui *et al*., 2000):

Technology gap = (Potential yield – Demonstration plot yield)

Extension gap = (Demonstration plot yield –Farmer's plot field)

Technology index= {(Potential yield – Demonstration plot yield)/ Potential yield} x 100

Economic impact analysis

Cost of cultivation of soybean includes the cost of inputs like seed, fertilizers, plant protection measures, hired labour for various field and post-harvest operation charges while the farmer's family labour was not considered in the present study. The gross and net returns were calculated by considering cost of cultivation and price of seed and straw yield and cost-benefit ratio was worked out as a ratio of costs and corresponding returns.

RESULTS AND DISCUSSION

Results of front line demonstrations conducted during *kharif* 2017, 2018 and 2019 in farmer's fields indicated that the yields of demonstrated plots were invariably higher than the corresponding farmer's plot yield in all years which were due to the adoption of recommended practices in front line demonstrations (Table 2).

The improved production technologies resulted in yield increase varying between 24.5 to

27.3 percent in Hara Soya and 25.5 to 30.1 percent in Him Soya as compared to existing traditional practices which indicated the positive effects of improved varieties and cultivation practices over the farmer's practices towards enhancing the yield of soybean in hills. The results were in conformity with the earlier findings of Singh (2002); Dixit and Singh (2003); Patel *et al.* (2009) and Dubey *et al.* (2011).

Yield of the front line demonstrations (demonstration plot yield) and potential yield of the crop was compared to estimate the yield gaps (Table 2) between soybean varieties which were further categorized into technology and extension gaps (Hiremath and Nagaraju, 2009). Technology gap (Yield gap-I) indicates researchable issues for realization of potential yield, whereas the extension gap (Yield gap-II) indicates the role of extension functionaries towards the transfer of improved technologies (Joshi *et al*., 2014).

The technology gap ranged from 497 kg/ha to 661 kg/ha in Hara Soya and 316 kg/ha to 524 kg/ha in Him Soya. The technology gap observed may be attributed to growing of the crop under rainfed conditions, the variation in the soil fertility status, marginal and sub-marginal land holdings, undulating topography and prevailing weather conditions. Although, technology gap is considered difficult to abridge because of environmental differences between on-farm and research station situations but it gives an indication of the upper limits of productivity that can be achieved in a given environment. A very narrow yield gap suggests the need to generate further better performing technologies in a given environment (Bhatia *et al*., 2006). Therefore, variety-wise location specific recommendation may be necessary to minimize the technology gap for yield under different situations.

The extension gap which ranged from 244 kg/ha to 291 kg/ha in Hara Soya and 259 kg/ha to 343 kg/ha in Him Soya emphasized the need to educate the farmers for adoption of improved agricultural production technologies to narrow-down the extension gap. Extension gap mainly arises as a result of differences in the management practices followed by the traditional farmers such as use of sub-optimal or no doses of inputs and cultural practices as compared to the improved practices followed.

The technology index shows the feasibility of the evolved technology in the farmer's fields. The lower value of technology index, more is the feasibility of the demonstrated technology (Balai *et al*., 2013). Reduction of technology index from 34.8 percent (2019) to 26.2 percent (2018) in Hara Soya and 29.1 percent (2019) to 17.6 percent (2018) in Him Soya exhibited the feasibility of technology demonstrated in farmer's fields for both soybean varieties. Therefore, as per technology index, Him Soya variety (17.6 percent) was found more feasible as compared to Hara Soya in hills. The location-wise variation in yield can be attributed to variation in climatic conditions, microclimate and agricultural production technology followed. More or less similar findings were reported by earlier workers (Sagar and Chandra, 2004 and Dubey *et al*., 2011).

Varietal economic analysis of soybean

A comparative variety-wise economic impact of soybean revealed that per hectare average demonstration yield (1407 kg/ha) and farmer's plot yield (1104 kg/ha) of soybean variety Him Soya were higher than the variety Hara Soya giving 1332 kg/ha and 1057 kg/ha, respectively (Table 2).

The profitability analysis indicated that the variety Him Soya exhibited comparatively more returns both in demonstrations (Rs. 35289) and farmer's plot yield (Rs. 23815) compared to Hara Soya under front line demonstrations. The additional cost of Rs. 3660 to Rs. 4431 in both varieties gave additional net returns ranging from Rs. 8473 to Rs. 11477 in Hara Soya and Rs. 9322 to Rs. 14193 per hectare in Him Soya. The benefit: cost ratio revealed that cultivation of Him Soya is more profitable both under demonstrations (0.95) as well as farmer's plot (0.72) as compared to soybean variety Hara Soya which exhibited the benefit: cost ratio of 0.84 and 0.65, respectively (Table 3). This may be due to higher yields obtained under recommended practices compared to farmer's practices. Bhatnagar (2009) reported that the research emanated production technologies were capable of enhancement of productivity of soybean by 32.26 per cent through front line demonstrations while Meena *et al*. (2012) reported about 23.32 per cent increase in yield under improved technologies over farmer's practices. Similar enhancement in the productivity of soybean over farmers practices by adoption of improved technology was observed by earlier workers (Raghuwanshi *et al*., 2009; Raghuwanshi *et al*., 2010; Badaya *et al*., 2017; Singh, 2018; Singh *et al*., 2018; Khedkar *et al*., 2020).

Table 1. Comparison of recommended production technology capsule and farmer's practice

Input/ Practice	Technology Demonstration capsule	Existing farmer's practice
Variety	Hara Soya and Him Soya	Soybean
Sowing time	June	May end to June/ on arrival of monsoon
Spacing	45 x 5-10 cm	Broadcast method
Seed rate (kg/ha)	75	100
Plant population	0.22 to 0.44 million/ha	Grown as mixed crop with maize
Depth of sowing	3-5 cm	3-5 cm
Manure and fertilizer	3 t FYM/ha + 20:60:40 $N:P_2O_5:K_2O$ kg/ha	3 t FYM/ha
Seed treatment	Thiram 75 WP + Cabendazim 50 WP (2:1) @ 3.0 g/kg seed or Thiram + carboxin @ 2 g/kg seed	Nil
Weed control	Two hand weedings at 20 and 40 DAS or Pendimethalin @4.5lt/ha (pre emergence spray) and Turga-super +Quirine @ 750ml+37.5g/ha (post emergence spray)	Two hand weeding at seedling and before flowering stage

Table 2. Productivity, gap analysis and technology index of soybean grown under FLDs in North Western Himalayan hills

Year	Area (ha)	No. of farmers	Improved variety	Potential yield	Yield (kg/ha)		% Increase over FP	Gap analysis (kg/ha)		Technology Index
					DP	FP		Technology	Extension	
2017	1.88	18	Hara Soya	1900	1354	1064	27.3	546	290	28.7
	1.64	16	Him Soya	1800	1461	1155	26.5	339	306	18.8
2018	2.38	23	Hara Soya	1900	1403	1112	26.2	497	291	26.2
	1.14	9	Him Soya	1800	1484	1141	30.1	316	343	17.6
2019	2.68	23	Hara Soya	1900	1239	995	24.5	661	244	34.8
	0.96	10	Him Soya	1800	1276	1017	25.5	524	259	29.1
Mean			Hara Soya	1900	1332	1057	26	568	275	29.9
			Him Soya	1800	1407	1104	27.4	393	303	21.8

Table 3. Comparative economic impact of soybean under front line demonstrations during *kharif* 2017, 2018 and 2019

Year	Improved variety	Cost of cultivation (Rs. /ha)		Net returns (Rs. /ha)		Additional cost of cultivation	Additional net returns	B:C Ratio	
		DP	FP	DP	FP	(Rs. /ha)	(Rs. /ha)	DP	FP
2017	Hara Soya	34350	29960	33331	23234	4390	10097	0.97	0.78
	Him Soya	34350	29960	38681	27774	4390	10907	1.13	0.93
2018	Hara Soya	38200	34540	34770	23293	3660	11477	0.91	0.67
	Him Soya	38200	34540	38962	24769	3660	14193	1.02	0.72
2019	Hara Soya	39403	34972	26248	17775	4431	8473	0.67	0.51
	Him Soya	39403	34972	28225	18903	4431	9322	0.72	0.54
Mean	Hara Soya	37318	33157	31450	21434	4160	10016	0.84	0.65
	Him Soya	37318	33157	35289	23815	4160	11474	0.95	0.72

Table 4. Constraints for yield gap and potential interventions perceived by farmers for improving the productivity of soybean in north western Himalayan hills

Constraints causing yield gap	Potential interventions to mitigate yield gaps
Wild life menace (bores, stray animals, rabbits, *Neel gai*)	Wild life management
Migration of working force and youth from villages to towns in search of white-collar job	Employment generation in villages to stop migration
Scattered and small land holdings	-
Ignorance of farmers for improved cultivation practices	Strengthening of extension services and timely advisories
Non availability of improved seeds and other inputs	Timely and assured supply of various inputs
Non-existent marketing network and poor transportation facilities	Assured marketing network and transport facilities
Undulating topography and challenging agro-climatic conditions	Adoption of varieties for niche-based areas
Unpredictable weather and changing climate	Adoption of climate resilient varieties

Among the possible constraints observed for yield gap, the wild life menace followed by migration of youths from villages, scattered and small land holdings, poor extension services and ignorance of farmers for improved cultivation practices, non-availability of improved seeds and other inputs, undulating topography and unpredictable weather and changing climate appeared to be the prominent constraints causing yield gap in soybean (Table 4). Potential interventions perceived by farmers include wild life management, initiatives for youth employment generation, strengthening of extension services and timely availability of agricultural inputs like seed, fertilizer, pesticides, assured marketing network and awareness programmes for improving the production and productivity of soybean in North Western Himalayas.

The study suggested that by using improved variety of soybean and scientific recommendations, the net returns may be increased up to 67-68 % by increasing cost of cultivation about 21% only in the form of interventions. Among the varieties, Him Soya appeared to be more profitable compared to Hara Soya as the farmers prefer yellow seeded varieties for use as soya milk, *tofu*, *dal*, flour and other preparations while green-seeded varieties need popularization among farmers by creating awareness and motivation to adopt appropriate recent production and protection technologies in the state. Hence, the result of front-line demonstrations suggested that by adoption of improved package of practices, the farmers can realize higher yields and net profit in soybean cultivation under North Western Himalayas.

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FMS - An Effective Remote Crop Monitoring System

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ABSTRACT

The Field Monitoring System (FMS) web application is developed for soybean scientists to monitor soybean fields without visiting the site. This web application played an important role during the COVID period. Remote monitoring is the key of this web application without any physical contact to anyone. It also provides comparative study on different aspects of soybean crops in any part of India. The design and development of the web application is discussed in the paper. The salient features of the web application are presented in detail. The functionality of the web application and overall look and feel of the web application is given.
Key words: Crop monitoring, field monitoring system, soybean, .Net, SQL server. web application.

Soybean enjoys the status of being the prime legume crop among the world's important agricultural commodities that contributes significantly (~25%) to the globe's edible oil production. Among the major soybean growing countries, India ranks fourth in terms of area and fifth in terms of production as per AMIS, FAO estimates (ICAR-IISR, 2022). Soybean production in India during 2021-22 is estimated to be 13.12 million tons from an area of 12.18 million ha and a productivity of 1077 kg/ha as per 2nd advance estimates of DAC&FW as compared to production of 12.61 million tons from an area of 12.92 million ha and productivity of 976 kg/ha (of DAC&FW) in 2020-21. Despite extraordinary growth in area and production of soybean during the past 40 years, the current productivity levels are much below the world average.

All India Co-Ordinated Research Project on Soybean (AICRPS) trials provides a research platform for the development of high yielding varieties to increase current productivity levels. It also strengthens soybean R&D with effective as well as efficient utilization of results of inter-disciplinary multi-locational research all over the country. Present AICRPS trial monitoring system is completely manual. The monitoring of AICRPS trials manually at different locations all over India, on weekly or monthly basis is not possible. The AICRPS trial monitoring is a regular activity that can be strengthened using the potential of Information Technology (Narayana *et al.*, 2018). The monitoring can be made more effective by getting the field and plant information in the form of pictures, videos, text information on field conditions and other related information. The development of the Field monitoring support system can make the monitoring highly effective (Chandgude *et al.,* 2018) and can lead to a transparent system making the information available to all. Therefore, the development of web Application-Field Monitoring Support System (FMS) for remote monitoring of AICRPS trials was taken up to strengthen the current field monitoring process in order to provide a cost-effective facility for continuous monitoring of AICRPS trials at every crop stage. This paper discusses the design and development of the FMS web application. The salient features and functionality of the system is also described.

METHODS AND MATERIALS

The FMS was developed using C# language of ASP.NET framework 4.5. Three-tier software architecture was used for clean and understandable code for the development of the system (Kolhe *et al.*, 2020). This architecture. basically contains three Layers-User Interface (presentation) Layer, Application (logic) Layer and Data (database) Layer (Figure 1). Here we separate User Interface, Application Logic, and Data in three divisions to provide maintenance, flexibility, updation flexibility without affecting other parts of the program code.

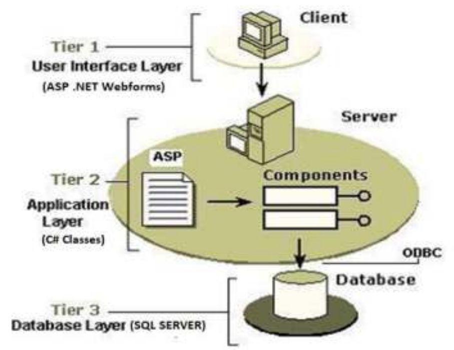

Fig1:Three-Tier Software Architecture

User Interface or Presentation Layer

This is the top layer of architecture. The topmost level of application is the User Interface (UI) that is what the user sees. The main function of this layer is to translate tasks and results in something which the user can understand. It contains menu options according to user role. The system provides UI for the retrieval of crop information based on Trial-wise, Discipline-wise, Location-wise, Date-wise and Variety-wise. The UI layer of our system has menu options for the search under "Data Retrieval" main menu option. The monitoring is made more effective with development of interface for getting the field and plant information in the form of pictures, videos, text information on different aspects of field conditions and other related information. The AICRPS in-charges at different locations take Geo-tagged photos and videos of their fields and plants of different trials with their smart phones. They upload it into the FMS along with other related information about their trials using the UI of main menu option- 'Data Entry'. It also includes interface for Comparative Study of varietal performances over multiple years.

Application or Business Logic Layer

This is the middle layer of architecture. This layer involves C# classes and logical calculations. The operations are performed under this layer. It processes the command, makes logical decisions and performs calculations. It also acts as a middleware between two surrounding layers that is presentation and data layer. It processes data between these two layers. This layer also validates the input conditions before calling a method from the data layer. This ensures the data input is correct before proceeding, and can often ensure that the outputs are correct as well. This validation of input is called business rule. In our application layer business logic was written in 45 programme Code files (.aspx) as shown in Figure 2.

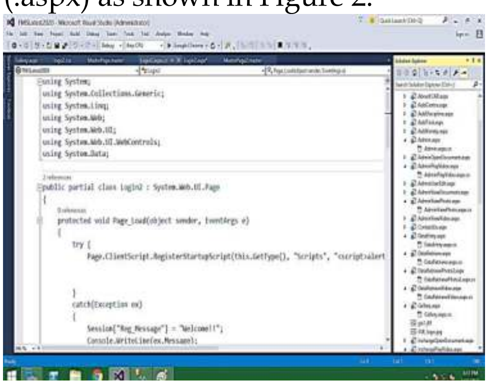

Fig 2: Screen showing code files(.aspx)

Data Layer

This layer is used to connect the business layer to the database or data source. It contains methods which are used to perform operations on databases like insert, delete, update, etc. This layer contains stored procedures which are used to query databases. Hence this layer establishes a connection with the database and performs functions on it. We used MS SQL Server 2012 for the storing of data. We created 'FMS Soybean Final' database having 10 database tables, 6 views and 57 stored procedures (Figure 3) for the development of FMS. The database has 1977 and 1408 number of Images collected from all AICRPS centres in the years 2020-21, 2021-22 respectively.

