

**Evaluation of Soybean Germplasm for Symbiotic Traits,
Nutrient Content and Yield Under Native Rhizospheric
Condition in Clay Loam Soil.**

THESIS



Submitted to the

**Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior
(M.P.)**

**In partial fulfilment of the requirements
for the Degree of**

**MASTER OF SCIENCE
In
AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)**

**BY
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2022**

CERTIFICATE – I

This is to certify that the thesis entitled “**Evaluation of Soybean Germplasm for Symbiotic Traits, Nutrient Content and Yield Under Native Rhizospheric Condition in Clay Loam Soil**” submitted in partial fulfilment of the requirement for the Degree of **MASTER OF SCIENCE (Soil Science and Agricultural Chemistry)** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bona-side research work carried out by **Ms. DAMINI PARASHAR ID.No. 20121302** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any degree or diploma (Certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been acknowledged by the scholar.

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This is to certify that the thesis the entitled “**Evaluation of Soybean Germplasm for Symbiotic Traits, Nutrient Content and Yield Under Native Rhizospheric Condition in Clay Loam Soil**” submitted by **Ms. DAMINI PARASHAR ID.No. 20121302** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfilment of the requirements for the Degree of Master of Science in **Agriculture in the Department of Soil Science and Agricultural Chemistry, R.A.K. College of Agriculture, Sehore** has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.

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Place : Sehore

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Date:

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Legend
&	And
@	At the rate of
°C	Degree Celsius
C.D.	Critical Difference
Cm	Centimeter
C.V.	Coefficient of Variation
DAS	Days after sowing
D.F.	Degree of Freedom
<i>et al.</i>	And others
Etc	and the rest
Fig.	Figure (s)
G	Gram
Ha	Hectare
HI	Harvest Index
i.e.	That is
K	Potassium
kg/ha	Kilogramme per hectare
L	Litre
MSS	Mean sum of square
Mg	Milligram
M	Meter (s)
N	Nitrogen
No.	Number (s)
NS	Non-significant
P	Phosphorus
T	Tonnes
R.V.S.K.V.V.	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
R.A.K.	Rafi Ahmed Kidwai
RH	Relative humidity
₹	Rupees
S.Em.±	standard error of mean
S.S.	Sum of Square
Viz.	Namely
□	Square root
%	Percent
±	Plus or Minus

CHAPTER - 1

INTRODUCTION

Soybean (*Glycine max* (L) Merrill) is the most widely grown worldwide as cash crops and has a high potential as a source of protein and oil, and it also enhances soil fertility for other crops by modifying the soil nitrogen budget. Soybean, commonly known as Soya, a protein rich pulse/oil crop has growing demand in Asia, especially in India because it can provide high quality protein in Indian diet. The plant has got immense medicinal value and is also used as fodder for cattle. There is need to enhance its productivity to meet the demand of growing population. The increase in soybean cultivation in India is likely to improve the rural economy and socio-economic status of the Indian farmers. Association of soybean with AM fungi increases the uptake of nutrients particularly phosphorus, zinc, and nitrogen as well as increasing crop production. The association of bradyrhizobial strains with the roots of soybean plants also improve soil health and nitrogen fixation thus further increasing crop production.

Soybean is known to be the highest protein and energy rich crop and its productivity is often affected by the low availability of essential nutrients or imbalanced nutrition is the important constraints to obtain soybean productivity in M.P. and other parts of India. It is the only pulse crop that contains 20-22% edible oil in the seed and 40% protein, 26% carbohydrates, 4% minerals, 2% phospholipids, rich in polyunsaturated fatty acid, vitamin C, 5- 6% crude fiber and lysine amino acid.

Soybean can be processed in many food products like de-oiled cake for cattle food and soya milk, soya paneer, aqua feed, soya curd, soya flour, fried and roasted soya nuts for healthy human diets.

The Madhya Pradesh is Known as “Fort of soybean” in India. The Total area under soybean crop is grown in India during Kharif 2021 was 12.2 million hectares with a production of 12.78 million tonnes. In Madhya Pradesh, soybean is an important Kharif legume and grown during 2021 in 5.51 million hectares, with a production of 6.68 million tonnes and productivity was 1285 kg/ha.

Among the different growth characters there may be change in nodulating traits, nutrients contents, growth patterns and yield of promising soybean germplasm, under native rhizospheric conditions due to different biotic and abiotic factors and therefore valuating the yield contributing traits and varietal adaptability and stability for nodulating ability in native rhizospheric conditions may be important factors in newly developed varieties for good quality of seed and high productivity.

Keeping in mind the above factors, the present investigation entitled "Evaluation of Soybean Germplasm for symbiotic traits, nutrient content and yield under native rhizospheric condition in clay loam soil." Has been carried out under All India Co-ordinated Research Project (AICRP) on soybean at R.A.K. College of Agriculture, Sehore (M.P.) during Kharif season 2021 with the following objectives

Objectives -

1. To study the symbiotic traits, growth and yield attributes of promising soybean germplasm under native rhizospheric condition.
2. To evaluate the soybean germplasms for nodulating ability, nutrients content and their uptake (N,P,K,S) in seed in native rhizospheric condition.
3. To estimate protein content in different germplasm of soybean.

CHAPTER - II

REVIEW OF LITERATURE

India has the 5th largest vegetable oil economy in the world. Soybean contributes 40% and 25% to the total oilseeds and edible oil production of the country and it earns a profitable foreign exchange by exporting soya meal. It is grown in several tropical and subtropical countries. It has a huge importance in the state economics and lot of research work has been done to increase the productivity of soybean but still per hectare yields are far below compared to the world average. There are numerous elements responsible for low yield of the cultivars with low productivity.

A brief resume of research work carried out in India on quantitative and qualitative feature of different cultivars of soybean and their effect on growth and yield of soybean has been presented here under the following heads:

- 2.1. Growth characters.
- 2.2. Yield attributing.
- 2.3. Grain yield and straw yield.
- 2.4. Nutrient content in seeds.

2.1. Growth characters as influenced by different germplasms of soybean under native rhizospheric condition in clay loam soil.

Soni (1984) observed that the plant height, branches plant⁻¹, leaves per plant, dry weight per plant, and dry weight of nodules per varied significantly among different varieties.

Nigam *et al.* (1989) have noticed highest total average dry matter plant⁻¹ in JS 76-188 (13.74 g) than other tested varieties.

Dubey and Billore (1993) observed at Sehore that soybean genotypes JS 81-335 and JS 81-1619 recorded higher nodule number plant⁻¹ among the genotype traits.

Mohammad Abbas *et al.* (1994) have concluded that erect type variety (JS 72-46) was superior in plant height (57.8cm), dry weight (17.5 g) , root nodules plant⁻¹ (32.5) while spreading type (JS 72-44) was superior in producing higher trifoliolate and branches plant⁻¹.

Choubey (1996) found that variety JS 89-27 produced more plant height, number of branch, trifoliolate, number and dry weight of root nodules plant⁻¹ and dry weight plant⁻¹ than remaining varieties.

Rajput and Shrivastava (1999) found at Morena that variety JS 71-05 was at par with JS 335 and significantly superior to PK 472 in respect to physiological parameters viz. CGR and NAR.

Parmar (2002) has found that variety JS 335 produced higher LAI and variety RAUS-5 had a higher number of branches, while variety JS 93-05 gave higher number of leaves. They further concluded that variety of JS 93-07 produced higher dry weight plant⁻¹.

Veni and Murthy (2003) reported that variety JS 335 produced higher plant height (42.55 cm) and higher number of branches (3.33).

Hakim *et al.* (2005) reported observed that cultivar spark produced the maximum plant height (92.67 cm).

Thakur and Vyas (2005) have concluded that variety JS 335 produced significantly higher plant height, number of branches, leaves per plant, dry weight plant⁻¹ and leaf area index (LAI), while variety JS 95-60 produced higher CGR and variety JS 93-05 gave maximum NAR.

Baghel and Singh (2009) found that plant height, number of branches, number of nodule plant⁻¹, dry weight plant⁻¹, dry weight of nodules found significant and JS(SH) 2004-8 and JS(SH) 2004-1 are found promising ones.

Rahman *et al.* (2013) found that the plant height, branches plant⁻¹, leaf area index(LAI), leaf area duration (LAD), total dry matter and crop growth rate (CGR) were varied significantly due to different cultivars. Cultivars BS-5 was highest for these growth parameter.

Reni and Rao (2013) evaluated forty live genotypes of soybean of divers origin for variability. Analysis of variance revealed highly significant differences among the genotypes for the all the characters. High PVC coupled with high GCV, observed for branches plant⁻¹, pods plant⁻¹, biological yield, harvest index and yield plant indicate the presence of wider adaptability for these traits in the genotypes studied, suggested the less influence of environment in the expression of characters.

Mondal *et al.* (2014) observed that variety BINA soybean-1 had greater root length, number of lateral root, pods bearing nodes, leaves plant⁻¹, plant height, leaf area plant⁻¹ and total dry mass plant⁻¹ than BINA soybean-2.

Solanki *et al.* (2014) studied stability for thirty newly development genotypes of soybean and found that G*E interaction was significant for most of the characters studied. They found stable genotypes namely RVS 2006-14, RVS 2006-27 and RVS 95-60.

Vyas and Khandwe (2014) reported that the cultivars JS 95-60 recorded significantly higher nodule (52.10) and nodule dry weight per plant (108.46mg), chlorophyll content (1.452mgg⁻¹), NAR (0.008mgcm⁻²day⁻¹), photosynthesis rate (19.90 micro, mol m⁻²sec⁻¹), stomatal conductance (0.643 mol H₂O m⁻²sec⁻¹) as compared to JS 97-52.

Chandrawat *et al.* (2017) conducted an experiment to evaluation of genetic variability present in the forty one genotype and five checks (two local +three nation checks) and observation were recorded on various yield and yield contributing characters viz., days to 50% flowering, days to maturity, plant height, no of branches plant⁻¹, no pods plant⁻¹, 100 seed weight, harvest index and grain yield plant⁻¹ at field level and oil content, protein content and trypsin inhibitor content in the laboratory. Analysis of variance showed the significant variability for all the studied characters. High values of GCV and PCV were observed for characters viz., number of pods plant⁻¹ (35.48, 38.62), plant height (23.49, 25.84), yield per plant(21.35, 24.86) and number of branches plant⁻¹(20.58, 24.22) which indicates the presence of high genetic variation.

Malviya and Jain (2020) have reported the enhanced nodulating abilities, growth, yields, and nutrient uptake (NPK, S)l a different soybean genotypes grown in a medium black soil AVT 2 Trial under All India Co ordinated Research Project on Soybean.

Jaiswal and Jain (2021) have reported the genotype RVS 2011-35 (1762.37 kg/ha) appeared largely suitable for sehere agro-climatic conditions in Vindhya plateau of Madhya Pradesh.

2.2. Yield attributing characters as influenced by different germplasms of soybean under native rhizospheric condition in clay loam soil.

Sharma and Sharma (1981) reported that soybean variety JS 81-335 gave significantly higher number of root nodules plant⁻¹ (64.62) among different varieties.

Soni and Vyas (1984) have inferred that plant height, branches plant⁻¹, leaves plant⁻¹, dry weight plant⁻¹ and dry weight of nodules plant⁻¹ varied significantly among different varieties.

The plant height, branches plant⁻¹, leaves plant⁻¹, dry weight plant⁻¹ and dry weight of nodules plant⁻¹ varied significantly among different varieties (Soni, 1984).

Singh and Sharma (1985) have reported that variety DS 76-1-29 produced significantly higher branches, trifoliates, pods plant⁻¹ and grain yield plant⁻¹. Singh et al. (1986) in an experiment have reported that Bragg had the highest 100 seed weight (19.75) than Ankur, UPSM-19, JS 2 and JS 72-46.

Nigam *et al.* (1989) have found that average number of pods plant⁻¹ were higher in Bragg. (28.50), while the seed index (18g) and harvest index (59.41) were significantly higher in JS 71-05.

Gwal (1990), Narolia (1990), Sony *et al.* (1990) and Yaduvanshi (1992) observed that seed yield was positively correlated with number of seeds pod⁻¹. While, Shinde et al. (1996), Patware et al. (2001) and Uchikawa et al. (2003) reported highly significant and positive association between grain yield and seeds per pod.

Narolia (1990) and Yaduvanshi (1992) recorded positively and highly significant correlation between seed yield and biological yield plant⁻¹. Singh *et al.* (1996) reported positive association; while Shukla *et al.* (1998) reported significant correlation between seed yield and biological yield per plant and negative association showed with harvest index reported by Patware *et al.* (2001).

Seed yield was positively and highly significant association with harvest index was reported by Narolia (1990), Yaduvanshi (1992), Mehetre *et al.* (1997) and Patware *et al.* (2001). While, Frederick and Hesketh (1994) observed positive significant correlation between these two traits. Singh *et al.* (1994) reported high positive association with grain yield plant⁻¹. Singh *et al.* (2000) reported negative correlation with almost all the characters under study except grains per pod.

Sharma and Sharma (1991) inferred that JS 81-335 produced significantly higher number of pods plant⁻¹ (43.56), grain yield plant⁻¹ (12.01g),

grain yield (2600 kg ha⁻¹) and grain efficiency production (23.70 kg ha⁻¹ day⁻¹) than other varieties JS 80-21, JS 81-220 and JS 81-714.

Dahtonde and Shava (1992) found that genotype MACS-13 was significantly superior in producing more number of pods and grain yield plant⁻¹ than PK-472.

Tiwari and Chourasia (1992) have found that yield attributes were higher with lower plant densities of 2.5 lakhs ha⁻¹ than high plant densities i.e. 3 lakhs and 3.5 lakhs per hectares.

Dubey and Billore (1993) have observed at Sehore that soybean genotypes JS 81-335 and JS 81-1619 recorded higher nodule number plant⁻¹.

Kim *et al.* (1993) found that harvest index was found in inter terminate index types of plants whereas seed index was higher in indeterminate types.

Kumari *et al.* (1993) have found that all tested varieties reaches at maximum plant height at 90 days after sowing. Maximum plant height (70.72 cm) was observed in Davis and JN 2750 cultivars. They further include that LAI is highest in JN 2750 (8.09) at 90 DAS.

Sharma and Sharma (1993) observed that CV JS 81-335 have significantly higher number of pods plant⁻¹ (43.56) and grain yield plant⁻¹ (12.01 g) followed by varieties JS 80-21, JS 220 and JS 81-214.

Jadhav *et al.* (1994) found that seed yield was highest at 0.3 million plants/ha as compared to 0.2 and 0.4 million plants ha⁻¹.

Mohamadd Abbas *et al.* (1994) have found that yield attributing character i.e. pods plant⁻¹, grain pod⁻¹, grain yield plant⁻¹, seed index, harvest index were significantly superior at population level of 0.4 million plants ha⁻¹ than 0.6 and 0.8 million plants ha⁻¹.

Mohammad Abbas *et al.* (1994) have observed that erect plant type (JS 72-46) was superior in producing higher pods plant⁻¹ (33.9): grain pod⁻¹ (1.75), grain yield plant⁻¹ (6.22g), seed index (11.89 g) and harvest index (42.28 %) than spreading types variety i.e. 72-44.

Paul and Guha (1994) have reported that number of branches, plant height ha⁻¹ (57.8) more in JS-2 than Bragg.

Sharma and Soni (1994) found that variety JS 87-28 produced higher number of branches, trifoliates, root nodules plant⁻¹, dry weight plant⁻¹ and variety JS (SH) -1310 recorded highest plant height than remaining varieties.

Bhosale *et al.* (1995) found that soybean CV MACS 13 sown with 2, 96,296,3,70,370 and 4, 44, 444 plants ha⁻¹ gave mean seed yield of 1.3, 1.36 and 1.34 t/ha respectively.

Choubey and Nema (1996) have found that variety JS 89-27 produced higher height, number of branches and trifoliates, number and dry weight of root nodules plant⁻¹, dry weight plant⁻¹ than remaining varieties.

Choudhary and Singh (2011) found pods per plant exhibited significantly highly positive correlation with biological yield plant⁻¹ and seed yield plant⁻¹ but non-significant positive correlation with harvest index. Seed index showed significant highly positive association with harvest index whereas maximum positive correlation observed between biological yield and seed yield plant⁻¹ (0.996).

Jain (1996) observed positive and highly significant association for the trait number of pods plant⁻¹ and biological yield plant⁻¹.

Karmakar and Bhatnagar (1996) found that genotypes PK-262, PK-564, PK-416, NRC-2 and PK-427 gave higher seed yield in rainy season.

Dubey and Nema (1997) have concluded that variety JS-335 produced higher number of root nodules plant⁻¹, dry weight plant⁻¹ and variety MAUS 53-2 superior in plant height while maximum number of trifoliolate recorded in MACS-431 than remaining varieties.

Mehtereet *et al.* (1997) have reported significant amount of variability in soybean genotypes for most of yield contributing characters.

Adams and Weaver (1998) reported that the plant population had no significant effect on number of seed pod⁻¹ and seed index.

AICRPS (1999) results reported from Indore that JS 71-05 recorded significantly higher seed yield (905 kg/ha) but was at par with JS-335 and DSb-1.

Pooranchand and Chand (1999) observed that the genotypic correlation for all characters studied were higher than the phenotypic correlation coefficients. Seed yield was positively correlated with branches, seeds per plant and pods per plant in terms of genotypic & phenotypic correlation coefficient. Plant height was negatively correlated with seed index.

Rajput and Shrivastava (1999) have found that variety JS 71-05 was at par with JS 335 and significantly superior to PK 472 in yield attributing characters.

Thorate et al. (1999) found genotypic and phenotypic coefficient of yield components were estimated using soybean cultivars. Seed yield was positively correlated with the number of pods plant⁻¹.

Billoreet al. (2000) have noticed in an experiment conducted at NRCS, Indore (M.P.) that the harvest index was higher in Ahilya 3 (85-51) and seed pod⁻¹ (1.87) was higher in JS 335 while seed index (12.7) was better in JS 71-05 and pods plant⁻¹ were highest in Ahilya 1 (39.03).

Dubey and Tomar (2000) reported increase in dry weight plant⁻¹ and seed yield ranged from 26.0 to 41.0% and 7.8 to 15.4%, respectively. The highest seed yield (19.45 q ha⁻¹) was recorded with Sehore.

Dubey and Tomar (2000) reported significant correlation was observed between nodule number and nodule dry weight, pods number, total biomass and seed yield.

Nimbalkar and Gujar (2000) found grain yield highly significant and positive correlation with plant height, number of nods plant⁻¹, number of pods plants⁻¹, number of seeds per plant and 100-grain weight. The greatest correlation ($r = 0.703$) was observed between grain yield plant⁻¹ and number of seeds plant⁻¹.