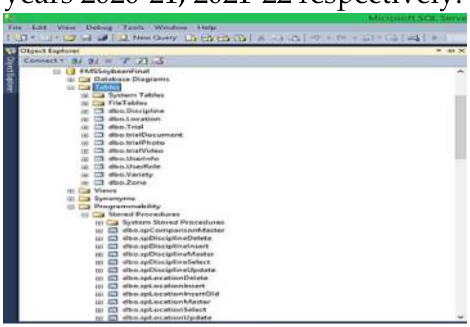

Fig 3: SQL server FMS Database

RESULTS AND DISCUSSIONS

The FMS system is implemented on ICAR-IISR server and is available on institute website http://iisrindore.icar.gov.in. The system provides access to only authorized users. The system provides authorization at four levels- i) Admin ii) In-charge iii) Manager and iv) Scientist as shown in system flow chart (Figure 4). The

Admin has full rights, In-charge and Scientist have data-entry and retrieval rights, Managers have data retrieval rights. The authorized user can login into the system using login window (Figure5). The user has different menu Options-Admin Panel, Data Entry, Data Retrieve, Profile Management, Master Module and Comparative Study as shown in Figure 6.

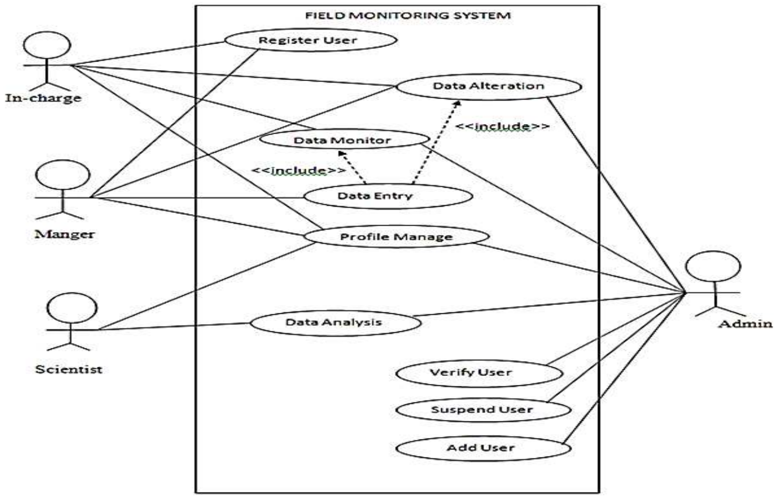

Fig 4: Flow chart showing different user roles

Fig 5: Login web page

Admin Panel: This is the interface provided for admin specific tasks. The rights to manage all the master database related expert tasks were provided to the "Admin" user. He can add, edit or delete master databases of SQL Server viz. Location, Discipline, Variety and Trial. The Admin Panel has the option to allow or disallow users to edit specific data. Admin can allow a particular location user to edit the data after the expiry of the data entry period. He can also disable editing of data of all the location with one command button using the facility provided in this module. (Figure 7)

Fig 6: Screen showing Main menu options

Fig 7: Admin Panel interface

Fig 8: User interface for data entry

Data Acquisition: The in-charges of AICRPS and other trials have a separate authorization to upload photos, videos and other relevant information. They enter data for different trials-IVT, AVT-I, AVT-II, Farmers Practice, Germplasm trials etc. of different Disciplines-Agronomy, Plant Pathology, Entomology, Plant Breeding, FLDs etc. at different crop stages (Figure 8). The photos are geotagged and contains date of capture and date of sowing. Separate user authorization is provided for different locations and different disciplines.

Information Retrieval: The authorization for information retrieval is provided to Managers, Higher officials, policy makers and End-users. The authorized user can view the information by applying different criteria. They can apply query based on Variety, Trial, Date of Sowing, Date of Capture, Locations and Discipline (Figure 9). They can check photos, videos and data anytime (Figure 10) and ask for additional information from any of the trials in-charges, in case of any doubt.

Fig9: Information retrieval interface

Fig10: Screen with retrieved information

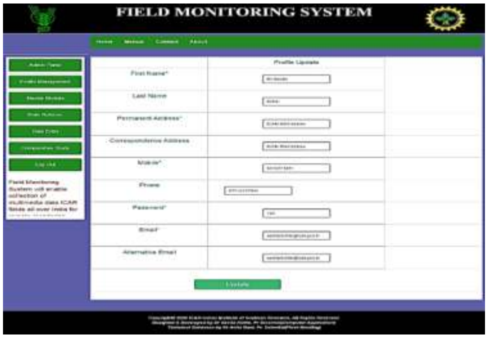

Fig11: User profile management interface

Comparative Study:
This module is designed specifically to compare the varietal performance over multiple years. The user can compare three varieties for different trials at a particular crop stage based on date of sowing or date of photo capture.

He can also apply different criteria for comparison (Figure 12). This is useful for taking decision on identification of an entry for release before a variety is finally released by Varietal Identification Committee (VIC). They can check the performance of the entry in Breeding trials, Agronomy trials and Pathology and Entomology trials in single go by simply clicking on criteria for comparison.

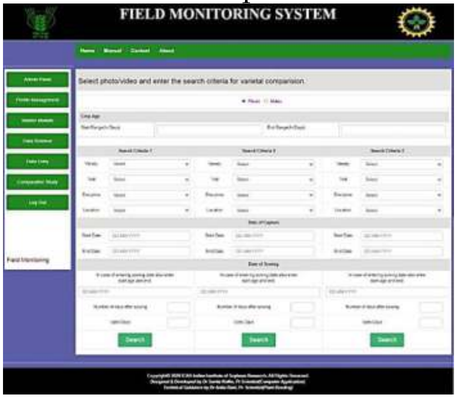

Fig12: Comparison Study Interface

CONCLUSION

The FMS system is developed using ASP.NET at front end and SQL Server at back end for remote monitoring of field trials. The current method of AICRPS monitoring has been made more effective by the development of the FMS system. It helped the users to get the field and plant information in the form of pictures, videos, text information on field conditions and other related information remotely. It provided a facility for continuous monitoring of AICRPS trials at every crop stage. Monitoring of AICRPS trials at different locations all over India, on weekly or monthly basis was made possible even du ring the lockdown in the country. The system is implemented successfully at ICAR-IISR Server and accessible through institute website (https://iisrindore.icar.gov.in). Presently, the system is used for remote monitoring of Front-Line Demonstrations and AICRP trials of soybean crop only but it is designed in such a way that it can be used for other crops also. The system is also useful for Varietal Identification Committee (VIC) to see the varietal performance in the fields over the years for taking decision on identification of an entry for release. VIC can check the performance of the entry in Breeding trials, Agronomy trials and Pathology and Entomology trials in single go by simply selecting an appropriate criterion for comparison. The development of the FMS has made the field monitoring process easy in the pandemic situation due to Covid-19 in the country. It has made the monitoring highly cost effective, user-friendly and lead to a transparent system making the information available to all.

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Carbon and Energy Budgeting of Soybean Under Different Management Systems and Preceding Crops

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ABSTRACT

A field experiment was conducted during kharif and rabi seasons of fifteen consecutive years from 2004-05 to 2018-19 to study the effect of management systems (organic, inorganic and integrated) on the productivity, energy and carbon budgeting of soybean grown after wheat and chickpea. Soybean yielded identically when grown after either of the crops. However, soybean yield had an edge over when grown after chickpea rather than wheat. All the energy and carbon indices except specific energy followed a similar trend as observed in yield. All the three management systems failed to bring any appreciable improvement in soybean yield. However, the integrated management system was found to be numerically better than organic and inorganic systems with reference to all other parameters. The inorganic management system required very less carbon input than integrated and organic system and resulted in higher net gain of carbon and carbon efficiency. The maximum carbon footprint was with organic management system followed by integrated and inorganic management systems.

Key words: Carbon emission, carbon efficiency, carbon footprint, energy, energy use efficiency, inorganic, integrated, organic, soybean

Currently, climate change is a common concern of mankind. It poses an urgent and potentially irreversible threat to human societies and the planet. Additionally, World Health Organization emphasized that the scale of environmental health problems has expanded from household (*e.g.* indoor air pollution), to neighborhood (*e.g.*, domestic wastes) to community (*e.g.* urban air pollution) to region (*e.g.* transboundary contamination), and now to global level (*e.g.* climate change) (WHO, 2003). N_2O emissions from soil nitrogen (N) incorporations and mineralization of soil organic matter were identified as a major contributor to the soybean greenhouse gases (GHG) balance (Brandao *et al*., 2010; Snyder *et al*., 2009; Reijnders and Huijbregts, 2008; Landis *et al*., 2007). In addition, a few studies have assessed how this influences the soybean GHG balance (Del Grosso *et al*., 2009; Smeets *et al*., 2009; Snyder *et al*., 2009; Panichelli *et al*., 2009; Smaling *et al*., 2008; Reijnders and Huijbregts, 2008; Miller, 2010; Miller *et al*., 2006). Carbon dioxide emissions from soil mostly come from decomposition of soil organic matter such as residues and litter (Lal, 1997). Microbial populations, using reduced carbon (C) compounds as an energy source account for the largest percentage of agricultural CO_2 emissions from the soil directly. However, this CO_2 often has a neutral effect on atmospheric CO_2 levels unless it takes C stored in soil for thousands of years and converts it to CO_2. When a soil is at equilibrium in regards to soil organic C concentrations, the soil is neither a source nor sink of CO_2. Jarecki *et al*. (2008) found that cumulative N_2O emissions were greater from a sandy loam soil than from a clay soil. Similarly, a loam soil was found to emit more of the applied fertilizer as N_2O than did a clay soil (Weitz *et al*. 2001). Soybean has multiple uses in global markets: directly in food consumption, as additives and supplements, animal feed and primary source for biofuels (Foley *et al*., 2011; FAO, 2017). The cultivation of soybean is highly dependent on fertilizers, fuels, machinery and pesticides, which contributes to GHG emissions and energy resource use, two relevant environmental-impact indicators related to agricultural practices. A way to assess their contribution to different production systems consists in estimating the carbon and energy footprint of agricultural products by quantifying the GHG emissions and energy inputs required to produce a given amount of food (Pelletier *et al*., 2011). Therefore, the present investigation was initiated to study the effect of management systems (organic, inorganic and integrated) on the productivity, energy and carbon budgeting of soybean when grown after either wheat or chickpea crop.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* and *rabi* seasons of fifteen consecutive years from 2004-05 to 2018-19 at the Research farm of Indian Institute of Soybean Research, Indore, Madhya Pradesh, (India). Soil of the experimental plot belongs to the order Vertisols with slightly alkaline pH 7.5-7.8 and medium in organic carbon (4.2 g/kg), available N (132.44 mg/kg) and available P (6.60 mg/kg) with high in available K (255 mg/kg). The experiment comprised- soybean grown after wheat and chickpea on 3 management systems (organic, inorganic and integrated) was laid out in the strip plot design with five replications on a fixed site.

Organic Management Practice

Encompassed pre-sowing incorporation of well decomposed farmyard manure (FYM) to all the three crops (soybean, wheat and chickpea) @ 10 t/ha. The FYM analyzed 0.51, 0.18 and 0.50 % of N, P and K, respectively. Phosphorus requirement of the crops was met through rock phosphate (16% P_2O_5). Soybean and chickpea seeds were treated with *Trichoderma viride* (5 g/kg seed) and inoculated with rhizobium culture (5 g/kg seed) and phosphate solubilizing micro-organism (5 g/kg seed) before sowing, and while the wheat seed treated with *Trichoderma viride* (5 g/kg seed) and inoculated with Azotobactor (5 g/kg seed) and phosphate solubilizing micro-organism (5 g/kg seed). Pest control was achieved through bio-pesticides such as Dipel @ 1.0 l/ha in soybean as well as in chickpea. Weed free conditions in the plots were maintained by hand weeding in all the three crops.

Inorganic Practice

Nutrients were supplied through inorganic fertilizers as per recommended doses (RDF) for soybean (20:60:20 N: P_2O_5: K_2O kg/ha), wheat (100: 60: 40 N: P_2O_5: K_2O kg/ha) and chickpea (20: 60: 20 N: P_2O_5: K_2O kg/ha). Soybean and chickpea seed was treated with thirum + carbendazim (2:1) @ 3 g/kg of seed. Weed infestation in soybean, wheat and chickpea was managed by post-emergence spray of herbicide imazethapyr @ 100 g a.i./ha, 2,4-D @ 1 kg a i/ha and pre-emergence spray of pendimethalin @ 0.75 kg a.i/ha, respectively. Pests were controlled through the spray of Chlorentranilipore @ 100 ml/ha for soybean as well as chickpea.

Integrated Practice

The FYM @ 5 t/ha and 50 % RDF were applied to all the three crops. Soybean and chickpea seeds were treated with thirum + carbendazim (2:1) @ 3 g/kg of seed and then inoculated with rhizobium culture and phosphate solubilizing microorganism culture before sowing. While, the wheat seed treated with *Trichoderma viride* (5 g/kg seed) and inoculated with Azotobactor (5 g/kg seed) and phosphate solubilizing micro-organism (5 g/kg seed). Weed infestation was managed through post- emergence spray of imazethapyr @ 100 g a i/ha in soybean, 2,4-D @ 1 kg a i/ha in wheat and pre-emergence application of pendimethalin @ 0.75 kg a.i/ha in chickpea whereas, plant protection was carried through integrated pest management practices whenever the incidence of pest and disease was noticed.

The inputs and outputs of different crops were converted in terms of energy input and output using energy equivalents and used for calculation of different energy parameters as suggested by Singh and Mittal (1992). The energy input/consumption under different inputs and nutrient supply options of crops was computed mean over years. The inputs used and field operations adopted in raising the crops were converted into carbon input equivalent per hectare (C/ha) using the carbon emission equivalents (West and Marlend, 2002) and carbon output was calculated as per Lal, (2004). The carbon input and output so obtained were used to calculate carbon efficiency and carbon footprint.

RESULTS AND DISCUSSION

Soybean yield remained unaffected due to preceding wheat and chickpea crops in a sequence (Table 1). The non-significant differences of soybean yield due preceding crops such as wheat and chickpea were also reported by Singh and Kushwaha (2018). However, soybean yielded numerically higher (2.32%) when grown after chickpea than wheat. The marginal increase in soybean yield when grown after chickpea has earlier been reported by Billore *et al.* (2006). Soybean yield was not influenced due to the management systems assessed under long-term trial (Table 1). However, the integrated system produced numerically higher yield by 3.36 and 4.01% over inorganic and organic management systems, respectively. The superiority of integrated nutrient management over inorganic nutrient management was reported by several researchers (Ghodke *et al*., 2018, Patel and Tiwari, 2018, Mourya *et al*., 2018, Gupta *et al*., 2019).

Soybean required almost identical energy input and also renewable energy inputs when grown after either of the crops (Table 2). This is attributed to the fact that legumes have much less energy expenditure than other crops (Baishya and Sharma, 1990). Similar results were earlier reported by Mandal *et al*. (2002); Zangeneh *et al*. (2010) and Negi *et al*. (2016). The maximum energy input required under organic system and closely followed by integrated system and least by inorganic system (Table 2) and similar pattern of renewable energy inputs was also observed. The inorganic system relies on only fossil energy based inputs therefore it accounts least amount of renewable energy inputs. Analysis of energy inputs for the crops showed that energy input from fertilizer and mechanical power was the highest, whereas the share of labor energy was very low (Kheiry and Dahab, 2016). Soybean produced slightly higher gross and net energy outputs (2.27 and 2.69%) when grown after chickpea as compared to grown after wheat (Table 3). Similarly, soybean showed higher energy use efficiency when grown after chickpea than wheat. However, the specific energy showed that the soybean after wheat possesses higher values than after chickpea. The higher bio-energy output from soybean due to production of higher biomass was also reported by Singh *et al*. (1997), Billore *et al*. (2009) and Jain *et al*. (2015). The soybean higher energy profitability was recorded when grown after chickpea (Table 4). The integrated management system produced maximum gross and net energy outputs and it was higher by 4.01 and 3.38 % and 6.20 and 1.42 % as compared to organic and inorganic management systems, respectively. The higher energy output recorded under integrated nutrient management owing to higher productivity of soybean. The results are in corroboration with those reported by of Mandal *et al*. (2002) and Singh and Ahlawat (2015), who also observed higher energy output with combined use of nutrient sources. The higher energy output with integrated supply of nutrients due to increased biomass production was also reported by Billore *et al*. (2005) and Prajapat *et al*. (2018). The highest energy use efficiency was observed under integrated management system and followed by inorganic and organic systems. However, the maximum specific energy was recorded under organic system as compared to integrated and inorganic systems. The maximum energy profitability was associated with inorganic management than integrated and organic management systems (Table 4). Soybean required identical carbon inputs when grown after either of the crops (Table 4). Similarly, soybean produced higher carbon output (2.71 %) and net gain of carbon (3.65 %) when grown after chickpea than wheat. Soybean when grown after chickpea was found to be more carbon efficient than grown after wheat. While the carbon footprint of soybean was found to identical when grown after either of the crop. Similar results were also observed by Prajapat *et al*. (2018).