Panchariya and Lidder (2000) have reported that variety JS 90-41 produced higher seed index, pods plant⁻¹ and grain pod⁻¹ than other tested varieties.

Weilenmann et al. (2000) found that at the rainfed site, differences between cultivars for biological yield were not significant. They also revealed results revealed that correlation between biological yield and harvest index with economics were 0.59 ($P < 0.01$) at the irrigated site. Under irrigated conditions, there was a good positive correlation between biological, economic yield and harvest index

Agrawal et al. (2001) found that clusters plant⁻¹ and pods plant⁻¹ were the most important selection criteria for increasing seed yield..

Akbari and Peat (2001) have reported that number of branches and pods plant^{-1} , number of seeds per pod, seed index, and stem leaf and seed dry weight and plant height were found significant.

Patware *et al.* (2001) found that seed yield plant^{-1} possessed highly significant and positive correlation with harvest index, pods plant^{-1} and branches plant^{-1} but pods plant^{-1} exhibited positive and significant association with harvest index and biological yield per plant.

Rocha *et al.* (2001) found that yield attributing characters i.e. pods, seed per pod and seed index were higher at population level of 0.4 and 0.5 million plant/ha than other plant density.

Jain *et al.* (2002) found branches plant^{-1} (0.57), nodules plant^{-1} (0.54), pods plant^{-1} (0.66), seed per pod (0.64), seed yield plant^{-1} (0.80) and seed index (0.41) were positively and significantly correlated with seed yield.

Parmar and Nema (2002) have found that variety JS-335 produced higher LAI and variety RAUS-5 had higher number of branches, while variety MAUS 61-2 recorded highest plant height and variety JS 93-06 gave higher number of leaves. They further concluded that variety JS 93-07 produced higher dry weight plant^{-1} .

Parmar and Nema (2002) observed that NRC-41 produced highest grain yield (1746 kg ha^{-1}), while JS 93-05 produced highest straw yield with low yield potential.

Parmar and Nema (2002) observed that seed index was higher in MAUS 61-2. They further reported that seeds pod^{-1} was higher in JS 93-05 and pods plant^{-1} was higher in RAUS-5, while NRC-41 gave higher seed yield per plant. Chamundeswari (2003) observed that seed yield showed positive correlation with pods plant^{-1} and biological yield per plant. The other characters did not show any correlation with yield at the genotypic and phenotypic levels.

Dwivedi (2003) found that grain yield was significantly and positively correlated with dry weight indicated an increase in production in acid soil. Mandloiet *al.* (2003) found that JS-335 produced significantly pods plant^{-1} (17.13), seeds pod^{-1} (2.83), seed index (6.8), grain yield plant^{-1} (2.74g), grain yield (731.26 kg/ha) and harvest index (34.26).

Mandloi *et al.* (2003) have inferred that JS-335 gave significantly plant height (43.68), leaves plant^{-1} (10.02), root nodules plant^{-1} (124.16) and dry weight plant^{-1} (14.21).

Neupane *et al.* (2003) have concluded that genotype PK-416 gave higher yield with medium bold seeds.

Oneml (2003) found that the plant yield showed positive and significant correlations with the number of leaves, number of branches and number of seeds pod^{-1} .

Veni and Murthy (2003) have found that variety JS 335 produced highest number of pods plant^{-1} , seed index and harvest index as compared to other tested cultivars.

Islam *et al.* (2004) have reported that variety Shohag (Pb-1) produced greater plant height and number of branches plant^{-1} than BS-60 and BS-16.

Islam *et al.* (2004) reported that variety Shohag produced higher number of seeds pod^{-1} and pods plant^{-1} over BS-60 and BS-16.

Kaul and Vyas (2004) found that JS-335 produced significantly higher pods plant^{-1} (40.51) and seed index (11.69).

Kaul and Vyas (2004) have found that JS-335 produced significantly branches plant^{-1} , leaves plant^{-1} , number of root plant^{-1} , dry weight of root nodules and dry weight plant^{-1} .

Khan *et al.* (2004) have observed that variety Epps (Epps, MGV) produced tallest plants as compared with Williams 82 (Williams 82, MG 111).

Khan *et al.* (2004) observed that cultivars kharif as produced the highest number of pods plant^{-1} (45.67) and seed index (19.90g) than other tested cultivars.

Hakim *et al.* (2005) have observed that cultivars kharif 93 produced the highest number of pods plant^{-1} (45.67) and 100 seed weight (19.90 g) than other tested cultivars.

Kumar (2005) recorded significantly higher number of pods per plant (82.40) with SL-231 as compared to other cultivars.

Kumar *et al.* (2005) have reported that cultivars PK-472 produced the higher plant (84.91cm), while cultivars SL-231 produced significantly higher number of branches plant^{-1} (6.47) as compared to other cultivars.

Thakur and Vyas (2005) have concluded that variety JS-335 produced significantly higher plant height, number of branches, leaves per plant, dry weight plant⁻¹ and leaf area index.

Thakur and Vyas (2005) observed that variety JS-335 produced higher number of pods plant⁻¹ than other varieties, while variety JS 95-60 produced higher number of seeds pod⁻¹, seed index, grain yield plant⁻¹ and harvest index.

Thakur and Vyas (2005) reported that variety JS 95-60 produced highest grain yield (1012kg ha⁻¹) and straw yield (1370 kg ha⁻¹) than the other tested varieties.

Number of nodules plant⁻¹ and their dry weight along with protein content of different soybean genotypes are significantly enhanced under native rhizospheric conditions in vertisol (Anonymous, 2006-07).

Patidar *et al.* (2006) found genotypes RKS-18 produced significantly higher grain yield plant⁻¹ (8.66g) and genotype NRC-64 gave significantly higher harvest index (50.60).

Patidar *et al.* (2006) inferred that genotype RKS-18 produced significantly higher grain yield (2673 kg ha⁻¹) and straw yield (2012 kg ha⁻¹) among JS 97-51, JS-335, RKS-15 and NRC-64.

Patidar *et al.* (2006) reported that genotype JS 97-51 produced significantly tallest plant (78.83cm) followed by genotype RKS-18, RKS-15 and NRC-64.

Highly significant and positive association was observed by Yaduvanshi (1992), Kumar *et al.* (1997) and Mahetree *et al.* (1997) whereas, Singh *et al.* (1996) Dogney *et al.* (1998), Rajana *et al.* (2000) and Uchikawa *et al.* (2003) observed significant and positive correlation. Negative association was reported by Narolia (1990), Jagtap and Choudhary (1993) and Shinde *et al.* (1996) between seed index and grain yield.

Highly significant and positive correlation of grain yield with number of primary branches plant⁻¹ was reported by Jadhav *et al.* (1995) and Mehetree *et al.* (1997) and, significant and positive correlation was observed by Narolia (1990), Rajarathinam and Pandian (1996), Singh *et al.* (1996) , Taware *et al.* (1997), Patware *et al.* (2001) and Deka and Talukdar (1994) observed positive association ; while, Shinde *et al.* (1996) and Kumar *et al.* (1997) observed

negative correlation between primary branches plant⁻¹ and grain yield in soybean.

Samaiya *et al.* (2007) revealed that pod number, seed pod⁻¹ and seed weight is the major parameters of productivity. The maximum node and effective nodes plant⁻¹ were highest in cultivar JS 75-46. Cultivar JS 72-280 and JS 80-21 had higher number of branches plant⁻¹. Cultivar which had high total biomass had higher yield JS 80-21 and JS 75-46 recorded maximum biological yield.

Vaskela and Jain (2009) reported that highest NPK content was noticed both in seed and straw under the genotype JS-335 followed by NRC-7, MOUS-158 and RKS-24.

Singh (2011) reported that the podsplant⁻¹ and 100 seed weight were varied significantly due to different genotypes, genotype SL 525 was highest for these parameter.

Liu *et al.* (2012) worked on photosynthetic characters and their relationship with seed yield during the genetic improvement of soybean. For that purpose, they grew 38 soybean cultivar representing genetic improvement progress in northeast china, released between 1923 to 2005 (82 years) and reported that yield was positively correlated with photosynthesis, chlorophyll content and SLW, whereas the leaf area, Ci/Ca and WUE were negatively correlated.

Rahman *et al.* (2013) found the highest number of fertile and non-fertile pods/plant, number of seedspod⁻¹, number of seedsplant⁻¹, weight of 100 seed and maximum harvest index (47.72 %) in cultivar BS-5 and the lowest in cultivar G-2.

Mondale *et al.* (2014) observed that the number of pods, seedsplant⁻¹ and seed weightplant⁻¹ were significantly greater in BINA soybean-2 than in BINA soybean-1 but 100 seed weight was not significant.

Kolariket *et al.* (2014) reported the greatest grain weightplant⁻¹ (13.09 g) in cultivar Balkan.

Vyas and Khandwe (2014) reported that the cultivar JS 95-60 recorded significantly higher seed index (11.73 g), HI (51.64 %), net returns (38577 Rsha⁻¹) and B:C ratio (4.37) as compare to JS 97-52.

Kumar *et al.* (2015) studied correlation analysis of forty two soybean genotypes. Analysis of variance and mean performance for yield and its components revealed significant differences among all the genotypes for all the characters. Correlation was also found significant with yield and its component traits.

Njorage *et al.*, (2015) Evaluated fifteen soybean genotypes for yield and found variation among genotype in number of pods plant⁻¹, plant height, number of nodes plant⁻¹ and weight among the genotypes. They concluded that these traits are important components of seed yield.

Malviya and Jain (2020) have reported the enhanced nodulating abilities, growth, yields, and nutrient uptake (NPKS) a different soybean genotypes grown in a medium black soil AVT 2 Trial under All India Co ordinated Research Project on Soybean.

2.3 Grain and Straw yield as influenced by different germplasms of soybean under native rhizospheric condition in clay loam soil.

Sarathe and Singh (1983) have observed that grain yield varied significantly among the different varieties of soybean.

Sharma *et al.* (1984) have reported that bragg and UPSM 19 gave the highest seed yield of soybean.

Sharma and Singh (1985) have observed in a study that DS 76-1-79 produced significantly higher grain yield than other varieties.

Dheer Singh and Sharma (1990) have concluded in a study that determinate variety PK 262 gave higher grain yield (23.86 qha⁻¹) than indeterminate variety T- 49.

AICRPS (1995) indicated that variety PK-1068 recorded significantly higher grain yield (23.8q/ha) that check variety Pk-472 (19.14 qha⁻¹) was at par with other two check varieties i.e JS-335 (22.27 qha⁻¹) and JS-802 (20.21qha⁻¹).

Choubey and Nema(1996) have found that variety JS 89-27 produced higher grain and straw yield and grain production efficiency than other tested varieties.

Rajput and Shrivastava (1999) have found at Morena that variety JS 71-05 was at par with JS 335 and significantly superior to PK 472 in respect of seed yield of soybean.

Taware *et al.* (1997) have noticed observed that MACS-63 cultivars gave the highest yield (20.32 q/ha) followed by MACS-124 (19.59 q/ha) and MACS-13 (19.24q/ha).

Panchariya and Lidder (2000) have found in an experiment that variety JS 90-41 produced highest grain yield, grain production efficiency and harvest index compared to remaining varieties.

Kumar and Badiyala(2005) have reported that row spacing had no significant effect on grain and straw yield of soybean.

Hakim *et al.* (2005) have observed that cultivars kharif-93 produced the highest seed yield (2562 kg ha^{-1}) than other tested cultivars.

Pandya *et al.* (2005) have reported that variety JS 335 was significantly higher in seed and straw yield (16.09 and 25.84 q ha^{-1}) than other varieties.

Patidar (2006) found genotypes RKS-18 produced significantly higher grain yield per plant (8.66g) and genotype NRC-64 gave significantly higher harvest index (50.60).

Acko and Trdan (2009) found most productive cultivar was Borostyan (3974 kg ha^{-1}) and the lowest yield was recorded for Aldana (1472 kg ha^{-1}).

Singh (2011) reported that genotype SL 525 produced highest grain yield (2432 kg ha^{-1}) followed by SL 517 (1802 kg ha^{-1}).

Rahman *et al.* (2013) found that the cultivar BS-5 gave the highest seed yield (151.24 g m^{-2}) and stover yield (169.23 gm m^{-1}).

Mondal *et al.* (2014) observed that the significantly higher seed yield in BINA soybean-2 than BINA soybean-1.

Kolaric *et al.* (2014) reported that the highest grain yield was achieved with Balkan cultivar (4773 kg/ha) and the lowest with Dragana cultivar (4284 kg ha^{-1}).

Vyas and Khandwe (2014) reported that cultivar JS 95-60 recorded significantly higher seed yield (2274 kg ha^{-1}) as compared to JS 97-52.

Malviya and Jain (2020) have reported the enhanced nodulating abilities, growth, yields, and nutrient uptake (NPKS) a different soybean genotypes grown in a medium black soil AVT 2 Trial under All India Co-ordinated Research Project on Soybean.

Nutrient Uptake as influenced by different germplasms of soybean under native rhizospheric condition in clay loam soil.

Dinh *et.al.* (2014) showed that mid season drought significantly reduced the uptake of all nutrient elements. Peanut genotypes with higher levels of drought tolerance took up more nutrients than those with lower levels. The uptake of all nutrient elements contributed to biomass production, pod yield, and the number of pods per plant. ICGV 98305 was the best genotype with the highest uptakes of all observed nutrient elements.

Malviya and Jain (2020) have reported the enhanced nodulating abilities, growth, yields, and nutrient uptake (NPKS) a different soybean genotypes grown in a medium black soil AVT 2 Trial under All India Co ordinated Research Project on Soybean.

2.4. Nutrients content in seeds

Agarwal and Vyas (1971) reported that soybeans was sown on 5 dates in 1969. Oil content of the seed increased, but protein content decreased with increase in mean temperature (23.4°C to 28.2°C) from 50% flowering stage to harvest.

Islam *et al.* (2004) have reported that Shohag produced significantly higher protein content yield (24.5%) than BS-60 and BS-16.

Khan *et al.* (2004) have observed that cultivars produced highest protein content in seeds (26.3%) than other tested varieties.

Kumar *et al.* (2005) have recorded that PK-416 produced the highest protein content in the plant and seed analysis.

Roy and Roquib (1998) have found correlation values of the highest magnitude were observed for protein content in seeds. There exist an inherent positive association between the eight plant traits studied except between protein content in seeds.

Vyas and Khandwe (2014) reported that the cultivar JS 95-60 recorded significantly higher protein content (38.96 %) as compared to JS 97-52.

Malviya and Jain (2020) have reported the enhanced nodulating abilities, growth, yields, and nutrient uptake (NPKS) a different soybean genotypes grown in a medium black soil AVT 2 Trial under All India Co ordinated Research Project on Soybean.

CHAPTER III

MATERIAL AND METHODS

The present investigation entitled “**Evaluation of Soybean Germplasm for Symbiotic Traits, Nutrient Content and Yield Under Native Rhizospheric Condition in Clay Loam Soil** ” was conducted at the farm area of R.A.K., College of Agriculture, Sehore during the Kharif season of 2021-2022. The particulars of materials and methods used for ascertainment of various parameters are presented in this chapter. The general climatic, soil and crop conditions of experimental area have also been described here under.

3.1 Experimental site

The present experiment was laid out at the Research farm area under the All India Coordinated Research Project on Soybean, Department of Soil Science and Agricultural Chemistry, R.A.K. College of Agriculture, Sehore (M.P.), during Kharif season of 2021-2022. The experimental area having fairly uniform topography, normal fertility status and soil homogeneity.

3.2 Climate and weather condition

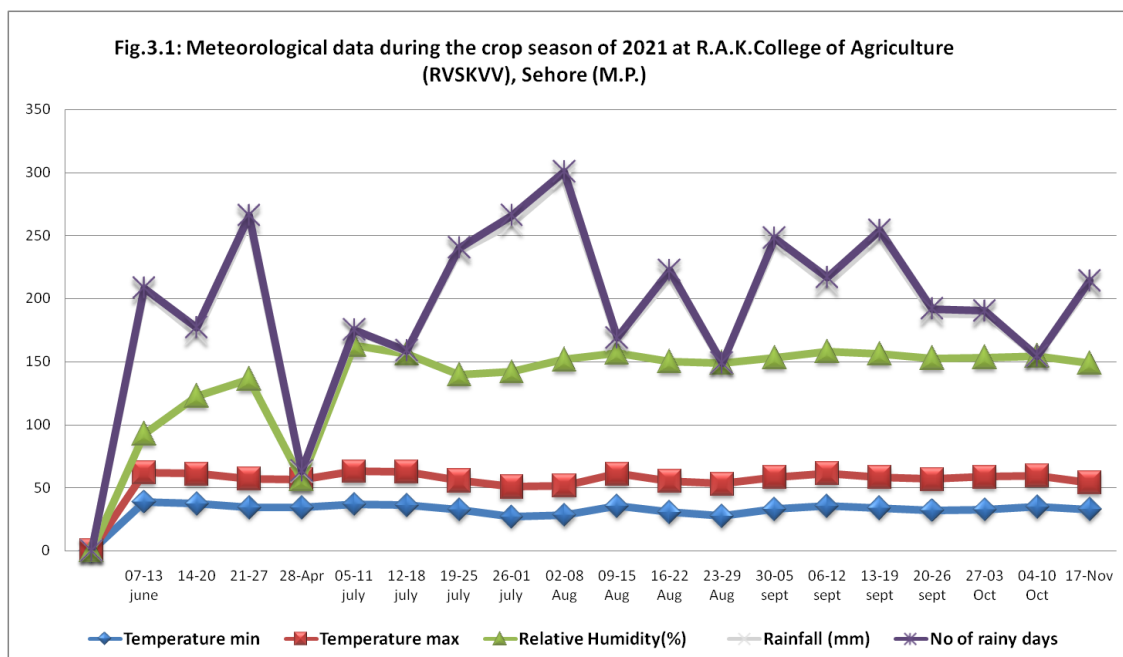
Sehore is situated in the eastern part of Vindhyan Plateau in sub-tropical zone at the latitude of 23^o 12' North and longitude of 77^o 05' East at an altitude of 498.77 m above mean sea level. The average rainfall of Madhya Pradesh varies from 1000 to 1200 mm concentrated mostly from June to September. The mean annual max and min temp are 31.16^oC and 18.5^oC, respectively. The summer months are hot and May is the hottest month with a max temp up to 45.60^oC. Winter months undergo mild cold with an average temp from 16.56^o C to 8.74^o C, The month of December is the coldest month as temp reaches up to 5^o C.

Meteorological data recorded during the period of experimentation are given in Table 1 and depicted in Fig 1

The weekly meteorological data viz., rainfall, temperature, relative humidity and number of rainy days during crop season were recorded in meteorological observatory of R.A.K. College of Agriculture, Sehore.