The highest carbon input was recorded under organic management followed by integrated and inorganic management, which was higher by 92.62 and 620.16 %, respectively. However, integrated management required more carbon (273.87 %) as compared to inorganic management system. The major share of carbon input was through the farmyard manure under organic and integrated management system. The highest and lowest carbon output was associated with integrated and organic management system. However, the maximum gain of carbon was recorded under inorganic management (16.48 and 68.66%) followed by integrated and organic system, respectively. Similar were the results in case of carbon efficiency. However, the carbon footprint indicated that the organic management was found to be superior to integrated and inorganic management systems. This may be ascribed to the variation in carbon inputs and outputs under different management systems. Energy use and GHG emissions in organic crop production are higher than in conventional crop production. GHG emissions in organic arable and vegetable farming were 0-15% and 35-40% higher, respectively. The most likely cause for higher energy use and GHG emissions in organic crop production is its high intensity level, which is expressed in crop rotations with a large share of high-value crops, relatively high inputs and frequent field operations related to weeding (Bos *et al*., 2014).

On the basis of fore going results, it is confirmed that the prevailing practice of soybean cultivation after either wheat or chickpea in soybean commend area is apt. However, the soybean grown after chickpea had slightly additional advantages with respect to yield, energy and carbon balance. The integrated crop management system was found to be the most viable system as compared to organic and inorganic management systems. However, soybean can also be successfully grown under organic system.

Table 1. Yield of soybean crops as affected by various management systems and preceding crops

Management/ cropping system	Soybean yield (kg/ha)			Straw yield (kg/ha)			Biological yield (kg/ha)		
	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean
Organic	1616	1576	1596	3029	2954	2992	4645	3630	4588
Inorganic	1585	1626	1606	2971	3048	3010	4556	4674	4616
Integrated	1634	1686	1660	3063	3160	3112	4697	4846	4772
Mean	1592	1629		2984	3053		4576	4682	
	SEm (±)	CD			SEm (±)	CD			
Cropping systems (CS)	40.00	NS			40.92	114.57			
Management (Mgt.)	49.00	NS			60.02	168.05			
CS x Mgt.	69.29	NS			80.52	225.45			

Table 2. Effect of different management systems and preceding crops on soybean energy input and output

Management/ cropping system	Energy input (MJ/ha)			Renewable energy input(%)			Energy output (MJ/ha)		
	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean
Organic				6873	6873	6873			
	13060	13060	13060				78263	76325	77300
Inorganic				2371	2371	2371			
	10540	10540	10540				74063	78750	77775
Integrated				4566	4566	4566			
	12180	12180	12180				79138	81650	80400
Mean	11927	11927					77155	78908	
	SEm (±)	CD			SEm (±)	CD		SEm (±)	CD
Cropping systems (CS)	76.26	213.53			134.23	375.86		172.68	483.52
Management (Mgt.)	93.40	262.52			164.40	460.33		211.49	592.19
CS x Mgt.	132.08	369.85			232.50	651.01		299.10	837.49

Table 3. Energy output, energy use efficiency and specific energy of soybean as affected by various management systems under different preceding crops

Management/ cropping system	Net energy output (MJ/ha)			Energy use efficiency			Specific energy(MJ/kg)		
	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean
Organic	65203	63265	64240	5.99	5.84	5.92	8.08	8.29	8.18
Inorganic	63523	68210	67265	5.67	6.03	5.96	6.65	6.48	6.56
Integrated	66958	69470	68220	6.06	6.25	6.16	7.45	7.22	7.33
Mean	65228	66981		5.91	6.04		7.39	7.33	
	SEm (±)	CD			SEm (±)	CD		SEm (±)	CD
Cropping systems (CS)	168.72	472.43			0.012	0.03		0.048	0.13
Management (Mgt.)	206.64	578.61			0.015	0.04		0.059	0.17
CS x Mgt.	292.24	818.28			0.021	0.061		0.084	0.23

Table 4. Energy profitability, Carbon emission and carbon output of soybean as affected by various management systems under different preceding crops

Management/cropping system	Energy profitability (MJ/MJ)			Carbon input (kg CE)			Carbon output (kg CE)		
	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean
Organic	4.99	4.84	4.92	887.60	887.60	887.60	2043.80	1597.20	2018.72
Inorganic	6.02	6.47	6.38	123.25	123.25	123.25	2004.64	2056.56	2031.04
Integrated	5.50	5.70	5.60	460.80	460.80	460.80	2066.68	2132.24	2099.68
Mean	5.50	5.67		490.55	490.55		2013.44	2068.08	
	SEm (±)	CD			SEm (±)	CD		SEm (±)	CD
Cropping systems (CS)	0.04	0.11			22.84	63.95		12.91	36.16
Management (Mgt.)	0.049	0.14			27.97	78.32		15.82	44.29
CS x Mgt.	0.070	0.19			39.56	110.76		22.37	62.63

Table 5. Carbon efficiency and foot print as affected by various management systems under soybean based cropping systems

Management/ cropping system	Net gain of carbon (kg CE)			Carbon efficiency (output/input C)			C foot print (C input/total productivity) kg/kg yield		
	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean	Preceding wheat	Preceding chickpea	Mean
Organic	1156.20	709.60	1131.12	2.30	1.80	2.27	0.55	0.56	0.56
Inorganic	1881.39	1933.31	1907.79	16.26	16.69	16.48	0.08	0.08	0.08
Integrated	1605.88	1671.44	1638.88	4.48	4.63	4.56	0.28	0.27	0.28
Mean	1521.89	1577.53		4.10	4.22		0.30	0.30	
	SEm (±)	CD		SEm (±)	CD			SEm (±)	CD
CS	31.50	88.20		0.45	1.28			0.014	0.04
Mgt	38.58	108.03		0.56	1.57			0.017	0.05
CS x mgt	54.56	152.77		0.79	2.22			0.024	0.07

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Evaluation of PRISE, A Commercial Formulation of Phosphate Solubilizing Microorganisms for Enhanced Nodulation, Plant Nutrition and Grain Yield of Soybean

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ABSTRACT

To increase phosphorus nutrition, many phosphorus solubilizing microorganisms (PSMs) are used, which solubilize the fixed unavailable form of phosphorus to the available forms and give it to the plants. PRISE, a PSM commercial formulation was evaluated in the current study for increased nitrogen and phosphorus uptake, increased nodulation, nitrogen fixation, and yield of soybean in field during kharif seasons. In the present investigation, a PSMs formulation-PRISE was evaluated in a field trial for two consecutive years. The experiment was conducted in completely randomized block design consisting different treatments comprising mode of application of PRISE such as seed treatments, soil application, and split application with or without a recommended dose of fertilizer (RDF) and compared with uninoculated control plots. We observed higher nodule biomass and symbiotic nitrogen-fixing traits in PRISE treated with soil and seed treatments (T5). Furthermore, higher and comparable grain yield was recorded in PRISE applied as seed treatment and the split application at 75% RDF (T6) compared to 100% RDF application and other combinations. Hence, the application of PRISE microbial formulation is the potential and may replace 25% RDF without compromising soybean productivity.

Keywords: Phosphorus solubilizing microorganisms (PSMs); *Bradyrhizobium japonicum;* acetylene reduction assay; soybean; nitrogen fixation.

In order to feed the world's rapidly expanding population, chemical fertiliser is widely used in agricultural production. The indiscriminate and non-judicious application of chemical fertilizers into the soil has polluted the soil environment and declined the soil microbial health which renders the optimum crop growth (NING et al., 2017). It was estimated that to feed the 1.4 billion Indian population, approximately 300 million tons of food production will be required by

2025. Thus, about 40-45 million tons of nitrogen, phosphorus, and potassium fertilizer are needed to increase productivity in limited land resources. Among these, 11-13 million tons of P_2O_5 are required to maintain the average N: P_2O_5: K_2O ratio of 4:2:1 (Tiwari, 2001) and sustain the agroecosystem's productivity by reducing the the toxic agrochemicals while harnessing the microbial potential is needed (Tahat et al., 2020).

Soybean [*Glycine max* (L.) Merrill] is an edible bean cultivated globally as a source of oil (20-22%), protein (40-42%), as a human diet, feed for livestock and essential bioactive mlecules (Sharma et al., 2012). In India, it is a leading oilseed crop grown mainly in the central and peninsular region in the kharif season as a rainfed crop. However, the average productivity of the Indian soybean is hovering 1 t/ha, which is lesser than the average world productivity mainly due to various abiotic and biotic stresses (Agarwal et al., 2013). Among the abiotic stresses, nutritional deficiency is a significant hindrance to soybean production. The nitrogen and phosphorus deficiency in production systems causes soybean yield reduction upto 10 % and 45 %, respectively In legumes, the plant fixes the unavailable form of nitrogen into plant-available form by biological nitrogen fixation (BNF). This is an energy-intensive process and requires 16 Mg ATP to fix one molecule of nitrogen by symbiotic rhizobia. Hence, the nitrogen and phosphorus economy is essential for legume crop production (Nag et al., 2020; Marschner, 2011).

Since a significant fraction of phosphorus gets fixed in tropical soil which requires additional phosphorus applications to meet plant requirements.. The phosphorus gets fixed in iron, aluminium, and manganese oxides in acidic soils and calcium and magnesium phosphate in alkaline pH resulting in low phosphorus use efficiency. So, there is an urgent need to replace traditional liming practice with sustainable, cheaper, and environmentally compatible alternative PSMs for phosphorus nutrition is needed for plants (Roy et al., 2016).

The bacterial PSMs belong to genera, namely *Bacillus, Pseudomonas, Azotobacter, Burkholderia, Erwinia, Rhizobium, Bradyrhizobium, Enterobacter,Serratia,Paenibacillus,* and *Thiobacillus,* etc. Among all these PSMs, the *Bacillus* species are *Bacillus megaterium, Bacillus subtilis, Bacillus cereus* (Saeid et al., 2018; Wyciszkiewicz et al., 2017), and *Bacillus circulans* (Mehta et al., 2015) are predominant in phosphorus solubilization. These PSMs employ various strategies like producing organic acids, protons, hydroxyl ions, siderophores, CO_2 production, and siderophore for solubilization (Alori et al., 2017). Another phosphorus transformation is mineralization, catalyzed by microbial acid- and alkaline phosphatase collectively termed phosphatases which de-phosphorylatephosphoanhydride and phosphorester bonds in DNA, RNA, and phytate (Nannipieri et al., 2011). These PSMs also promote plant growth of underground plant parts by various mechanisms such as the production of hormones like IAA, ABA, cytokinins for altering the root system architecture, nitrogen fixation, siderophore production, antibiotic synthesis, antifungal activities, uptake and mobilization of heavy metals, ACC-deaminase activity, and quenching of toxic reactive oxygen species by many antioxidant enzymes (Sharma et al., 2013; Zaidi et al., 2017).

In the present study we evaluated the PRISE, a PSM commercial formulation for increased nitrogen and phosphorus uptake, increased nodulation, nitrogen fixation, and yield in soybean in a field trial during kharif season consecutive for two years.

MATERIAL AND METHODS

Site selection

The field experiment was carried out at the field experimental research farm, ICAR-Indian Institute of Soybean Research, Indore, India (latitude 22◦ 40′ 42′′ N and longitude 75◦ 52′ 33′′ E) with an altitude of 568 meters from above mean sea level. The experiment was carried out for two consecutive years in kharif 2015 and kharif 2016 on same site. The experimental site was located in a tropical climate with an average annual temperature of 24.6 ˚C, a yearly rainfall of 961 mm, and deep medium black soil/ Vertisols. The nutrient contents at zero time were as follows: pH 8.2, organic carbon 4.6 g/kg, and clay content 56.2%. The soil nitrogen, phosphorus, and potassium content were 76.23, 5.84, and 255.00 mg/kg soil, respectively (Ramesh et al., 2014).

Field preparation, PRISE inoculation, Experimental Design and Sowing

The field site was divided into equal plot sizes of 3.6 m × 5 m. Seeds of soybean (cutltivar: JS 95-60) was obtained from the crop Improvement section, ICAR-IISR, Indore. The experiment was done in a randomized block design with three replications in the popular soybean genotype JS 95-60 obtained from the crop Improvement section, ICAR-IISR, Indore. The PRISE commercial formulation was obtained from Zytex Biotech Private Limited, Mumbai, Maharashtra, India. The soybean seeds were added with carboxymethyl cellulose (CMC) as a sticky compound for making uniformly thin PRISE layers on the seed coat. Seeds were air-dried for 30 min in low-light intensity and sown manually at a spacing of 4-5 cm (about 2 cm deep) in rows of 40 cm apart. One kg was thoroughly mixed with 20 kg of FYM/ acre and uniformly distributed in the bullock-drawn plow's furrow opening for soil application of PRISE. The PRISE formulation was tested in 8 different treatment combinations comprsing of: T1- control recommended dose of fertilizer (RDF) only as 20:26.2:16.6 kg NPK / ha as basal dose, T2- seed treatment at 15g / kg seed along with RDF, T3- soil application at 1kg /acre along with RDF, T4- Split doses 1/2 Kg/acre soil application at sowing and 1/2 kg /acre at 30 DAS along with RDF, T5- (T2+T3), T6- (T2+T4), T7-(T5+ 75% RDF), and T8- (T6+ 75% RDF).

All standard and recommended agronomic practices (hoering, weeding and rouging etc.,) were followed during the field experimentation. No preparatory plant protection chemicals were used. During crop growth, to check weed growth two hand weeding was done manually 30 days after sowing (DAS) and 50 DAS.

Nodulation, nitrogen-fixing attributes, nutrient analysis and grain yield

Nodule number and dry nodule weight were recorded at the 50 % flowering stage. The nitrogen-fixing attribute was measured through acetylene reduction assay (ARA) as per the Hardy et al., (1968). Similarly, the leghaemoglobin content was measured per the method (Wilson & Reisenauer, 1963). The nitrogen content in nodules, seeds, and straw was quantified using a modified Kjeldahl method (Prasad et al., 2006). The protein content (%) was obtained by multiplication (5.8) with the seed nitrogen percentage. The phosphorus was quantified by the phosphor molybdate-vanadate-yellow method (Gupta et al., 1993). The plants were harvested at maturity (95 days after germination) and grain yield from each plot was obtained and extrapolated per hectare basis.

Statistical analysis

The data were analyzed using ANOVA through IBM SPSS Statistics version 26. The multiple comparison test was carried out by Tukey's HSD (p <0.05) at a 95 % confidence interval. The combined analysis was done when the same parameters were tested in both consecutive years in Microsoft Excel version 16.43.

RESULTS AND DISCUSSION

Our investigation validated the commercial formulation PRISE carrying the phosphate solubilizing microbes to increase the bioavailability of phosphates to the plant and increase the nitrogen uptake by increasing the biological nitrogen fixation and yield in government firms for two consecutive years.