Table 3.1. -: Meteorological data during the crop season of 2021 at R.A.K. College of Agriculture (RVSKVV), Sehore (M.P.)

Month	SWW	Week	Temperature		Relative Humidity(%)	Rainfall (mm)	No of rainy days
			Max.	Min.			
June	23	7-13 June	38.3	23.4	76.23	112.8	3
	24	14-20	36.9	23.8	65.76	49.3	5
	25	21-27	39.95	23.24	69.0	90.23	4
	26	28-04	34.3	21.8	29.0	6.2	1
	Average		36.6	23.06		64.63	
July	27	05-11 July	36.5	26.3	76	11.5	1
	28	12-18 July	36	26.3	76.5	11.5	1
	29	19-25 July	32.20	23.2	75	98	3
	30	26-01 July	26.9	23.6	92.24	117.4	7
	Average		32.9	24.85		59.6	
August	31	02-08 Aug	27.9	23.6	94.76	143.3	6
	32	09-15 Aug	35.1	25.7	72.2	10	2
	33	16-22 Aug	30.1	24.9	85	67.4	5
	34	23-29 Aug	27.2	25.7	94	0	0
	35	30-05 Sept	32.7	25.3	82	91	4
	Average		31.5	25.04		62.34	
September	36	06-12 Sept	35.2	25.8	86	53.8	5
	37	13-19 Sept	33.7	24.4	74	93	5
	38	20-26 Sept	31.6	25	95	35.4	4
	39	27-03 Oct	32.2	26.1	93.64	34	3
	Average		33.17	25.32		54.05	
October	40	04-10 Oct	34.4	25	84	0	0
	41	17 Nov	32.5	21.2	85	62.5	3
		Average		33.45	23.1		31.25
					GT	1347.7	62



Source: Meteorological Observatory, R.A.K. College of Agriculture, Sehore (M.P.)

The data in Table 3.1 indicates that during the crop season total rainfall was 1347.7 mm which was sufficient for the growth and development of soybean, with maximum and minimum rain, ranged from 143.4 mm to 6.2 mm was observed in 31st and 26th meteorological standard week, respectively. The maximum temperature 39.95 was observed in 25th meteorological standard week, and the minimum temperature 21.8 was observed in 26th meteorological standard week, while the maximum relative humidity of 94.26 per cent was observed in 31st meteorological week and the minimum relative humidity of 29 percent was recorded in 26th meteorological week.

3.3 Soil

The soil of the experimental field clay loam in texture (medium black) having a slight slope from west to east, which provides good drainage.

To examine the initial soil fertility status of the soil, soil samples to a depth of 0-15 cm were taken from arbitrarily selected spots covering the entire experimental area with the help of soil augur before sowing. Those samples collected were analysed for various parameters in the soil-testing laboratory of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Sehore. The analysed values are presented in table 2.

Table -2: Chemical composition and analysis of the soil

S.No	Particular	Content	Level	Method adopted
1	Soil organic carbon (%)	0.42	Low	Walkley and Black Method (1934)
2	Available Nitrogen (kg ha ⁻¹)	246.00	Low	Modified alkaline permanganate method (Subbiah and Asija, 1956)
3	Available Phosphorus (P ₂ O ₅ kg ha ⁻¹)	13.86	Medium	Olsen's extractant colorimetric method (Olsen's <i>et al.</i> , 1954)
4	Available Potassium (K ₂ O kg ha ⁻¹)	444.00	High	Neutral normal Ammonium acetate (Hanway and Heidel, 1952)
5	Available Sulphur (mg kg ⁻¹)	9.60	Normal	Turbidimetric Methods (Chesnin and Yien, 1951)
6	Soil pH	7.3	Normal	By pH meter using 1:2.5 soil: water extract as described by (Jackson, 1973)
7	Electrical conductivity (dSm ⁻¹)	0.33	Normal	By conductivity meter as described by (Jackson, 1973)

Table -3 Chemical analysis of plant samples

S.No.	Particular	Method adopted
1	Nitrogen Content (%)	Micro Kjeldahl method as described by Jackson, 1973.
2	Phosphorus Content (%)	Vanadomolybdo Yellow Colour Method (Koeing and Johnsons, 1942)
3	Potassium content (%)	Di-acid digestion method by Flame photometer (AOAC, 1984)
4	Sulphur content (%)	Turbidimetric Method (AOAC, 1984)

3.4 Crop history of the experimental field

Following cropping system was followed in the experimental field during the preceding six years:

Table-5: Cropping history of the field

Year	Kharif Season	Rabi Season
2015-2016	Soybean	Gram
2016-2017	Soybean	Gram
2017-2018	Soybean	Gram
2018-2019	Soybean	Gram
2019-2020	Soybean	Gram
2020-2021	Soybean	Gram
2021-2022	Present soybean experiment	

3.5 Experimental details

The experiment was laid out in a randomized block design with seven treatments, replicated three times. The details of the experiment and treatments are given below and the layout plan is illustrated in table no. 6.

Table-6: Details of the experiment

Design	:	Randomized Block Design
Treatments	:	07
Replications	:	03
Total number of plots	:	21
Gross plot size	:	5 m x 4.8 m (24m ²)
Net plot size	:	4.5 m x 4.0 m (18 m ²)
Distance between replications	:	1.5 m
Distance between plots	:	1 m
Crop	:	Soybean
Variety	:	RVS 2011-10, NRC 86, DLSb 01, JS 20-116, MACS 1520, PS 1569, JS 22-12.
Seed rate	:	65 kg ha ⁻¹
Distance between rows	:	40 cm
Number of rows per plot	:	12

Treatment details ; The following germplasms were used in the study and each genotype was considered as one treatment

T1 :- RVS 2011-10

T2 :- NRC 86

T3 :- DLSb 01

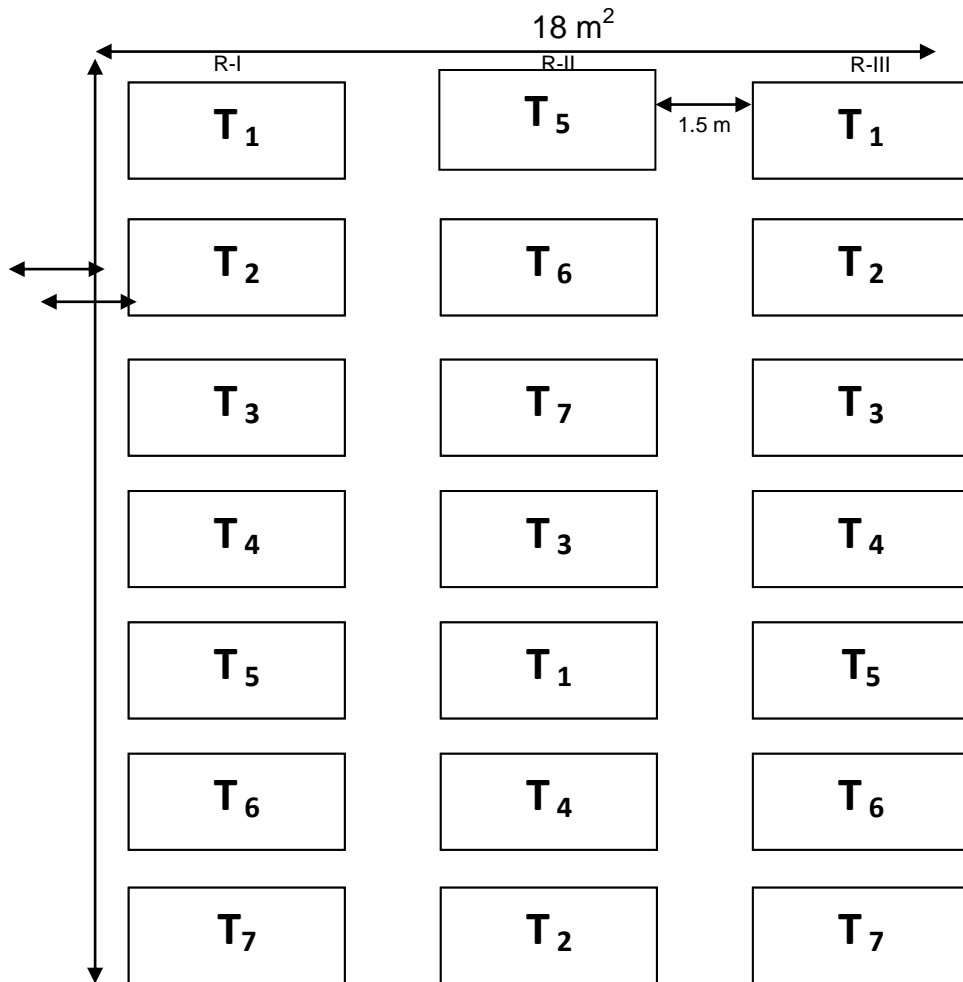
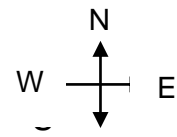
T4 :- JS 20-116

T5 :- MACS 1520

T6 :- PS 1569

T7 :- JS 22-12

Fig. 2: Layout plan of Experiment field
 (Randomized Block Design)



3.6 Details of field operations

The schedule of field operation, crop management and post-harvest operations are briefly presented in Table 7