Nodule dry weight, Nitrogen fixation evaluation traits (Acetylene reduction assay (ARA) and Leghaemoglobin content)

The application of PRISE formulation The PRISE application showed non-significant differences ($p < 0.05$) in the nodule dry weights in kharif 2015. However, kharif 2016, showed highly significant differences ($p < 0.05$) among the treatments (Table 1). A significant increment in dry nodule weight was recorded in T5 (0.26 ± 0.01 g/plant) and T2 (0.24 ± 0.01 g/plant) compared to the other combinations. The combined analysis of variance showed a highly significant difference ($p < 0.001$) in the planting year and the treatment × planting year interactions (Table 3). The ARA content was recorded only for kharif 2015, with significant differences ($p < 0.05$) in ARA among the tested treatments. In decreasing order, the maximum ARA activity was shown by T4, T5, T3, and T6 (Table 1). It showed that PRISE application, either with split doses in soil or combined seed and soil application along with RDF, enhanced the nitrogen fixation activity. In kharif 2016, leghaemoglobin was recorded as an indicator of nitrogen fixation activity. It showed highly significant differences ($p < 0.01$) in 2016. The leghaemoglobin content varied between 9.82 to 17.18 mg/gm nodule (Table 2). Significant maximum leghaemoglobin content was recorded in treatment T5 (17.18 ± 0.65mg/g nodule). Additionally, quantitatively T2, T3, T7 and T8 were also at par with T5. We showed higher nodule weight, and higher phosphorus and nitrogen uptake in PRISE treated plots; seed or soil amended with RDF gave the best results compared with the control recommended dose of fertilizer only. It showed that these PSMs present in the PRISE formulation interacted with native *Bradyrhizobium* present in the soil synergistically. The increased phosphorus nutrition to the plants helped in the greater ATP formation, which is required for energy-intensive nitrogen fixation. Further, the inoculated PSMs may have also interacted with native arbuscular mycorrhizal fungi (AMF), which further mobilized phosphorus and enhanced the symbiosis, nutrient uptake, and yield of the soybean crops (Mahanta et al., 2018).

The phosphorus is required for carbohydrate metabolism and translocation, plant biomass, root development, nodulation initiation, nodule number, nodule weights, and functioning in the soybean (Shu-Jie et al., 2007; Tsvetkova & Georgiev, 2003). There are several reports where amendments of PSMs with *Rhizobium* enhanced the legume- *Rhizobium* symbiosis, plant growth, and soybean yields. The two strains of phosphate solubilizing *Pseudomonas putida* SP21 and *P. putida* SP22 inoculated with *Bradyrhizobium japonicum* TIIIB in different combinations in soybean enhanced the plant biomass, nodule number, and nodule dry weight as compared with the control uninoculated and only *Bradyrhizobium* inoculation (Rosas et al., 2006).

Nitrogen content in nodule, seed, and straw, and protein content

The nitrogen content in nodules was highly significantly ($p < 0.001$) different in various treatments of PRISE applied in soybean in kharif 2016. The nodule nitrogen content varied between 3.39 to 4.27%. The maximum nodule nitrogen content was recorded in T7 (4.27 ± 0.04%). However, T2, T4, T5, and T6 were also at par with T7 (Table 2). Seed nitrogen content significantly ($p < 0.05$) differs in the field trial in 2015 and 2016. Except for T8, other treatments were non-significant each other. Except for T8, other remaining treatments showed non-significant differences from each other in kharif, 2015. In 2016, the maximum seed nitrogen was recorded in T2 (7.42 ± 0.24%) and the minimum in T8 (6.37 ± 0.12%). However, the remaining treatments were also at par with T2 (Table 1 and 2). The combined analysis of variance showed a highly significant difference in the planting years ($p < 0.001$), and the interaction of treatment × years had a significant effect on the nitrogen content of the seed ($p < 0.01$) (Table 3). Nitrogen content in straw was also significantly different in the various treatment of PRISE in 2015 ($p < 0.05$)

and in 2016 ($p < 0.001$). The maximum straw nitrogen content was recorded in T4 (2.42 ± 0.05%) and the minimum in T7 (1.5 ± 0.07%) in 2015 (Table 1). Whereas, in kharif 2016, the maximum straw nitrogen was recorded with T3 (0.94 ± 0.04%) and minimum in control (0.17 ± 0.01%). The combined analysis of both year field trials showed a highly significant difference in the both planting years ($p < 0.001$), and treatment and planting year ($p < 0.001$) on the nitrogen content of straw (Table 3). The protein content was significantly different among the various PRISE treatment in 2015 ($p < 0.05$) and in 2016 ($p < 0.05$). Except for T8, all other treatments were non-significantly different in 2015. Whereas, in 2016 kharif, protein content in seed was maximum in treatment T2 (41.82 ± 0.70%) and was minimum in T5 (35.93 ± 1.52%). Moreover, other treatments T1, T3, T4, T6, T7, and T8 were also at par with T2 (Table 1). The interaction effect of protein content in seed between treatment × year was significant ($p < 0.01$) (Table 3). The PSMs provide phosphorus nutrients to the plants and promote plant biomass and grain yields by nitrogen fixation, auxin synthesis, HCN enzyme, and siderophore formation in wheat crops and could be a better alternative to chemical fertilizer(Batool & Iqbal, 2019). The phosphorus solubilizing multiple plant growth-promoting traits bacteria, namely *Pseudomonas* sp. LG and *Bacillus* sp. Bx co-inoculated with *Rhizobiumphaseoli* in *Phaseolus vulgaris* plant enhanced the shoot biomass, phosphorus, nitrogen content, nodule number, and dry weight compared with *Rhizobium* alone treated plants (Stajkovic et al., 2011). The co-inoculation helps in synergistic response in the plants. Two PGPR *Bacillus megaterium* co-inoculated with common bean *Rhizobium* strains (IITA-PAU 987) showed higher nodule dry weight, shoot dry weights, and higher nitrogen content in the plants(Korir et al., 2017).

Phosphorus content in seed and straw

The application of PRISE formulation showed a non-significant difference ($p < 0.05$) in seed phosphorus content in both years (Table 1 and 2). The combined analysis of both years showed a planting year had a highly significant ($p < 0.001$) and treatment × planting year interaction had a significant ($p < 0.05$) effect on phosphorus content in seed (Table 3). The straw phosphorus content also showed significant differences ($p < 0.05$) among the various treatments of PRISE in 2015 and in 2016 ($p < 0.001$). The straw phosphorus content was maximum in T3 (0.42 ± 0.05%) and minimum in T2 (0.28 ± 0.01%) in 2015. The maximum straw phosphorus content was observed in T2, T3, T6, and T7 treated plots and the minimum in control T1 in 2016 (Table 1and 2). The combined analysis of both years showed a planting year had a highly significant effect on treatments ($p < 0.001$) and treatment × planting year interactions was significant ($p < 0.01$) on phosphorus content in straw (Table 3).

The PSMs isolated from the rhizosphere, mainly *Burkholderia* sp. and *Gluconacetobacter* sp., secreted various organics acids and were involved in the solubilization of the unavailable phosphorus compounds and seed treatment improved the nitrogen and phosphorus uptake, plant biomass, nodule weight, and grain yield in the cowpea (Linu et al., 2009; Ku et al., 2018)reported soybean plants inoculated with PSMs; Bacillus *cereus* YL6 can solubilize fixed and unavailable phosphorus forms and increase the plant's total phosphorus content and plant biomass. Similarly, *Pseudomonas striata* inoculation in soybean crops amended with fly ash increased the grain yield and nitrogen and phosphorus content in plants (Gaind and Gaur, 2002). The six PSMs genus *Pantoea* sp. J49, *Serratia* sp.S119, *Serratia* sp.J260, *Bacillus* sp.L55, *Enterococcus* sp.L191 and *Pseudomonas fluorescens* isolated from the peanut rhizosphere released gluconic acid, PQQ, and phosphatase enzymes for phosphorus solubilization and increased the phosphorus content and peanut plant growth (Anzuay et al., 2017). The inoculation of *Bacillus amyloliquefaciens* (AY 932823), a PGPR, and phosphorus solubilizer in soybean enhanced the phosphorus content in soybean plants and seed over uninoculated plants (Sharma et al., 2013). Similarly, *Enterobacter cloacae* subsp. *dissolvens* (MDSR 9), a PGPR, phosphorus solubilizer, and phytate mineralizer enhanced the soybean grain yield and nutrient uptake of macronutrients and micronutrients (Ramesh et al., 2014).

Yield

The soybean grain yield was found to be significantly ($p < 0.001$) different among the various treatment PRISE applied in both the years. During first year due to severe infestations of anthracnose and drought stress at reproductive stages (R5-R6) the grain yield was declined drastically and varied between 145.55 to 376.24 kg/ha. However, the inoculation of PRISE formulation increased the grain yield significantly compared to control plots. A significant maximum grain yield was obtained in T6 (357.37 ± 8.84). During second year, the grain yield was at par in all the tested treatments. However, the highest yield mean was observed in T3 and showed comparable yield in T7 (at 75% RDF) with 100% RDF (Figure 1). The inoculation of PRISE at 75% RDF comparably increases the grain yield compared to control plots (100% RDF). The combined analysis showed that planting year had a highly significant effect on the yield ($p < 0.001$), and the interactions between treatment × planting year were non-significant ($p < 0.05$) (Table 3).

Table 1. Effect of PRISE on Nodule dry weight, Acetylene reduction assay (ARA) of nodule (per g/h), N content (%) in seed, N content (%) in straw, protein content (%) P content in (%) seed and P content (%) in straw in soybean (JS 95-60) under field conditions (first year)

Treatments	Nodule dry weight (g/plant)	ARA (nmoles ethylene/g nodule/h	N content (%) in seed	N content (%) in straw	Protein content (%) in seed	P content (%) in seed	P content (%) in straw
T1	0.06 ± 0.01a	263.80 ± 67.23b	6.53 ± 0.21a	1.65 ± 0.05cd	37.85 ± 1.21a	0.84 ± 0.01a	0.33 ± 0.01ab
T2	0.12 ± 0.01a	287.24 ± 1.35b	5.73 ± 0.23ab	1.75 ± 0.04c	33.23 ± 1.33ab	0.80 ± 0.03a	0.29 ± 0.01b
T3	0.1 ± 0.02a	404.73 ± 28.49ab	5.58 ± 0.21ab	2.21 ± 0.01b	32.38 ± 1.22ab	0.91 ± 0.03a	0.42 ± 0.05a
T4	0.09 ± 0.02a	582.08 ± 71.85ab	6.37 ± 0.06ab	2.42 ± 0.05a	36.95 ± 0.35ab	0.92 ± 0.05a	0.38 ± 0.04ab
T5	0.09 ± 0.02a	474.63 ± 85.45ab	6.37 ± 0.32ab	2.13 ± 0.01b	36.96 ± 1.84ab	0.83 ± 0.02a	0.32 ± 0.01ab
T6	0.09 ± 0.01a	369.85 ± 103.22ab	6.14 ± 0.02ab	1.74 ± 0.04c	35.61 ± 0.11ab	0.91 ± 0.00a	0.31 ± 0.01ab
T7	0.09 ± 0.01a	204.98 ± 1.59b	5.97 ± 0.39ab	1.50 ± 0.07d	34.64 ± 2.25ab	0.86 ± 0.02a	0.30 ± 0.01b
T 8	0.1 ± 0.01a	240.35 ± 0.19b	5.35 ± 0.11b	1.74 ± 0.02c	31.03 ± 0.63b	0.93 ± 0.01a	0.34 ± 0.01ab
($p < 0.05$)	NS	0.005	0.019	0.021	0.019	NS	0.024

* Data are average of 3 replications represented as mean ± standard error followed by an alphabet. The same letter did not differ significantly ($p < 0.05$) by Tukey's HSD post hoc significance test at a significance level of 5 %, where, NS- non-significant ($p < 0.05$).
Where, T1-Control recommended dose of fertilizer (RDF) only as 20: 26.2: 16.6 kg NPK / ha as basal dose, T2-Seed treatment at 15 g/ kg seed along with RDF, T3- Soil application at 1 kg /acre along with RDF, T4- Split doses 1/2 kg/acre soil application at sowing and 1/2 kg /acre at 30 DAS along with RDF, T5-(T2+T3), T6-(T2+T4), T7-(T5+ 75% RDF), and T8- (T6+75%RDF)

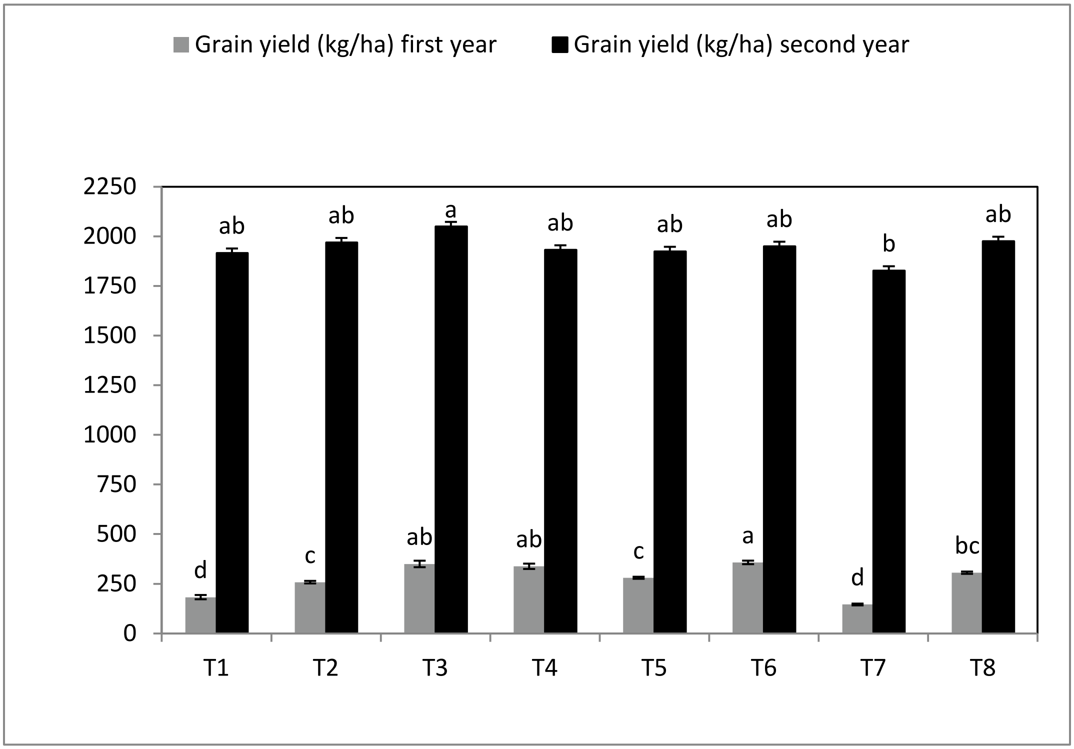
Table 2. Effect of PRISE on Nodule dry weight, Leghaemoglobin, N content (%) in nodule, N content (%) in seed, N content (%) in straw, protein content (%) P content in (%) seed and P content (%) in straw in soybean (JS 95-60) under field conditions (second year)

Treatments	Nodule dry weight (g/plant)	Leghaemoglobin (mg/g nodule)	N content (%) in nodule	N content (%) in seed	N content (%) in straw	Protein content (%) in seed	P content (%) in seed	P content (%) in straw
T1	0.16 ± 0.02b	10.97 ± 0.66bc	3.39 ± 0.07 d	6.79 ± 0.28ab	0.17 ± 0.01e	39.38 ± 1.64ab	0.49 ± 0.01a	0.04 ± 0.01c
T2	0.25 ± 0.01a	14.86 ± 1.24ab	3.78 ±0.05 abcd	7.42 ± 0.24a	0.36 ± 0.01d	41.82 ± 0.70a	0.57 ± 0.03a	0.08 ± 0.01a
T3	0.14 ± 0.01b	13.96 ± 0.75abc	3.64 ± 0.18cd	6.86 ± 0.08ab	0.94 ± 0.04a	39.79 ± 0.47ab	0.56 ± 0.02a	0.09 ± 0.01a
T4	0.17 ± 0.01b	9.82 ± 1.05c	4.17 ± 0.02ab	6.44 ± 0.16ab	0.69 ± 0.00b	37.35 ± 0.94ab	0.53 ± 0.01a	0.05 ± 0.00bc
T5	0.26 ± 0.01	17.18 ± 0.65a	4.00 ± 0.03abc	6.20 ± 0.26b	0.52 ± 0.01c	35.93 ± 1.52b	0.56 ± 0.04a	0.05 ± 0.01bc
T6	0.15 ± 0.02b	11.94 ± 1.05bc	4.22 ± 0.18ab	6.72 ± 0.21ab	0.64 ± 0.02b	38.98 ± 1.24ab	0.58 ± 0.02a	0.07 ± 0.01ab
T7	0.16 ± 0.01b	13.16 ± 1.22abc	4.27 ±0.04a	6.53 ± 0.20ab	0.50 ± 0.02c	37.89 ± 1.18ab	0.54 ± 0.02a	0.09 ± 0.01a
T 8	0.15 ± 0.01b	13.90 ± 0.30abc	3.73 ± 0.10bcd	6.37 ± 0.12b	0.48 ± 0.03c	36.95 ± 0.70ab	0.55 ± 0.02a	0.05 ± 0.01bc
($p < 0.05$)	0.001	0.001	0.001	0.022	0.001	0.043	NS	0.001

* Data are average of 3 replications represented as mean ± standard error followed by an alphabet. The same letter did not differ significantly ($p < 0.05$) by Tukey's HSD post hoc significance test at a significance level of 5 %, NS-non-significant ($p < 0.05$).