Table 7: Schedule of field preparation

S.No	Operation	Date	Remark
1	Land preparation		
	a) Ploughing	25/04/2021	By Tractor
	b) Cross bukhering and planking	30/06/2021	By Tractor
2	Layout of the field	01/07/2021	Manual
3	Sowing	03/07/2021	Manual
4	Intercultural operation		
	(a) Thinning	14/07/2021	Manual
	(b) Hand weeding (30 DAS)	03/08/2021	Manual
5	Plant protection		
	i) Weedicide 5 ppm	18/08/2021	Pendimethalin38.7%CS@1lit.
	ii) Control of Blue beetle	26/8/2021	a.i./ha
7	Harvesting	Varied with varieties	Chloropyriphos 20%EC@1.5lit/ha.
8	Threshing	17/10/2021	Manual
			Manual

3.6 Varietal characters

a) RVS 2011-10:- Colour of flower of this variety was white , Days of maturity 103, The leaves of this variety is broad leaf , , yellow seed coat, seed size medium bold, pod (2 and 3 seeded) and pod was hairy, multiple disease and insect management. Test weight was 10.45g.

b) NRC – 86 :- Colour of flower of this variety was purple , Days of maturity 104, medium seed size It had resistance against girdle beetle and stem fly and tolerance to moisture stress conditions. The leaves of this variety was broad and hairy pod.

c) DLSb – 1 :- Plant height was 43.08 cm., it takes 50% flowering in 50 days and matures in 90-95 days. Flower colour was Purple and Broad leaf ,yellow seed coat with black hilum , multiple insect and disease resistance.

d) JS 20-116 :- variety has been evolved by JNKVV, Jabalpur Madhya Pradesh. This is a wide adaptable, high yielding and multiple resistant variety. The flower colour was white, Broad leaf and non hairy pod. It takes 50% flowering in 50 days.

e) MACS 1520 :- This variety plant height was 56 cm. It takes 50% flowering in 44 days and matures in 90-95 days having multiple insect and pest resistant and seed was yellow coat with black hilum having test weight was 11.0g .Flower colour was purple, Broad leaf and Hairy pod.

f) PS 1569 :- Determinate growth habit, white flower, tawny pod pubescence, Dark Green narrow leaf, brown hilum, round shaped small seed. Moderately resistant to Bacterial Pustule, Pod Blight and Collar Rot; highly resistant to Charcoal Rot; Moderately resistant – highly resistant for girdle beetle; moderately resistant to stem fly, Days of maturity 55.

g) JS 22-12 :- Determinate growth habit, white flower, dark green round Broad leaf and non hairy pod , yellow pod, black hilum, medium seed size. Extra early (87 days); resistant to Charcoal Rot; moderate to high resistance to girdle beetle; moderately resistant to stem fly, Days of maturity 100.

3.7 Preparation of field and layout of the experiment

Land for cultivation was prepared with tractor drawn plough followed by bukhering to obtain a well-pulverized seedbed. After that it was labeled with the help of tractor driven leveler. At the last the layout was made as indicated in table 6.

3.7.2 Seed rate and seed treatment

An optimum plant population is principal for higher crop production which may be achieved by using appropriate seed rate. Before sowing the seeds were treated with fungicides (Thiram 2 g/kg seed) Recommended seed rate of 65 kg ha⁻¹ was applied.

3.7.3 Method of sowing

The sowing was done on 3 July 2021, maintaining row spacing of 40 cm. The seeds were drilled manually and covered instantly.

3.7.4 Fertilizer dose and method of application

The fertilizers were applied (N,P₂O₅,K₂O and S @ 20,60,20,20) through diammonium phosphate (DAP), murate of potash (KCL) and gypsum respectively below seed row as basal.

3.7.5 Intercultural operation

a) Thinning

To maintain plant population excessive plants were thinned out at 12 DAS keeping 4-5 cm spacing between two plants in a row.

b) Weeding

To provide a clean cultivation one hoeing with the help of hand-driven wheel hoe and hand weeding in soybean lines were given on 30 DAS.

3.7.6. Plant protection

The weedicide pendimethalin 38.7% CS @ 1 lit ai/ha was applied for weed control as pre emergence.

The incidence of blue beetle (*Cneorane spp.*) was observed in the second week of August. It was controlled by a spray of chlorpyriphos 20% EC @1.5 lit./ha.

3.7.7 Harvesting

The harvesting was done manually using sickle. The produce of each net plot was tied into bundles, dully labeled and allowed to sun drying for one day in respective plots. The weight of bundles was recorded from each plot by using spring balances then the bundle of each plot was transported to threshing floor.

3.7.8 Threshing and winnowing

Threshing of bundles of each plot was done separately by beating with wooden sticks, and then seeds were cleaned by using hand fan manually for each plot and weighed it. The straw yield was obtained by subtracting of grain yield from total biological yield (grain + straw).

3.8 Experimental observations

The details of the observations recorded during the investigation for studying the effect of various treatments are given below:-

3.8.1 Pre-harvest studies

Plant height plant⁻¹ (cm):

Height of the three randomly selected plants in each plot was measured from the soil surface to the main apical bud.

Number of branches plant⁻¹:

The branches emerging from the base of five-tagged plants were recorded.

Root length plant⁻¹ (cm):

Five randomly selected plants were uprooted from each plot and root length was measured with a scale, then mean length was calculated.

Dry weight plant⁻¹ (g):

Five randomly selected plants were uprooted from each plot and oven-dried in an oven at 70°C and dry weight was recorded at 30, 45 & 60 days after sowing and the maturity stage.

Number of root nodules plant⁻¹:

The number of root nodules of three randomly selected plants was recorded in each plot at 30, 45 and 60 days after sowing. Plants were uprooted carefully and after washing root nodules were separated from the roots of the plants. The dark pink colored root nodules of plants were counted and the number was recorded.

Dry weight of root nodules plant⁻¹ (mg):

The dry weight of root nodules of five randomly selected plants was recorded in each plot at 30, 45 and 60 days after sowing. Isolated root nodules were kept in an oven for 72 hours at 70°C temperatures and subsequently the dry weight of nodules was recorded.

3.8.2 Post-harvest studies:

Number of pods per plant:

The total number of pods was counted in tagged plants and their average was used for statistical analysis.

Number of seeds pod⁻¹:

After threshing the bunch of three plants, number of seeds was counted and divided with the total number of pods recorded from these three plants.

Seed yield plant⁻¹ (g):

After threshing, the total yield of three tagged plants per plot was weighed and the resultant was divided by the total tagged plants and the seed yield per plant was obtained.

Seed index (g):

One hundred seeds were taken randomly from finally cleaned produce of each net plot and weighed separately by physical balance.

Seed yield (kg plot⁻¹):

Seed yield of each net plot was weighed and recorded after threshing and winnowing.

Straw yield (kg plot⁻¹):

Straw yield was calculated in kg by subtracting the grains yield from the biological yield.

Seed yield (kg ha⁻¹):

Seed yield of each net plot was weighed and recorded in kg after threshing and winnowing.

Straw yield (kg ha⁻¹):

Straw yield was calculated in kg by subtracting the grains yield from the biological yield.

Harvest index (HI):

It was calculated by using the following formula and expressed in percent.

$$\text{Harvest Index (\%)} = \frac{\text{Economical yield of plot}}{\text{Biological yield of plot}} \times 100$$

3.8.3 Procedure of calculation of parameters to be calculated**(a) Protein percentage**

Crude protein was analyzed by micro Kjeldahl's method (Kanwar and Chopra).

Procedure for protein estimation (Micro –Kjeldahl's method)

Firstly Weighed accurately 0.5 g of oven dried seed sample and transferred it into Kjeldahl's flask then add 30 ml of H₂SO₄ (conc.), 10 g of

potassium sulphate and 1 g of copper sulphate in to this and then heated first gently but more strongly after the frothing was ceased and heat it continuously till transparent solution was obtained or produced in flake. And then cooled the digested mixture . Transferred that cool solution into 100 ml volumetric flask and made the final volume 100 ml with distilled water, took 5 ml of this solution into micro Kjeldahl's distillation unit and then we added 25 ml of 40 per cent caustic soda solution and after that distillation process should be carried out. The distillate was collected in receiving flask containing 30 ml of N/10 sulphuric acid and distilled it till the volume of the sulphuric acid become double after that removed the flask and titrated it against N/10 caustic soda using methyl red as indicator. The Nitrogen Percent was calculated using formula and then protein content by multiplying % N with factor 6.25 .

Crude protein = % Of nitrogen X 6.25

(b) Soil analysis

Preparation of soil samples

Soil samples were collected from 0-15 cm depth from randomly selected places in the experimental field before sowing than these samples were mixed and finally a composite soil sample was prepared for determining the initial nutrient status of the field. Similarly post harvest soil samples were also collected from individual plots after harvesting of soybean crops to determine post-harvest status under various treatments. These samples were crushed with the help of wooden mortar and piston and were passed through 2 mm sieve and finally were stored for chemical analysis in polythene bags.

Soil pH

The pH of the soil was determined by using digital pH meter using 1:2.5 soil-water suspensions (Jackson, 1973).

Electrical conductivity (dSm^{-1})

The same 1:2.5 soil-water suspensions used for pH determination was used for the determination of electrical conductivity with the conductivity bridge as described by Jackson,(1973).

Organic carbon (%)

For estimation of organic carbon from previously prepared soil sample one gram soil sample was taken in 500 ml conical flask and 10 ml of 1N $\text{K}_2\text{Cr}_2\text{O}_7$ (Potassium dichromate) was pipette poured and swirled a little. 20 ml

concentrated H_2SO_4 (Sulphuric acid) was added in and swirled. The flask was allowed to stand for 30 minutes and after that, 200ml of distilled water was added. After incorporation of 10 ml of phosphoric acid and 1 ml of diphenylamine indicator the contents were titrated with Ferrous Ammonium Sulphate solution until the colour of the solution changes from blue violet to green. Simultaneously a blank was also run without soil for correction of background.

Estimation of Nitrogen

In a digestion tube of automatic Kjeldahl instrument 2 gm of soil was taken. To this 20 ml of distilled water and 25 ml of 0.32% KMnO_4 and 25 ml of 2.5% NaOH was added in the Kjeldahl tube. Before doing the process 25 ml of mixed indicator solution of boric acid poured in a conical flask for ammonia absorption. After that, the distillation process was carried out for estimation of nitrogen. After distillation conical flask was removed and titrated against 0.02 N H_2SO_4 until original pinkish shade appeared. Blank reading (without soil) was also taken for the final calculation.

Estimation of phosphorus

Extraction

For estimation of Phosphorus first extraction was done in which 2.5 grams of processed soil sample was weighed in a 250ml conical flask To this 50 ml of 0.5 M NaHCO_3 was added as an extractant of the pH to 8.5 (Olsen *et al.* 1954) together with 1 g of Darco G-60 (free from soluble phosphorus) and then flasks were shaken on a mechanical shaker for 30 minutes and then filtered through filter paper (whatman 1).

Development of color

5ml of colorless filtrate was taken in a 25 ml volumetric flask for determination of P and then 5 ml of 1.5 percent ammonium molybdate solution was added. The contents were diluted to about 20 ml with distilled water, Then shaking should be carried out. One ml of fresh working solution of SnCl_2 (stannous chloride) was added to develop blue colour and diluted to the mark and shaken thoroughly. The colour intensity was measured on a Spectrophotometer within 10 minutes at 660 nm wavelength after setting the instrument to zero with blank prepared similarly but without soil, as described by Jackson (1973). The

amount of available phosphorus was calculated and the results were expressed in kg P ha^{-1} by using standard curves.

Estimation of potassium in soil samples

The neutral normal ammonium acetate extractant was used to determine the readily exchangeable plus water-soluble K. Five grams of soil was shaken with 25 ml of neutral normal ammonium acetate (pH 7) for 5 min and then filtered immediately through a dry filter paper. After that the first few ml of filtrate was rejected. Potassium concentration in the extract was determined in the flame photometer after the necessary setting and calibration of the instrument. The amount of potassium was calculated and the results were expressed in kg K ha^{-1} the standard curve.

Estimation of sulphur

Sulphur was extracted with 0.15% CaCl_2 and the soluble sulphate measured turbidimetrically on a spectrophotometer using blue filter (at 340nm). 5 gm processed soil was transferred into a 150 ml Erlenmeyer flask and 25 ml of 0.15% CaCl_2 was added to it. Shaking for 30 minutes was done on a reciprocation shaker. ($180+$ oscillation min^{-1}). Filtration of the suspension was done through Whatman No.42 paper.

Development of turbidity

Pipette out 10 ml extract in a 150 ml volumetric flask and 20 ml of water was added and then 0.2 gm of BaCl_2 crystals was added into the flask. The flask was shaken for 1 minute manually at a constant rate and after 3 minutes turbidity was measured in a colorimeter using a blue filter. The amount of sulphur was calculated and the results were expressed in mg kg^{-1} by using standard curve.

(c) Plant Analysis

Estimation of nitrogen

Nitrogen in plant samples was determined by the Macro kjeldhal method. Total N includes all forms of inorganic N present in plant, All the N present in plant is converted into ammonium form, which is distilled and estimated by using standard acid.

Commonly used catalysts

- 1) CuSO_4 , to accelerate the process .

- 2) Potassium sulphate is added to raise the boiling point of the acid so that loss of acid by volatilization is prevented.

The apparatus required for this method consists of: A Kjeldhal digestion and distillation unit; some conical flasks; some burettes; some pipettes.

The reagents required are:

- 1) Sulphuric acid (93–98 percent).
- 2) Copper sulphate ($\text{CuSO}_4 \cdot \text{H}_2\text{O}$) (AR-grade).
- 3) Potassium sulphate or anhydrous sodium sulphate (AR-grade).
- 4) Forty percent sodium hydroxide solution

Procedure:-

- 1) Weighed 0.5 g of plant sample, Place in a Kjeldhal flask.
- 2) Add 3 g of digestion mixture was added (consisting of Copper sulphate and Potassium sulphate in the ratio of 1:5) and 10 ml of conc. H_2SO_4 was placed into digestion tube
- 3) The contents were digested initially at 150°C for 2 hours and there after at high temperature ($300\text{-}400^\circ\text{C}$) till the content of digestion tube becomes clear solution of light green color.
- 4) Removed the flask from the heater and cool, then content transfer in volumetric flask (100ml) and makeup the volume with distill water.

Distillation

10 ml of the digested material was taken and transferred in to micro kjeldahl distillation tube while in conical flask, 10 ml of 4% boric acid solution containing bromocresol green and methyl red indicators was taken which is placed at the condenser outlet to trap released ammonia. For distillation After adding the aliquot, the funnel of the apparatus was washed with 2.3 ml of deionized water and then 10 ml of 40% NaOH solution was the added. Subsequently 100 ml aliquot was distilled to the flask containing 10 ml of boric acid. After distillation the distillate was titrated against 0.02 N H_2SO_4 . Blank without taking aliquot of digested sample was also run.

Estimation of phosphorus

Phosphorus determination in the plant samples was done by Vanadomolybdo-phosphoric acid yellow colour method of Koeing and Johnson (1942).When orthophosphates are made to react with molybdate and vanadate, a yellow-coloured vanadomolybdo-phosphoric heteropoly complex is formed.

The intensity of the yellow colour is directly proportional to the concentration of P present in the sample, which can be read on the spectrophotometer.

Preparation of digested material:-

- 1) Taken 0.5 g grinded plant sample (seed) was taken for analysis. It was placed in a 100-ml conical flask, and 10 ml of di-acid mixture [HNO_3 and HClO_4 (9:4)] is added and the contents were mixed by swirling.
- 2) The flask is placed on a hot plate in the fume hood and heated, first at 80–90°C and then the temperature was raised to about 150–200°C. Heating continues until the production of red NO_2 fumes ceases.
- 3) The contents were further heated until the volume was reduced to 3–4 ml and becomes colourless, but did not allow to dry. After cooling the contents, the volume is made up 10 ml with the distilled water and filtered through No. 1 filter paper. This solution was used for nutrient estimation.

Development of colour

The reagents required are:

- 1). Ammonium molybdate
- 2). Standard phosphate solution

The procedure is:

- 1) Preparation of the standard curve: Put 0, 1, 2, 3, 4, 5 and 10 ml of standard solution ($50 \mu\text{g P ml}^{-1}$) in 50-ml volumetric flasks. Add ten ml of vanadomolybdate reagent was added to all the six flask containing volume 0, 1, 2, 3, 4, 5 and 10 $\mu\text{g P ml}^{-1}$, respectively.
- 2) The standard curve is prepared by measuring these concentrations on a spectrophotometer (420 nm) by and recording the corresponding absorbances.
- 3) Took 0.5 g of plant sample and digest as per the wet digestion method, and made the volume up to 100 ml.
- 4) Took 5 ml of digest in a 50-ml volumetric flask, and added 10 ml of vanadomolybdate reagent and volume was made up to mark with distilled water, and shake thoroughly. Kept it for 30 minutes.
- 5) Made up the volume with distilled water, and shake thoroughly. Kept it for 30 minutes.

- 6) A yellow colour was developed, which was stable for days and was read at 420 nm on spectrophotometer.
- 7) For the observed absorbance, determine the P content from the standard curve.

Estimation of potassium

Potassium determination in the plant sample was done by AOAC (1984) Official Methods of Analysis of Analytical chemists (W. Hartwitz ,Ed). 14th Ed. AOAC Washington DC, U.S.A. flame photometer.

Principle

Potassium in solution is atomized to flame and the flame excites atom of potassium causing them to emit radiation at specific wavelength. The amount of radiation emitted is directly proportional to concentration of K in the solution and it is measured in a flame photometer with suitable filter, which transmits only potassium wavelength (420 nm red filter).

Extraction

For estimation of Potassium One gram of oven dried plant sample was taken and digested in 100 ml conical flask with 12 ml of di-acid mixture of (9:4 concentrate nitric acid and perchloric acid) and digested material was filtered through Whatman No. 40 filter paper in 100 ml volumetric flask and the filtrate was diluted upto the mark. The samples were then read in flame photometer using K-filter.

Estimation of sulphur

Total plant sulphur was determined by barium sulphate turbidimetric method.

Extraction

One gram oven dried plant sample was taken and digested in 100 ml conical flask with 12 ml of di-acid mixture of (9:4 concentrate nitric acid and perchloric acid) and digested material was filtered through whatman No. 40 filter paper in 100 ml volumetric flask and filtrate was diluted up to the mark.

Development of turbidity

10 ml of aliquot from plant digest was pipette to 50 ml volumetric flask. Then 10 ml 6 NHCL and 1 ml of 0.5% gum acacia solution were added. Mixed the content by swirling and added 0.5 gm barium chloride crystal was added. Allow the flask to stand for one minute and then swirled the content gently until

the barium crystals were dissolved. The absorbance of the solution was read on spectrophotometer at 420nm.