Where, T1- Control recommended dose of fertilizer (RDF) only as 20: 26.2: 16.6 kg NPK / ha as basal dose, T2- Seed treatment at 15 g/ kg seed along with RDF, T3- Soil application at 1 kg /acre along with RDF, T4-Split doses 1/2 kg/acre soil application at sowing and 1/2 kg /acre at 30 DAS along with RDF, T5-(T2+T3), T6-(T2+T4), T7-(T5+ 75% RDF), and T8-(T6+75%RDF). NS-non-significant.

Figure 1. Effect of PRISE on yield (kg/ha) on soybean (JS 95-60) under field condition (second year)



The bars followed by same letter did not differ significantly ($p < 0.05$) by Tukey's HSD post hoc significance test at a significance level of 5 %, NS-non-significant ($p < 0.05$). Where, T1- Control recommended dose of fertilizer (RDF) only as 20: 26.2: 16.6 kg NPK / ha as basal dose, T2- Seed treatment at 15 gm/ kg seed along with RDF, T3- Soil application at 1 g/acre along with RDF, T4- Split doses 1/2 kg/acre soil application at sowing and 1/2 kg /acre at 30 DAS along with RDF, T5-(T2+T3), T6-(T2+T4), T7-(T5+ 75% RDF), and T8- (T6+75%RDF).

CONCLUSION

Overall, considering the response of two-year yield data (consolidated response), the plots applied with the product as seed treatment together with the split application (at sowing and after 30 days) at 75% RDF produced a comparative yield when compared to 100% RDF application and other combinations hence application can save 25% NPK fertilizers to soybean without compromising the productivity.

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Climate Change and Soybean in Madhya Pradesh: Farmers' Perspective

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ABSTRACT

The per hectare yield of soybean in the country is stagnant for the last two decades and it is hovering around 1.0 to 1.12 t/ha. Madhya Pradesh alone contributes about 55% both in terms of both area and production of soybean in the country. The crop is grown during kharif as a rainfed crop mostly by the small and marginal farmers using very limited input. The farmers are found growing JS 95-60 as a single dominant soybean variety indicating their preference for short-duration varieties in spite of having choices of recently released varieties like JS 20-34, JS 20-69, JS 20-98, RVS 24, etc. with superior yield attributing characters beside resistance to biotic and abiotic stresses. During the last couple of years, the crop is found increasingly affected both in terms of quality and quantity produced by the farmers. The increased incidences of aberrant weather conditions during the crop season, more precisely about the delayed, erratic and uneven distribution of rainfall, increased chances of a long dry spell, and increase in atmospheric temperature have been experienced more recently in this state. Considering this, a study was conducted in three districts of Madhya Pradesh viz. Indore, Dewas and Dhar which are the epicenter of soybean cultivation in the state. The data were collected from 280 randomly selected farmers using an interview schedule containing basic information about the cropping pattern followed by them and their experience of decade-wise changes experienced by them in the area during the last six decades, post-soybean introduction in the area. The results of the study revealed that the farmers are concerned about the changes in the prevailing climate particularly delayed arrival and un-even distribution of monsoon, long dry spells as well as increased temperature during the crop growth period. They also perceived that the yield of soybean was affected due to delayed sowing, poor germination, and establishment of the crop resulting in less podding and increased cost of cultivation on account of increased incidences of pests and diseases. More than 40 percent of farmers also perceived that the yield losses due to climatic adversities were even up to 50 percent during the last two decades in spite of following management practices. The results also indicated that there has been a declining trend in yield for the farmers who used to achieve more than 2,000 kg per ha. They are also of the opinion that the adverse weather condition during the soybean crop season has affected the yield losses. Therefore, more efforts should be taken to develop climate-resilient varieties as well as technologies considering the prevailing climate factors.

Soybean is commercially grown for the last five decades predominantly by small and marginal farmers of central India and has witnessed a remarkable increase in area and production (Agarwal *et al* 2013). Madhya Pradesh has continued to contribute a major chunk of soybean area and production in the country (more than 55%) and therefore is known as Soya State. Malwa Plateau having black cotton soils has been considered an epicenter of the soybean revolution in India (Tiwari *et al.* 2003). However, the average soybean productivity of the area has recently seen stagnation and is adversely affected. Unavailability of critical input including quality soybean seed and, yield losses on account of incidences of insect pests and diseases and certain abiotic factors are cited as the major problems for the same (Dupare *et al.* 2009 & 2010,). One of the reasons for the low/stagnant productivity is the rainfed nature of the crop which is grown during the *kharif* season and exposed to adverse climate experienced during the last two decades.

The studies on the impact of climate change in India revealed the changes with respect to increased seasonal temperature, the occurrence of more events like severe and prolonged droughts, delayed onset of monsoon, uneven distribution and variation in seasonal rainfall, less rainy days of high-intensity rainfall, heat waves, etc. According to the results of the study conducted by Mishra *et al.* 2016, a majority of the state of MP experienced a significant decline in the monsoon, and air temperature increased significantly in the post-monsoon (October- December) along with an increase in the frequency of severe, extreme, and exceptional droughts and a number of hot days. The studies of Mall *et.al.* 2006; Guhathakurta and Rajeevan 2008; Dash *et al*. 2009; Dash and Mamgain 2011; Jain and Kumar 2012; Birthal *et al.* 2015; Oza and Kishtawal 2015, 2016; Mishra *et al*. 2016; Kumar *et al*. 2010) have also reported similar findings. With this background, a study was conducted with 280 soya farmers belonging to three major districts of Madhya Pradesh to know their perception of the climatic variation in the area and its relative impact on soybean yield levels.

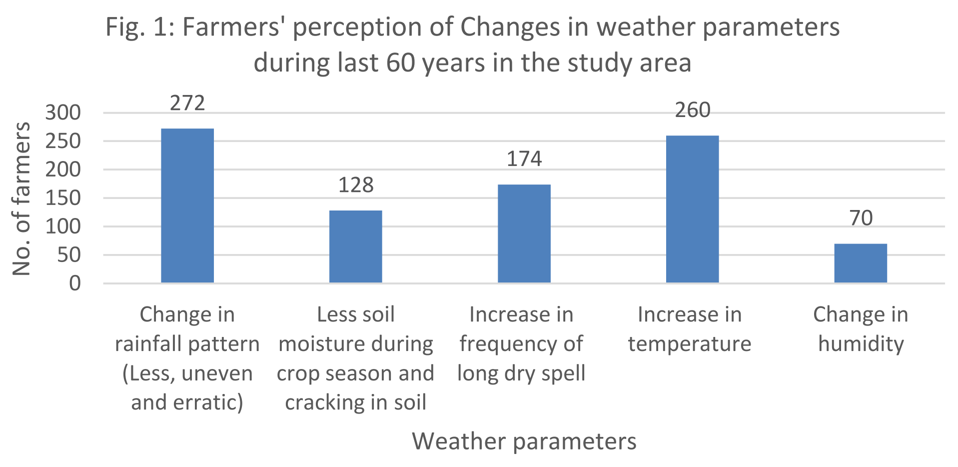
MATERIALS AND METHODS

The study was conducted in three major soybean growing districts viz. Dewas, Indore and Dhar districts of Madhya Pradesh state in Central India constituting a sample of 280 soybean growers drawn randomly from six selected villages from whom the primary data was collected using an interview schedule containing basic information of the respondents on cropping pattern followed by them during the last five decades. The open-ended questions included in the interview schedule on changes in the weather parameters like long-term changes in rainfall and temperature, as well as farmers' experience and their opinion about the prevailing climatic situation as well as its impact on crops were also included.

RESULTS AND DISCUSSION

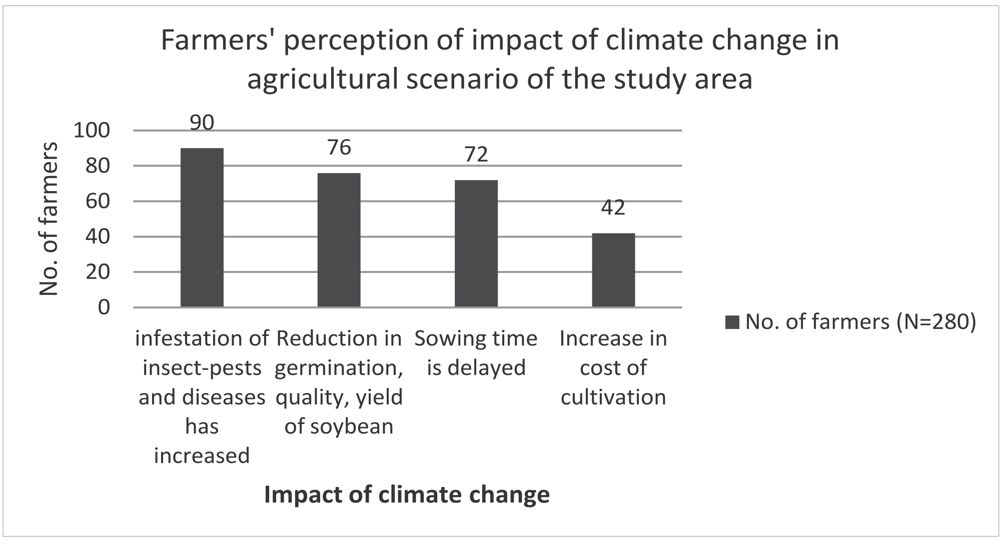
Farmers' perception of changes in climate parameters during the last 60 years

The majority of the farmers have agreed with their fellow farmers' perception that they have seen drastic changes in the pattern of rainfall during the last 60 years, particularly on account of its arrival and distribution throughout the *kharif* season (Fig 1). The delayed arrival of monsoon and its erratic distribution is felt by 97 percent of farmers. Similarly, around 93 percent of them have also perceived that the temperature has risen. Around 62 percent of the farmers have also experienced increased incidences of dry spells. Further, 45.71 percent of the farmers also reported having observed the soil moisture deficit condition more frequently nowadays. In addition, a small proportion of the farmers also perceive to report a decrease in humidity gradually during the last sixty years. The published reports of Mishra et.al. 2016, Mall *et al* 2016, Kawadia and Tiwari 2017; Mall *et al*. 2017; Singh *et al*. 2017; Rama Rao *et al*. 2018; Ramdas *et al*. 2018) also reported similar results.



Farmers' perception of the impact of changed climate during the last 60 years

The respondents were asked about the visible impact of climate change as perceived by them in their area and how it affects their farming as a profession. According to their responses, climate change has affected their farming in terms of the increased cost of cultivation for control of insect pests and diseases which has seen a sharp increase and decline in yield and viability of soybean seed and delayed arrival of monsoon causing a shift in sowing time. It can be seen from the data presented in Fig.2, the majority of the respondents (32%) perceive that the infestation of the insect pest and diseases has increased. They (27.14%) also perceived that climate change has also affected on yield of soybean which has seen a decline besides seed viability. Similarly, about one-fourth of them (25.71%) feels that the sowing time for their *kharif* crop is delayed while the remaining 15% of respondents perceive the increased cost of cultivation as having a major impact on their overall farming. As per the simulation results (Mall *et al.* 2003), the sowing of soybean in central India might be delayed from June and the first week of July to the first fortnight of August. Similarly, Ramteke *et al*. (2015) noted that there is a shift in the peak rainfall from July to August, and the total rainfall during the peak month was reduced. The rainfall during the field emergence and vegetative growth of the soybean crop has been reduced.



Perception of farmers about the changes in crops grown in the area

An effort was made to document prominent changes experienced by the farmers in their area. These changes were documented decade wise starting from 1960-70 till the last decade. This includes the perception of farmers about the change in cropping pattern in the area, weather parameters like rainfall (arrival, distribution, and total receipt), temperature, humidity, and sunlight intensity as given in the following sub-heads.

The data presented in Tables 1 and 2 reflect the change in the cropping pattern experienced by the farmers both during the *kharif* and *rabi* seasons. It can be noted that the crops like Groundnut, Pigeonpea, Sorghum, Green gram, and Black gram which were grown earlier are now out of cultivation in the area. But cotton, earlier preferred by the farmers of both Malwa and Nimar Region has lost its base in Malwa but still is a popular *kharif* crop grown by the farmers of the Nimar region.

The same is the case of Maize, a most preferred crop grown by more than 75% of farmers during the 1970s, which has gradually seen a reduction in area. But it is quite interesting to note see the remarkable response given to soybean for its cultivation by the farmers of central India. The crop had a negligible presence during the 1970s, has fascinated the farmers and gradually occupied a prominent place after the 1980s, and is grown almost by every single farmer in the study area.

So far as the changes in the crops grown during the *rabi* season are concerned, the data indicated (Table 2) the progress of farmers who gradually created irrigation facilities and thus increased the area under wheat in place of chickpea which otherwise was a preferred crop grown in marginalized condition. The same trend was seen in the case of potato, onion, and garlic which has increased area consequent to the up-gradation of irrigation sources particularly tube wells and canals, and has removed crops like Lentil, Linseed, and Barley completely from the picture in the study area.

Perception of farmers about the changes in weather parameters

The data related to the changes in weather parameters as perceived by the farmers of the study area as given in Table 3 gives a clear indication of the monsoon arrival pattern. The majority of the farmers (97.14%) believe that the arrival of monsoon which earlier used to be the first week of June is delayed by a fortnight and follows the pattern of uncertainty and variation within the district/block/village level. Similarly, more than 80% of farmers perceived that the distribution of rainfall is mostly erratic nowadays and distribution is uneven as experienced during the period of last six decades. The change in the distribution of rainfall by the majority of farmers (61%) started during 180-90 and is now endorsed by around 81% of farmers who perceived that the distribution of rainfall is mostly noted the change in the distribution of rainfall since 1990-2000. So far as the receipt of rainfall is concerned, the change was also noted by most of the farmers. According to them, earlier during 1960-70 the area used to receive about 50″ rainfall during the *kharif* season. But from 1990 onward, the receipt of total rainfall started declining and the majority of the farmers (72%) perceive that it is reduced to about 35″-40″. The data relating to the perception of farmers about the change in temperature during the *kharif* season is presented in Table 3. The majority of the farmers have perceived that the day temperature has started increasing since 2000-10 and is now very hot compared to 1960-70. A similar trend is also noted in the case of relative humidity.

The majority of the farmers have perceived that they have seen the change in the humidity which started a declining trend during 1990-2000 giving this impression.

Similarly, the majority of the farmers in the study area are of the opinion that the daytime sunlight intensity (photoperiod) has also seen an increase during the last six decades. This change was conspicuously noted for the last two decades. The majority of the farmers (95%) also perceived that earlier during 1960-70 the sunlight intensity was less but now it is very high and thus giving an impression of increased incidences of heat strokes.

Farmers' perception of the extent of yield loss due to climatic adversities

The farmers were asked whether they felt any effect of changing climate on the reduction in yield of *Kharif* crops. According to the data given in Table 4, 65% and 40% of the farmers felt that the climatic adversities have resulted in about 31-40 per perceive that during the decades 2000-2009 and 2010-2019. It is also mentioned that about 37% of farmers also believed that during the last decade, the yield losses due to climatic adversities could be as high as 40-50 percent in spite of the adoption of recommended production technologies. The results clearly indicated that yield loss in the *Kharif* crops due to aberrant weather conditions has increased over the years as perceived by the farmers in the study area. Some of the studies on the perception of the farmers about climate change in Madhya Pradesh found that 70% of the farmers identified a significant decrease in crop yield induced by an increase in an insect-pest infestation. in soybean is the major cause of reducing the realized yield (Kawadia and Tiwari, 2017; Punithavalli *et al*. 2014).

Table 1: Changes in *kharif* crops grown in the area during last six decades

Period	Cotton	Groundn ut	Pigeon pea	Sorghum	Green gram	Black gram	Maize	Soybean	Chili
1960-70	78(27.85)	80(28.57)	82(29.28)	238(85.0)	24(8.57)	18(6.42)	146(52.14)	-	-
1970-80	10(3.57)	34(12.14)	40(14.28)	222(79.28)	18(6.42)	10(3.57)	212(75.71)	2(0.71)	-
1980-90	24(8.57)	4(1.42)	-	28(10.00)			54(19.28)	194(69.28)	-
1990-00	28(10.00)	-	-	6(2.14)			28(10.00)	220(78.57)	4(1.42)
2000-10	22(7.85)	-	-				2(0.71)	262(93.57)	16(5.71)
2010-20	16(5.71)	-	-				16(5.71)	280(100.00)	18(6.42)

Table 2: Changes in rabi crops grown in the area during last six decades

Period	Wheat	Gram	Lentil	Linseed	Barley	Sugarcane	Potato	Garlic	Onion
1960-70	26(9.28)	252(90.00)	58(20.71)	2(0.71)	1(0.35)	22(7.85)	-	-	-
1970-80	26(9.28)	248(88.57)	36(12.85)	-	-	8(2.85)	2(0.71)	2(0.71)	-
1980-90	264(94.28)	210(75.00)	-	-	-	2(0.71)	20(7.14)	12(4.28)	6(2.14)
1990-00	214(76.42)	98(35.00)	2(0.71)	-	-	-	128(45.71)	92(32.85)	32(11.42)
2000-10	218(77.85)	94(33.57)	-	-	-	-	146(52.14)	114(40.71)	58(20.71)
2010-20	242(86.42)	104(37.14)	-	-	-	-	152(54.28)	126(45.00)	72(25.71)

Table 3: Perception of farmers about the changes occurred in the weather parameters

Weather parameter	1960-70	1970-80	1980-90	1990-2000	2000-10	2010-20
1. Arrival of monsoon in the area						
First week of June	272(97.14)	268(95.71)	154(55.00)	16(5.71)	-	-
Second week of June	8(2.85)	12(4.28)	126(45.00)	222(79.28)	204(72.85)	162(57.85)
Third week of June	-	-	-	8(2.85)	-	-
Last week of June	-	-	-	34(12.14)	66(23.57)	86(30.71)
First week of July	-	-	-		10(3.57)	32(11.42)
2. Distribution of rainfall						
Even	256(91.42)	262(93.57)	186(66.42)	70(25.00)	26(9.28)	18(6.42)
High	18(6.42)	16(6.42)	22(7.85)	14(5.00)	-	-
Less	6(2.14)	2(0.71)	2(0.71)	20(7.14)	34(12.14)	36(12.85)
Uneven	-	-	70(25.00)	176(62.85)	220(78.57)	226(80.71)
3. Receipt of total rainfall						
30″-35″	2(0.71)	6(2.14)	10(3.57)	26(9.28)	56(20.00)	30(10.71)
35″-40″	22(7.85)	24(8.57)	112(40.00)	148(52.85)	166(59.28)	218(77.85)
40″-45″	34(12.14)	76(27.14)	86(30.71)	66(23.57)	56(20.00)	32(11.42)
45″-50″	18(6.42)	30(10.71)	22(7.85)	10(12.50)	2(0.71)	-
Above 50″	204(72.85)	144(51.42)	50(17.85)	30(10.71)	-	-
4. Temperature						
Low	268(95.71)	274(97.85)	264(94.28)	108(38.57)	16(5.71)	-
Medium	4(1.42)	4(1.42)	6(2.14)	10(3.57)	8(2.85)	4(1.42)
High	8(2.85)	2(0.71)	10(3.57)	162(57.85)	254(90.71)	112(40.00)
Very high	-	-	-	-	2(0.71)	164(58.57)
5. Humidity						
High	266(95.00)	266(95.00)	268(95.71)	54(19.28)	10(3.57)	12(4.28)
Medium	4(1.42)	4(1.42)	2(0.71)	22(7.85)	14(5.00)	
Less	10(3.57)	10(3.57)	6(2.14)	192(68.57)	244(87.14)	114(40.71)
Very less	0	0	4(1.42)	12(4.28)	12(4.28)	146(52.14)
6. Sunlight intensity						
Less	260(92.85)	274(97.85)	138(49.28)	46(16.42)	6(2.14)	2(0.71)
Medium	20(25.00)	4(1.42)	6(2.14)	4(1.42)	22(7.85)	0
High		2(0.71)	36(12.85)	230(82.14)	250(89.28)	106(37.85)
Very high	0	0	0		22(7.85)	20(7.14)

Table 4: Farmers' perception of yield losses in soybean due to climate change

Yield loss	1960-70	1970-80	1980-90	1990-2000	2000-10	2010-20
No loss	232(82.85)	210(75.00)	22(7.85)	240(85.71)	96(34.28)	54(19.28)
Up to 20%	10(3.57)	40(14.28)	230(82.14)	2(0.71)	-	8(2.85)
21-30%	38(13.57)	8(2.85)	28(10.00)	-	-	-
31-40%	-	22(7.85)	0	38(13.57)	182(65.00)	114(40.71)
41-50%	-	-	-	-	2(0.71)	104(37.14)

CONCLUSIONS

The farmers of the study area during the last few years have experienced adverse climatic conditions, particularly the delayed, erratic and uneven distribution of rainfall, increased chances of a long dry spell, and increase in atmospheric temperature which is reflected in their perception. They are also of the opinion that the adverse weather condition during the soybean crop season has affected the yield losses. However, more efforts should be taken to develop climate-resilient varieties as well as technologies considering the prevailing climate factors.

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Effect of Different Organic Formulation on Growth and Yield of Soybean in South-Eastern Rajasthan

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ABSTRACT

A field experiment was conducted at Research Farm of Agricultural Research Station (Organic Block, field No. 14), Ummedganj, Kota during kharif season 2020 on clay loam soil to study the "Effect of Different Organic Formulation on Growth and Yield of Soybean in South-Eastern Rajasthan" which was laid out in randomized block design with three replications. The experiment comprised of tenth treatments viz. T_1 *(Control),* T_2 *(100 % OM + 10% CU),* T_3 *(100 % OM + 5% Panchgavya),* T_4 *(75 % OM + 25 % VC + 10% VW),* T_5 *(50 % OM + 50 % VC + 10% VW),* T_6 *(75 % OM + JA 500 L/ha),* T_7 *(75 % OM + GJA 500 kg/ha),* T_8 *(100 % OM + LCB 1250 ml/ha),* T_9 *(75 % OM + LCB 1250 ml/ha),* T_{10} *(75 % OM + LCB 1250 ml/ha + 10% SG). In this experiment application of different organic sources were applied to the soybean variety "JS 20-34". A critical examination of data revealed that significantly higher plant height (40.9), number of branches/plant (4.9), total number of nodules/plant (45.0), effective nodules/plant (40.3), chlorophyll content (3.28 mg/g), plant dry weight (105.3 g/mrl) and crop growth rate (13.40 g/m*^{2}*/day) were observed in application of 50% OM + 50% VC + VW spray 10% over control at 45 DAS. Application of 50% OM + 50 %VC + VW spray 10% was recorded significantly higher number of pods/plant (45.0) and pod length (4.75 cm), seed yield (2120 kg/ha), straw yield (3111 kg/ha) and biological yield (5231 kg/ha) as compared to over rest of treatments. It can be inferred from the economic assessment of data that all the different organic formulation treatments recorded significantly higher gross return (₹125934), net return (₹91346), B: C ratio (2.64) and production efficiency (23.82 kg/ha/day) were recorded in application of 50% OM + 50% VC + VW spray 10% as compared to over rest of treatments.*

Keywords: Soybean, Organic manure, Vermicompost, NPK Liquid consortia of biofertilizer

Organic farming as a sustainable production management system provides long-term benefits to people and the environment (Hans, 2014). It is not new in India but it has been practiced since immemorial. Organic farming is a unique production management system which promotes and enhances agro-ecosystem health including biodiversity, biological cycles and soil biological activity and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs (viz. fertilizers, pesticides, hormones and feed additives) and to the maximum extent feasible rely upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection (Raahinipriya and Rani, 2018).

Soybean (*Glycine max* L.) is an important pulse as well as oil seed crop. It is believed to be originated in China in around 2838 B.C. (Singh *et al*., 2010). Global soybean area and production in 2021 is expected to be 130.98 million ha and 348.44 million tons. India ranks fifth in the world in production after USA, Brazil, Argentina and China and fourth ranks in area after Brazil, (AMIS, FAO estimates 2021-22) USA and Argentina, these accounting for 80% of the world's soybean supply. Presently soybean production in India is 13.2 million tonnes from 12.5 million ha area and with an average productivity of 1060 kg/ha (AMIS, FAO estimates 2021-22). It contributes 40% of oilseed area and 25% of edible oil production. Soybean is mainly grown in central part of the country, Madhya Pradesh, Maharashtra and Rajasthan contributing about 95% of the production (Prajapat *et al*., 2014). In central India, major three soybean producing states, Madhya Pradesh produces 5.85 million tonnes production from 4.18 million ha area, Maharashtra 4.04 million tonnes from 4.54 million ha area, and Rajasthan, 1.1 million tonnes from 0.86 million ha area (AMIS, FAO estimates 2021-22) with average productivity of 761 kg/ha (SOPA 2021-22) while, mainly grown in the districts of Jhalawar, Kota, Baran and Bundi.

Soybean is known as 'vegetarian meat', 'wonder crop', 'miracle crop and "*Golden Bean*" of the 20th Century and it continues to be sown in the current millennia. It is an excellent health food and it contains about 40 to 42 per cent good quality protein rich lysine, 20 per cent Cholesterol free oil have essential fatty acid (Omega-6 and Omega-3), 20-26 per cent carbohydrates (Gowda and Kaul, 1982), 4 per cent minerals and 2 per cent phospholipids (Halwankar *et al*., 1992). In addition to this, it also contains vitamin A, B, C, D, E, K (Rahman, 1982) and all other essential amino acid. It is used in the manufacturing of anti-biotics and for producing soya milk and soya protein in food industries (Gahukar, 1997). Continuous cropping without adequate restorative practices may endanger the sustainability of agriculture (Dwivedi and Dwivedi, 2015 and Dwivedi *et al*., 2007) and proper management of soil fertility demands, careful identification of constraints of current nutrient status with monitoring the changes in soil fertility so as to sustain food production at a reasonable level to ensure continued high productivity in future (Nagwanshi *et al*., 2018). The adequate availability of organic manures in bulk, selection of suitable improved variety with solid and liquid organic manures that adapts itself under the peculiar climatic condition of humid south eastern plain zone V for sustainable organic production of soybean. Therefore, keeping the above facts in view, the objective of present study was therefore to evaluate, effect of different organic formulation on growth and yield of soybean in South-Eastern Rajasthan.

MATERIALS AND METHODS

The soil of the experimental field was clay loam, having BD (1.39), PD (2.57), Porosity (45.91), MWHC (40.05%), organic carbon (0.45%), pH (7.85), EC (0.38 dS/m), available N (348 kg/ha) available P_2O_5 (44.0 kg/ha) available K_2O (429 kg/ha), available Zn (0.79 mg/kg), available Fe (3.45 mg/kg), available Cu (0.50 mg/kg) and available Mn (3.05 mg/kg). The experiment was laid out in randomized block design with three replications and comprised of tenth treatments with different organic formulation, solid organic manures *viz*., farmyard manure and vermicompost which were calculated on the basis of 20 kg/ha nitrogen equivalency and ghanjeevamrut 500 kg/ha, jeevamrut 500 lit./ha, liquid consortia of biofertilizers 1250 ml/ha was applied as per treatment. Organic manure (FYM) was done 15 days before sowing, vermicompost incorporate just before sowing, jeevamrut, ghanjeevamrut and liquid consortia of biofertilizers applied at sowing or applied with first irrigation in soybean crop. Liquid organic manures *viz*., cow urine, vermiwash, panchgavya and sasyagavya sprayed on soybean crop at 30 and 45 day after sowing. Soybean variety JS 20-34 was sown in 30 cm apart at a seed rate of 80 kg seed/ha on the third fourth night of July. The crop was thinned 15 days after sowing to maintain a plant to plant spacing of 10 cm. The recommended cultural practices and plant protection measures were followed to raise the healthy crop. The crop was generally manually harvested in the second week of October. In order to test the significance of variation in experimental data obtained for various treatment effects, the data were statistically analysed as described by Panse and Sukhatme (1985).

Panchgavya was prepared with a mixture of five components in the ratio of 5:4:3: 2:1, *viz.,* cow dung, cow urine, milk, curd, ghee, tender coconut water and six ripe bananas. first of allow dung and cow ghee mix in plastic drum and kept it for 3 days then after mix remain ingredient were mixed and keep it for 21 days.

Jeevamrut was prepared with a mixture of five components (fresh cow dung 10 kg, 10 lit. cow urine, 2 kg jaggery, 2 kg chickpea flour and 1 kg sajiv soil (Soil below baniyan tree) for one acre use one time added in 200 lit. water. All the items added to a wide mouthed plastic tank having a capacity of 300 liters. The container should be kept under shade. This mixture is to be stirred twice a day in clock wise direction both in morning and evening. The Jeevamrut stock solution will be ready after 7 days. The volume of the final solution obtained is 200 liters. It was rate of applied @ 500 lit./ha at a time. It may be applied on soil when it is wet. It was also applied along with irrigation water in soybean crop.

Ghanjeevamrut was prepared with a mixture of five components (fresh cow dung 200 kg, 10 lit. cow urine, 1 kg jaggery, 2 kg chickpea Flour and 1 kg sajiv soil (Soil below baniyan tree). All the items mixed well and mixed materials should be kept under shade for 7 days, then after prepared materials is crushed/ bating by stick / stone in fine particles before use in field. The ghanjeevamrut becomes ready for use after 7 days and was kept in the shade. The rate of application is 500 kg/ha at a time applied on soil when it is wetted. It was applied as Basel dose as per treatment.

Sasaygavya was prepared with a mixture of six components in the ratio of 1:1:1:2:0.20:0.20 (fresh cow dung 5 kg, 5 lit. cow urine, 5 kg cutting of herbs (rich nutient weed, vegetable, fruits) 10 lit. water and added 1 kg (Leafs or Chatani of dhatura, deshi Tobacco, neem, and calotropis) as activator and 1 kg sajiv soil (Soil below baniyan tree) in prepared solution. All the items diluted mixed well in a wide mouthed plastic tank having a capacity of 50-100 liters. The container should be kept under shade. This mixture is stirred twice a day in clock wise direction both in morning and evening. The sasaygavya stock solution was ready after 15 days.

Vermiwash is a liquid extract obtained from vermicomposting process and used as an organic fertilizer for crop plant. To maintain the moisture level of cow dung kept in plastic tank, water is sprinkled to the vermicompost heap drop by drop. The earthworms eat up and digest the wet organic waste and thus some amount of water is absorbed by the earthworms. During vermicomposting process drained continue nutrient enrich solution from vermi-bed or heap in a pot generated wash which is an extract of not only earthworm-worked biomass but also the earthworm body fluids. This yellowish liquid released by the earthworms is known as vermiwash. Cow urine is a traditional output of dairy enterprise. Recent research suggests that in addition to milk, urine and dung obtained from cow are valuable resources of bioactive compounds, which can be converted into value-added products.

Beejamrut was prepared with a mixture of five components in the ratio of 1:5:5:0.5:0.1:0.025, *viz.,* water, cow dung, cow urine, milk, sajiv soil and lime respectively, (for treating 100 kg seeds) which was fermented for 12 hours, then the seeds of soybean were treated with filtered beejamrut @ 50 to 100 ml/kg for 5-7 minutes.

RESULTS AND DISCUSSION

A critical examination of data revealed that application of different organic sources significantly enhanced growth parameters at 45 DAS successive growth stages. Data referred that organic sources significantly influenced the plant height (40.9), number of branches/plant (4.9), total number of nodules/plant (45.0), effective nodules/plant (40.3), chlorophyll content (3.28 mg/g), plant dry weight (105.3 g/mrl) and crop growth rate (13.40 $g/m^2/day$) of soybean over control at 45 DAS. Significantly higher plant height, effective nodules/plant, chlorophyll content and crop growth rate were recorded in application of 50% OM + 50% VC + VW spray 10% and found statistically on par with application of 75% OM+ 25% VC + VW spray 10%, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + SA spray 10% and 75% OM + LCB 1250 ml/ha. Further data indicate that significantly higher number of branches/plant, total number of nodules/plant and plant dry weight per metre row length were observed in application of 50% OM + 50% VC + VW spray 10% and found statistically on par with application of 75% OM + 25% VC + VW spray 10%, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + SA spray 10% at 45 DAS. Maximum RGR (0.068 g/g/day) was recorded with application of 50% OM + 50% VC + VW spray 10% followed by application of 75% OM + 25% VC + VW spray 10%, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + SA spray 10%. The increase in plant height due to organic inputs might be growth attributed to increase in the availability of cytokinine to shoot which in turn play a role in cell elongation process either through cell division or cell elongation. Similar results have been reported by Bacchav *et al*., (1996) and Patil and Udmale (2016). Increase number of branches/plant might be due to availability of proportionate quantity of nutrients and organic formulation supplied sufficient quantity of phosphorus and other essential nutrient, these findings are in accordance with the results of Bish and Chandel 1991; Babhulkar 2000 in soybean. Increase nodulation application with organic manure such as Farmyard manure, vermicompost along with two spray of vermiwash may be linked to its impacts on availability of macro and micro nutrients, on moisture supply or on better soil structure creating a more favorable environment for nodulation (Rurangwa *et al*., 2018). Additionally, the significantly increased number of nodules/plant might have been due to the ready availability of nutrients like phosphorus, through liquid organic formulations, *i.e*., vermiwash as foliar spray at critical stages, which would have triggered nodulation. Similar findings were reported by Ahlawat and Omprakash (1996). The different solid and liquid forms of organic manures certainly played a role in steady release of nitrogen, iron and magnesium *etc*, which lead to the synthesis of chlorophyll content in an enhanced manner in soybean leaves. Application of organic manures such as Farmyard manure, vermicompost along with two spray of vermiwash this is balance supply of nutrient resulted in greater amount of chlorophyll a, b and total chlorophyll content thus the practical consequence of this effect is self-explanatory that other factors being favorable the greater amount of the solar energy utilized under optimum environmental condition will contribute to accumulation due to their greater photosynthesis capacity and convert to higher dry matter production thereby increased crop growth rate of soybean these results corroborate the finding Nagar *et al*., (2016); Elicin *et al*., (2021).

A perusal of data revealed that application of different organic sources significantly influenced yield attributes and yield. Application of 50% OM + 50 %VC + VW spray 10% was recorded significantly higher number of pods/plant (45.0) and pod length (4.75 cm), seed yield (2120 kg/ha), straw yield (3111 kg/ha) and biological yield (5231 kg/ha) as compared to over rest of treatments. Further data indicate that significantly higher number of pods/plant, pod length, seed yield, straw yield and biological yield were observed in application of 50% OM + 50% VC + VW spray 10% and found statistically on par with application of 75% OM + 25% VC + VW spray 10%, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + SG spray 10%. Maximum number of seeds/pod (2.77) and seed index (10.90 g) were recorded with application of 50% OM + 50% VC + VW spray 10% followed by application of 75% OM + 25% VC + VW spray 10%, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + SA spray 10%. It indicates that the increased availability of nutrients can affect the yield attributes and yields. Most nutrients are found continuously available in vermicompost such as nitrates, phosphates, soluble potassium as well as micronutrients, it has the highest potassium element compared to other manures, which is 1.2% where the potassium element functions to transport assimilated products in the form of photosynthate which is channeled into the pit in the form of pods, these results are in close conformity with the findings of Rahayu, *et al*., (2021). Combined application of solid and liquid organic manures is quite obvious, as these provide a steady supply of nutrients leading better growth of plants. Moreover, the increased availability of P and K in addition to other plant nutrients released by the organic manures might have contributed in enhancing the yield attributes. The positive impact of availability of individual plant nutrients and humic substances from manure and balanced supplement of nitrogen through liquid organic manures might have induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells, resulting in the enhancement of overall growth and development. The overall growth and development of crop is reflected in the development of yield contributing characters which affect the final yield of the crop as these parameters are positively correlated to seed yield. Yield is the synthesis and outcome of physiological biochemical process. The results corroborate with the findings of Verma *et al*., (2017).

It can be inferred from the economic assessment of data that all the different organic formulation treatments recorded significantly higher gross return (₹125934), net return (₹91346), B: C ratio (2.64) and production efficiency (23.82 kg/ha/day) were recorded in application of 50% OM + 50% VC + VW spray 10% as compared to over rest of treatments. Further data indicate that application of 50% OM + 50% VC + VW spray 10% was registered significantly higher net return and B: C ratio it was found on par with the application of 75% OM+ 25% VC + VW spray 10%, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + SG spray 10% and 75 % OM + LCB 1250 ml/ha. However significantly higher gross return and production efficiency was registered in application of 50% OM + 50% VC + VW spray 10%, it was found on par with the application of 75% OM+ 25% VC + VW spray 10%, 100% OM + LCB 1250 ml/ha and 75% OM + LCB 1250 ml/ha + SG spray 10%. The cost of integration of organic manure (farmyard manure + vermicompost + vermiwash) was compensated with the higher yield of soybean similar results were also reported by Verma *et al*., (2017). This trend in economic return is mainly due to the higher cost and treatment effect on the seed and haulm yield of soybean. Similar findings were respected by Ramesh *et al*., (2010), Chaturvedi *et al*. (2012), Konthoujam *et al*., (2013) and Gharpinde *et al*. (2014).

Table 1 Effect of different organic formulation on growth parameters of soybean

Treatment		Soybean growth parameters at 45 DAS							
		Plant height (cm)	**Branches/ plant**	**Total nodules/ plant**	**effective nodules/ plant**	**Chlorophyll (mg/g)**	**Plant dry weight (g/mrl)**	**CGR ($g/m^2/day$) At 30-45 DAS**	**RGR (g/g/day) At 30- 45 DAS**
T_1	Control	27.2	3.3	30.7	23	2.08	67	9.07	0.075
T_2	100 % OM + 10% CU	34.1	4.2	38	30.7	2.41	83	10.6	0.068
T_3	100 % OM + 5% *Panchgavya*	35.5	4.3	38.7	31.3	2.47	86	10.67	0.065
T_4	75 % OM + 25 % VC + 10% VW	40.6	4.8	44	38	3.11	103	13.13	0.068
T_5	50 % OM + 50 % VC + 10% VW	40.9	4.9	45	40.3	3.28	105.3	13.4	0.068
T_6	75 % OM + JA 500 L/ha	34.1	4.1	37.7	30	2.3	80.7	10.53	0.071
T_7	75 % OM + GJA 500 kg/ha	32.3	3.9	37	28	2.26	77.3	10.47	0.075
T_8	100 % OM + LCB 1250 ml/ha	40.4	4.7	43	37	3.03	101.3	13.07	0.069
T_9	75 % OM + LCB 1250 ml/ha	38.6	4.4	39.3	35	2.87	96	12.4	0.069
T_{10}	75 % OM + LCB 1250 ml/ha + 10% SG	38.7	4.6	41	36	2.89	100	13	0.07
SE ±		1.52	0.17	1.85	1.82	0.15	3.06	0.56	0.002
CD (P=0.05)		4.52	0.5	5.49	5.42	0.44	9.09	1.67	NS
CV(%)		7.26	6.77	8.12	9.59	9.57	5.89	8.37	5.77

OM= Organic manure, VC= Vermicompost, JA = Jeevamrut, GJA = Ghanjeevamrut, LCB= Liquid consortia of biofertilizers, CU= Cow Urine, VW= Vermiwash spray, SG= sasyagavya

Table 2 Effect of different organic formulation on yield attributes and yields of soybean

Treatment		Number of pods/plant	Number of seeds/pod	Pod length (cm)	Seed Index (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
T_1	Control	28	2.44	3.17	10.07	1020	1622	2642
T_2	100 % OM + 10% CU	35.8	2.55	3.81	10.57	1603	2467	4070
T_3	100 % OM + 5% *Panchgavya*	36.6	2.55	3.87	10.6	1726	2620	4347
T_4	75 % OM + 25 % VC + 10% VW	44	2.66	4.7	10.85	2010	2975	4985
T_5	50 % OM + 50 % VC + 10% VW	45	2.77	4.75	10.9	2120	3111	5231
T_6	75 % OM + JA 500 L/ha	34.4	2.55	3.77	10.55	1546	2407	3953
T_7	75 % OM + GJA 500 kg/ha	34.2	2.55	3.62	10.5	1493	2340	3833
T_8	100 % OM + LCB 1250 ml/ha	43.2	2.66	4.66	10.82	1886	2810	4697
T_9	75 % OM + LCB 1250 ml/ha	39	2.66	4.22	10.72	1755	2640	4395
T_{10}	75 % OM + LCB 1250 ml/ha + 10% SG	42	2.66	4.5	10.78	1835	2753	4588
SEm ±		1.99	0.09	0.14	0.17	110.4	128.4	236.2
CD (P=0.05)		5.91	NS	0.42	NS	328	381.5	701.8
CV (%)		9.01	5.95	6.03	2.82	11.25	8.64	9.57

OM= Organic manure, VC= Vermicompost, JA = Jeevamrut, GJA = Ghanjeevamrut, LCB= Liquid consortia of biofertilizers, CU= Cow Urine, VW= Vermiwash spray, SG= sasyagavya

Table 3 Effect of different organic formulation on economics and production efficiency (kg/ha/day) of soybean

Treatment		Gross return (₹/ha)	Net return (₹/ha)	B:C ratio	Soybean production efficiency (kg/ha/day)
T_1	Control	60965	31875	1.1	11.46
T_2	100 % OM + 10% CU	95583	62393	1.88	18.01
T_3	100 % OM + 5% *Panchgavya*	102827	67237	1.89	19.4
T_4	75 % OM + 25 % VC + 10% VW	119475	85486	2.52	22.58
T_5	50 % OM + 50 % VC + 10% VW	125934	91346	2.64	23.82
T_6	75 % OM + JA 500 L/ha	92287	60097	1.87	17.38
T_7	75 % OM + GJA 500 kg/ha	89153	56063	1.69	16.78
T_8	100 % OM + LCB 1250 ml/ha	112197	79597	2.44	21.2
T_9	75 % OM + LCB 1250 ml/ha	104445	72345	2.25	19.72
T_{10}	75 % OM + LCB 1250 ml/ha + 10% SG	109185	75185	2.21	20.62
SEm ±		6442	6442	0.19	1.24
CD (P=0.05)		19140	19140	0.58	3.69
CV (%)		11.03	16.37	16.46	11.25

OM= Organic manure, VC= Vermicompost, JA = Jeevamrut, GJA = Ghanjeevamrut, LCB= Liquid consortia of biofertilizers, CU= Cow Urine, VW= Vermiwash spray, SG= sasyagavya

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Influence of seaweed sap and phosphorus on growth and yield of soybean (*Glycine max* L.)

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ABSTRACT

*A field experiment was carried out during Kharif season of 2022, at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P.). The experiment field was entitled as "Influence of seaweed sap and phosphorus on growth and yield of soybean". The treatment consisted of 3 levels of seaweed sap foliar application (10, 15 and 20%) and phosphorus (50, 60 and 70 kg/ha) basal application and a control. The experiment was layout in Randomized Block Design (RBD) with 10 treatments andreplicated thrice. Application of seaweed sap 20% along with phosphorus 60 kg/ha recorded highest plant height (69.01 cm), maximum number of branches per plant (18.07), maximum plant dry weight (24.05 g), crop growth rate (21.16 g/m^2/day), higher number of pods per plant (126.27), maximum number of seeds per pod (3.00), seed index (8.73 g), higher seed yield (2.39 t/ha), highest oil content (19.33 %), maximum protein content (38.28 %) and the maximum gross return (1,42,037.93 INR/ha), net return (1,01,073.53 INR/ha) and B:C ratio (2.47)**.** This study shows that application of seaweed sap (Kappaphycus alvarezii and Sargassum spp.) 20% along with combination of phosphorus 60 kg/ha (Treatment 8) recorded higher yield and benefit cost ratio of soybean.*

Keywords: Soybean, Seaweed sap, Phosphorus, Growth, Yield and Economics.

Soybean (*Glycine max* L.) is a diploidized tetraploid (2n = 40), belongs to the family *Fabaceae* (*Leguminosae*), subfamily Faboideae (Papilionoideae). It is native to Eastern Asia, (Nagata, 1960) Suggested soybean origin in China, probably in North central region. The eastern half of north china is the area where soybean was first domesticated about 11th century BC. The lower and middle yellow river valley is the main area of origin of soybean (Chang *et al*., 1989). In India, it is known by several names as *Bhat, Bhatman, Bhatmas, Kulthi, Ramkulthi, Bhut, Kalitur, Teliakulth, and Gerakalay*. Soybean is considered as a 'wonder crop', 'Miracle crop' and 'Golden Bean' of 21st century which is the top oil seed in the world production. It is also instrumental in bringing the yellow revolution in the country. Out of nine oilseeds grown, soybean alone contributes nearly 20% to domestic vegetable oil production. It is an important oil seed and pulse crop in addition to source of food, feed and nutrition. Being the rich source of protein, it is also called "poor man's meat". It contains about 40-42% high quality protein, 20-22% edible oil, 20-30% carbohydrates, 4.5% minerals, 3.7% fiber, 8.1% water, large amount of Phosphorus, high level of amino acids such as lysine, lucien, lecithin and vitamins (Barik and chandel, 2001). Soybean products are widely used for human consumption. Common soybean products include; for seed making food - soy milk, soy beverage, soy curd, soy ice-cream, soy candy, weany foods (Protein+), soy nuts, cheese, soy snakes, nutria nuggets-50% protein. (Gahukar *et al*., 1997). For oil prepare products; varnish, paint, soap, painting ink, glycerine, and soya lecithin is some of the important products of soybean. World production of soybean is 333.67 million tons. From a total area of 120.50 million hectares. In India, it occupies an area of 12.1 million hectare with production of 12.9 million tons with an average productivity of 991 kg/hectare. Madhya Pradesh is known as the 'Soybean bowl' of India, contributing 45.86% of the total production of soybean in the country and deserves to be called 'Soya state'. Soybean has revolutionized social-economic condition of soybean farmers of Madhya Pradesh. Followed by Maharashtra with 37.79% contribution and Rajasthan with an 8.72% contribution. (Source; *Soybean Outlook, October 2021*).

The macroscopic marine algae are known as 'Seaweeds'. Seaweed sap from Red algae (*Kappaphycus alvarezii)* and Brown algae (*Sargassum spp*.) Seaweed extracts contains major and minor nutrients, amino acids, vitamins, minerals and growth regulators like; Cytokinins (Durand *et al.* 2003), Auxin the presence of indole-3-acetic acid (Sahoo, 2000), Gibberellins GA_3 and GA_7, (Strik and Staden, 1997) and Abscisic Acid **(**Hussain and Boney, 1973). Seaweed sap promote root and shoot growth, mineral absorption, also enhance photosynthesis rate and plant chlorophyll content (Blunden *et al*. 1997). It is a new generation of natural organic fertilizer containing highly effective nutrients, promotes growth and yield as well as enhance the resistant ability of many crop from biotic and abiotic stress. Unlike chemical fertilizers, extract derived from seaweeds are biodegradable, non-toxic, non-polluting and non-hazardous to humans, animal and birds

(Dhargalkar and Perira, 2005). It has been reported to stimulate the growth and yield of plants and also used to enhance the yield potential without impairing the soil health. Seaweed extracts have gained in popularity due to their potential use in organic and sustainable agriculture (Russo and Beryln, 1990).

Phosphorus is non-renewable and second most important macro nutrient. It is also called 'The key of life' because it regulates many metabolic activities of the plant life. It is taken by plants mostly as the primary orthophosphate ion ($H_2PO_4^-$), however, some is absorbed as secondary orthophosphate (HPO_4^{--}). Phosphorus is an important plant nutrient involved in several energy transformation and biochemical reactions including biological nitrogen fixation. Role of Phosphorus is root development, stalk and stem strength, cell division, photosynthesis, Flower and seed formation, resistance to plant diseases, crop maturity and production all the attributes associated with phosphorus nutrition. The most obvious effect of phosphorus is on the plant root system. It promotes early root formation and thus formation of lateral fibrous and healthy roots, which is very important for nodule formation and fixing atmospheric nitrogen in soybean. Phosphorus application significantly increases dry matter production as well as yield and yield contributing characters of soybean (Singh *et al.* 1973).

MATERIALS AND METHODS

A field experiment entitled "Influence of Seaweed Sap and Phosphorus on Growth and Yield of Soybean". Has been conducted at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj 211007, Uttar Pradesh During the *Kharif* season of 2022, with the following objectives to study the effect of seaweed sap and phosphorus on growth and yield of soybean. And to work out the economics of different treatment combinations. The Crop Research Farm is situated at 25.770 North latitude, 81.500 East longitude and 98 m altitude from the sea level, in the Northern Gangetic alluvial plains, Uttar Pradesh. The soil of experimental field was Sandy loam in texture, sand (59.25 %), silt (23.25 %) and clay (18.63 %). Chemical properties soil pH (6.9), with normal EC (0.296 ds/m), and organic carbon (0.29) contents. The NPK availability was medium (278.93 kg/ha), low (10.8 kg/ha) and high (206.4 kg/ha) respectively. The weekly minimum and maximum temperature ranged from 18.09 to 36.43 ˚C. Relative humidity ranged from 50.43 to 94.29 % and rainfall was 1282.1 mm, weather condition was normal throughout the crop season. The treatment consisted of 3 levels of seaweed sap foliar application (10, 15 and 20%) and phosphorus (50, 60 and 70 kg/ha) basal application and a control. Recommended dose of fertilizers of soybean is NPK 20:60:40 kg/ha. The experiment was laid out in Randomized Block Design along with 10 treatment combinations and replicated thrice. Ten treatment comprising of different levels of seaweed sap and phosphorus with control, 1. Seaweed sap (10%) + Phosphorus 50 kg/ha., 2. Seaweed sap (10%) + Phosphorus 60 kg/ha., 3. Seaweed sap (10%) + Phosphorus 70 kg/ha., 4. Seaweed sap (15%) + Phosphorus 50 kg/ha., 5. Seaweed sap (15%) + Phosphorus 60 kg/ha., 6. Seaweed sap (15%) + Phosphorus 70 kg/ha., 7. Seaweed sap (20%) + Phosphorus 50 kg/ha., 8. Seaweed sap (20%) + Phosphorus 60 kg/ha., 9. Seaweed sap (20%) + Phosphorus 70 kg/ha. and 10. Control (Farmer Practice) 20:60:40 NPK kg/ha. Treatments were randomly arranged in each replication, divided into 30 plots. Soybean variety JS – 335 was sown 30 cm row spacing with 10 cm plant to plant spacing on 4th week of July 2022. Sowing time application of nutrient and as per treatment basal application of phosphorus and as per treatment seaweed sap species from Red algae (*Kappaphycus alvarezii)* and Brown algae (*Sargassum spp*.) was foliar spray applied 20, 40, 60 and 80 DAS of intervals. Weed control hand weeding and other plant protection measures (Neem oil) were performed under all the treatments were applied in 500 liters of water per hectare using flat fan nozzle. Different observations on the crop parameters were carried out during the course of investigation. Data were recorded on growth attributes of soybean at 20, 40, 60, 80 days after sowing are plant height length from base to tip of the main axis, number of branches per plant were estimated on basis of five randomly selected plants from each experimental unit, Plant dry weight are three randomly uprooted plants without damaging the root from each plot, oven dry and weight analysis of plant. Crop Growth Rate was recorded at periodic interval. Yield attributes traits of soybean are number of pods per plant and number of seeds per pod was recorded from five randomly selected plants from each plot and then averaged and seed index (100 seeds weighed to the nearest 0.01g). The crop was harvest on 1st week of November, 2022 as per the treatments. The recorded data were further computed for an average hectare. Yield traits of soybean are seed yields and stover yield was recorded after threshing and the grains obtained were weighed plot-wise. The amount obtained in kilograms from the net area was converted into t/ha. Qualitative observations oil content percentage of soybean seeds was determined by Soxhlet's apparatus using petroleum ether as organic solvent (40-60 ˚C) as per the methodology of (Perry and Green, 1988). And nitrogen content percentage of soybean seeds was determined by Kjeldahl method and multiplied by a conversion factor (6.25) to get seed protein percentage (A.O.A.C., 1990). Finally economics viability of the treatments was also determined in terms of cost of cultivation (Fixed cost + Variable cost), Gross monetary returns (Grain yield market price INR/kg + Stover yield market price INR/kg), net monetary return (Gross return – Cost of cultivation), and benefit cost ratio (Net return (INR/ha) divided by Total cost of cultivation (INR/ha) on per hectare area basis. Data pertaining to various parameters were tabulated and subjected to statistical analysis as per method of analysis of variance (Fisher *et al*. 1947). The significance and non- significance of the treatment effect were judged with the help of 'F' test. The significant differences between the means were tested against the critical difference at 5% probability level.

RESULTS AND DISCUSSION

Growth attributes

Application of seaweed sap 20 % with combination of phosphorus 60 kg/ha (Treatment 8) recorded significantly higher growth attributes; plant height (69.01 cm) maximum number of branches per plant (18.07) and Maximum plant dry weight (24.05 g) at 80 days after sowing. Treatment 5 and 9 was found to be statistically at par with treatment 8. Similarly, significantly higher crop growth rate (21.16 g/m^2/day) recorded at 60-80 days after sowing. Were growth attributes observed highest under (treatment 8) in combination of seaweed sap 20 % along with phosphorus 60 kg/ha while minimum under (Treatment 10) application of control. (Table 1). Seaweed sap (*Kappaphycus alvarezii* and *Sargassum spp*.) contain multiple growth regulators such as Cytokinins (Durand *et al.* 2003), auxins (Sahoo *et al*. 2000), gibberellins (Strik and Staden, 1997) and various macro and micronutrients necessary for plant growth and development. Moreover, it helps in promoting the growth of beneficial soil microorganisms. Is might be due to presence of macro, micro nutrients, natural enzymes and plant growth hormones like cytokinine in seaweed extract which involved in boosting of number of branches through participating in cell enlargement during development of auxiliary buds of plant. Seaweed sap capable of increasing nutrient concentrations in leaves, through involvement of growth hormone in process of nutrient absorption and movements in a plant, thus increasing the weight of the plant. Similar results were supporting the findings of (Rathore *et al.* 2009) and (Pramanick *et al.* 2013). Similar, Essential role of phosphorus in legumes which support early root formation and development of lateral, fibrous and healthy roots. Phosphorus tends to increased growth and development in terms of plant height, branches and dry matter by improving nutritional environment of rhizosphere and plant system leading to higher plant metabolism and photosynthetic activity. These similar findings corroborate the results of (Tanwar *et al*. 2003) and (Kumawat *et al.* 2013)

Table 1. Effect of seaweed sap and phosphorus on growth attributes of soybean.

Treatment	**Plant height (cm)**	**No. of branches/plant**	**Plant dry weight (g)**	**Crop growth rate ($g/m^2/day$)**
1.	58.90	15.40	15.02	13.03
2.	60.13	14.90	15.21	12.94
3.	58.37	15.40	17.17	14.38
4.	60.53	14.60	15.28	12.99
5.	64.67	16.93	21.76	17.88
6.	60.93	15.27	18.64	16.11
7.	61.13	15.80	16.28	11.67
8.	69.01	18.07	24.05	21.16
9.	66.27	16.90	21.14	17.76
10.	54.83	13.63	14.29	12.89
SEm (±)	2.01	0.53	0.36	0.75
CD (P=0.05)	5.99	1.59	1.07	2.25

Yield attributes and yield

Application of seaweed sap 20 % with combination of phosphorus 60 kg/ha (Treatment 8) recorded significantly higher yield attributes; maximum number of pods per plant (126.27), number of seeds per pods (3.00) and seed index (8.73 g). Treatment 5 and 9 was found to be statistically at par with treatment 8. Yield attributes were found highest in (treatment 8) in which seaweed sap 20% was applied with combination of phosphorus 60 kg/ha. While minimum under (Treatment 10) application of control. Similarly, yield traits significantly higher seed yield **(**2.39 t/ha) observed under (treatment 8) in seaweed sap 20% was applied with combination of phosphorus 60 kg/ha. However, Treatment 5 was found to be statistically at par with treatment 8. Maximum Seed yield were recorded in (treatment 8) in which seaweed sap 20% was applied with combination of phosphorus 60 kg/ha and maximum straw yield (5.65 t/ha) were found in (Treatment 9) in application of seaweed sap 20% along with phosphorus 70 kg/ha which was superior over all other treatments (Table 2). Growth hormones like cytokinin and gibberellins along with other trace element havebeen detected in the extract of *Kappaphycus spp.* and *Sargassum spp.* which might be responsible for beneficial effects in the present study. Increase in yield and yield attributes may be due to the presence of plant growth regulators (indole 3 acetic acid, gibberellins GA_3, kinetin and zeatin) present in *Kappaphycus alvarezii* sap. Similar achievements reported by (Zodape *et al*. 2011). And Phosphorus promotes root growth, regulates many metabolic activities, ensures strong formation of plant, rapid physiological maturity, flowering, support seed formation, improve cold tolerance and ultimately enhanced the crop productivity reported by (Malavolta *et al*. 1989). Stover yield of soybean was also increased with increasing level of phosphorus fertilizer. The higher value of stover yield at higher level of phosphorus is owing to significantly higher value of dry matter per plant besides the other growth and yield parameters. These findings are in conformity with the results of (Sarkar, *et al.* 1997).

Table 2. Effect of seaweed sap and phosphorus on yield attributes and yield of soybean.

Treatments	Number of pods/plant	Number of seeds/pod	Seed index (g)	Seed yield (t/ha)	Stover yield (t/ha)
1.	98.73	2.60	7.37	1.83	5.48
2.	104.33	2.47	7.33	1.74	4.85
3.	94.33	2.53	6.98	1.42	5.00
4.	109.87	2.73	7.21	1.53	5.23
5.	114.47	2.93	8.40	2.18	5.29
6.	109.53	2.80	7.55	1.61	5.10
7.	82.33	2.47	7.77	1.83	5.16
8.	126.27	3.00	8.73	2.39	5.20
9.	111.87	2.93	8.33	2.02	5.65
10.	88.53	2.33	6.95	1.15	4.18
SEm (±)	5.46	0.12	0.23	0.08	0.25
CD (P= 0.05)	16.22	0.38	0.68	0.24	0.75

Quality parameters of soybean

The data showed that the highest oil content (19.33 %) and highest protein content (38.28 %) was observed in treatment 8 in which seaweed sap 20% was applied with combination of phosphorus 60 kg/ha which was superior over all other treatments. While minimum oil and protein content was observed under (Treatment 10) with application of control (Table 3). The application of seaweed sap also significantly increased oil content, oil yield, K, Na and crude protein of sunflower seed reported by (Osman and Salem, 2011). Similar, application of phosphorus significantly improves the oil content of many oilseed crops reported by (Brennan and Bolland, 2004). Oil content of soybean seed increases with increasing levels of phosphorus fertilizer (Prasad *et al*. 1991). Similarly, the protein content in seed increased mainly due to increase in nitrogen content in seed. Also found that protein content increased with the application of seaweed sap on different crop due to growth hormones and micronutrient present in seaweed sap reported by (Babu and Rengasamy 2012). An increase in protein content with the increasing levels of phosphorus might be due to increase in amino acids as well as improved nitrogen nutrition of crop resulting the better root growth and more efficient utilization of other nutrients and water by plant and the protein content in seed increases. Such positive effect of Phosphorus application on pulses has also been reported by (Awomi *et al.* 2012).

Table 3. Effect of seaweed sap and phosphorus on quality parameters of soybean

Treatments	**Oil content (%)**	**Protein content (%)**
1.	17.66	36.80
2.	17.33	36.93
3.	17.00	37.65
4.	18.22	36.85
5.	19.00	38.10
6.	17.80	36.95
7.	18.66	37.28
8.	19.33	38.28
9.	18.50	37.33
10.	17.01	36.50

Economics

Cost of cultivation was found maximum (41036.80 INR/ha) in (Treatment 9) in which application of seaweed sap 20 % with combination of phosphorus 70 kg/ha and with increase the dose of seaweed sap it increase gradually (Table 4). The maximum gross return (1,42,037.93 INR/ha) was found in (Treatment 8) closely followed by (130882.13 INR/ha) in (Treatment 5) application of seaweed sap 20 % with combination of phosphorus 60 kg/ha. While minimum gross return was recorded in (Treatment 10) with application of control. Maximum net return (101073.53 INR/ha) and Benefit Cost ratio (2.47) recorded in (Treatment 8) in combination of seaweed sap 20 % along with phosphorus 60 kg/ha. While closely found (90917.73 INR/ha and 2.27 respectively). And minimum net return (37727.13 INR/ha) and Benefit Cost ratio (1.04) recorded in (Treatment 10) with application of control (Table 4). At present, the use of natural seaweed products as substitutes to conventional inorganic fertilizers has gained importance. Seaweed fertilizers are better than other fertilizers and are very economical. Recent, research demonstrated that seaweed fertilizers can compete with other fertilizers and are very economical reported by (Gandhiyappan and

Perumal, 2001). Application of seaweed extract enhanced the early growth and yield attribute properties in legume plants and yield return 12-25% more than that of control achievement. Net return and Benefit: Cost ratio is the indicators to evaluate the economic viability of any crop production system. Variation in cost of cultivation was due to differential cost of concentration of seaweed sap associated with different treatments applied. Similar, reported by (Sethi and Adhikary,2008).

Table 4. Effect of seaweed sap and phosphorus on economics of soybean

Treatments	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	Benefit cost ratio(B:C)
1.	38892.00	126958.13	88066.13	2.26
2.	38964.40	105596.70	66632.30	1.71
3.	39036.80	88158.83	49122.03	1.26
4.	39892.00	94986.13	55094.13	1.38
5.	39964.40	130882.13	90917.73	2.27
6.	40036.80	99001.00	58964.20	1.47
7.	40892.00	111270.97	70378.97	1.72
8.	40964.40	142037.93	101073.53	2.47
9.	41036.80	122743.53	81706.73	1.99
10.	36364.40	74091.53	37727.13	1.04

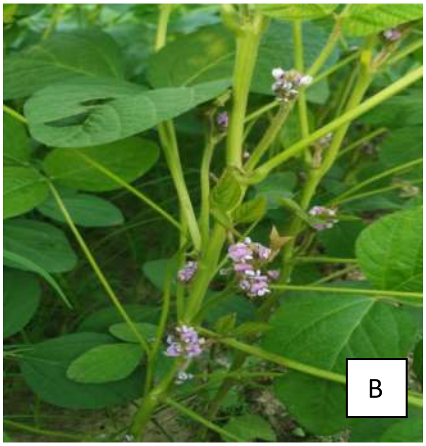

Plate (A and B). Field overview 30 days after sowing and flowering full bloom (R2) stage.

Plate (C and D). Experiment plot overview at time of full pod (R4) stage of soybean crop

Plate (E and F). Beginning of maturity (R7) stage and pods or soybean seeds overview.

CONCLUSION

It is concluded that application of seaweed sap (*Kappaphycus alvarezii* and *Sargassum spp*.) 20% along with combination of phosphorus 60 kg/ha (Treatment 8) recorded higher yield and benefit cost ratio of soybean.

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- A full paper should not exceed 4000 words (up to 15 typed pages, including references, tables etc.) Its contents should be organized as: Title, Author(s), Address, Abstract, Key words, Introduction, Material and Methods, Results and Discussion, Acknowledgements and References.

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

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

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

Pansae V G and Sukhatme P V. 1978. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi. pp.186. **(Book)**

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