3.9 Biological analysis

3.9.1. Estimation of Dehydrogenase enzyme activity(Klein et al., 1971)

Dehydrogenase activity was estimated by monitoring the rate of production of tri-phenyl formazan (TPF) from tri-phenyl tetrazolium chloride (TTC), which was used as an electron acceptor. The method of Klein *et al.* (1971) was followed for the assay of dehydrogenase activity as outlined below.

1. 1 g of air-dried soil was placed in a 15ml screw-capped tube.
2. To this 0.2 ml of 3% TTC and 0.5 ml of 1% glucose were added and ensured to make the system anaerobic. The tube were incubated at 28°C for 24 hours.
3. After incubation 10 ml of methanol was added and shaken for exactly one minute.
4. It was allowed to stand in the dark for six hours.
5. The color intensity developed was measured at 485 nm (blue filter).
6. From the standard curve, drawn in the range of 0.004 to 0.4 mg TPF per 10 ml of methanol, the TPF produced in the samples were computed.
7. Dehydrogenase activity was expressed as TPF formed per g soil for 24 hours on an oven-dry weight basis.

3.9.2. Estimation of Soil microbial population, (Bacteria and Fungi), (Chhonkar et al., 2006)

Media Preparation:-

1.Nutrient Agar Media (for Bacteria)

NaCl	5 g
Peptone	5 g
Beef extract	3 g
Agar-agar	18 g
Volume to make distilled water	1 L
Ph	7

2. Rose Bengal red media (for Fungi)

Dextrose	10.0 g
Peptone	5.0 g
Potassium dihydrogen phosphate	1.0 g

Magnesium sulphate heptahydrate	0.5 g
Agar-agar	20.0 g
Streptomycin (Antibiotic) traces (use just before plating)	
Volume to make distilled water	1 L

To be added after autoclaving and just before plating. The final concentration of streptomycin is maintained be about 30 ppm.

Procedure:-

Separated soil closely adhered to the plant roots after gentle tappen / shaken. This was constituted the rhizosphere soil sample. The other soil sample from non –cropped area was the non – rhizosphere sample. Prepared serial dilutions for plated of the soil within the laminar flow assembly and add 10 g soil sample in 95 ml sterile water blank in 500 ml conical flask. Replaced cotton plug with a surface-sterilized rubber stopper. Shacked thoroughly too dispersed soil by given vertical strokes. The shaken was uniform for all soil samples. Transfer 1 ml soil suspension was obtained in the previous steps into 9 ml sterile water blank in the test tubes. Shaken was uniformly between palms of your hands to provided horizontal shaken. Continue the series similarly to get up to 10^{-6} dilution level. Mark the dilutions properly on the test tubes. Transfer 1 ml of requited dilution (10^{-4} for fungi and 10^{-5} to 10^{-6} for bacteria) into sterile Petri plates. Pout the required selective media (at approx 48°C) for specific organisms uniformly into plates. To rate clockwise and anti-clockwise to mix soil suspension with a medium. Make the rotation uniform for all samples. Allow the medium to solidify. Make details on the lid. Incubate plates in an inverted position at 28°C in the incubator for 48 hours for fungi and 4 days for bacteria. Take at least four replications for each sample. Examine plates for the colonies developed after the required incubation period. Swatch colonies and note pigmentation if any. Count the number of colonies. Discard plates shown large spreaders and mold colonies. Number of colonies multiplied by the respective dilution factor was given the number of viable cells g^{-1} soil. Examine the most dominant colonies under the microscope. Calculate standard deviation and standard error of mean. Statistically compare the number of organisms in the rhizosphere soil samples.

3.10 Economics of treatments

As per the existing market prices, input and output costs were computed treatment wise and net returns and cost benefits ratio were estimated.

3.11 Statistical analysis

The relevant data were tabulated systematically and analyzed statistically by Fisher's Method. The calculated "F" value was compared with the tabulated "F" value at a 5 percent level of significance. Critical difference (C.D.) or the least significant difference at 5 percent level of probability was calculated to judge the difference between the treatment means.

The skeleton of analysis of variance and formula for standard error of mean (SEm ±), critical difference (C.D.) and Coefficient of variation (C.V.) are given below (Cocharan and Cox, 1957).

Table 8: The skeleton of the analysis of variance

Source of variation	DF	SS	MSS	Fcal	SEm ±	CD	CV%
Replication	2						
Treatment	6						
Error	12						
Total	20						

The following formula was used for various estimations:

1. Standard error of means for various treatment compressions.

$$SEm \pm = \sqrt{\frac{EMS}{R}}$$

2. C.D. = SEm ± x $\sqrt{2}$ x t₁₂ (at 5% level of significance)

$$3. C.V. (\%) = \frac{\sqrt{EMS}}{\text{Grand mean}} \times 100$$

Where,

- R = Number of replication
- T = Number of treatment
- D.F. = Degree of freedom
- SS = Sum of square
- MSS = Mean sum of square
- EMS = Error mean square
- SEm ± = Standard error of mean
- C.D. = Critical difference
- C.V. = Coefficient of variance

CHAPTER – IV

RESULTS

This Chapter explain and discuss the findings of experiment laid out on "**Growth Nodulating Abilities, Nutrient Content and Yield of promising Soybean Genotypes [*Glycine max (L.) Merrill*] Influenced Under Native Microcosm Conditions in Clay Loam Soil**" during kharif 2021. The information generated noted during the field to evaluate the impacts of different treatments on production parameters, including nodulation characteristics, yield properties, nutrient uptake and yield. After statistical analysis the results are prepared in tabular form plus depicted through figures wherever is necessary are described with suitable headings and sub headings.

4.1: Pre-harvest studies:

4.1.1: Plant height (cm)

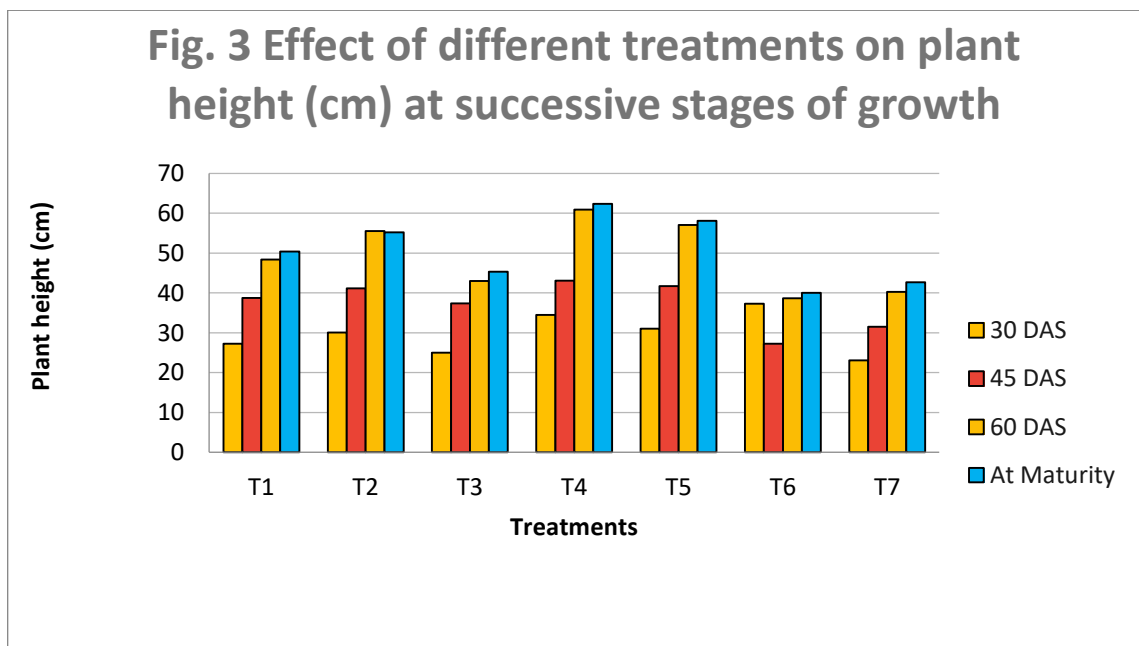
Plant height was observed at 30, 45, 60 DAS and at maturity. A regular observation of soybean germplasms on plant height (cm) found that plant height gradually increased up to 60 DAS before crop maturity (Table 4.1).

The data on plant height presented in table 4.1 and depicted in fig. 4.1 revealed that in general plant height increased in all the germplasms studied with time and height varied with germplasm. The range of plant height was observed varied from 34.5 cm to 62.33 cm in the JS 20-116. Persual of data further revealed that germplasm can be grouped into two category. The maximum plant height at maturity was recorded in germplasm JS 20-116 followed by MACS 1520, NRC 86, RVS 2011-10, DLSb 01, JS 22-12, PS 1569 and the respective height at maturity were 56.07, 55.23, 46.9, 43.08, 38.33, 31.41 .

Table – 4.1 Effect of different treatments on plant height (cm)of soybean at different successive stages.

	Treatments	Plant height (cm)			
		30 DAS	45 DAS	60 DAS	At maturity
T ₁	RVS 2011-10	27.23	38.73	48.40	50.47
T ₂	NRC 86	30.03	41.13	55.53	55.23
T ₃	DLSb 01	25.00	37.33	42.96	45.33
T ₄	JS 20-116	34.50	43.06	60.93	62.33
T ₅	MACS 1520	31.03	41.73	57.04	58.10
T ₆	PS 1569	22.20	27.26	38.66	40.04
T ₇	JS 22-12	23.03	31.53	40.23	42.66
	SEm±	1.73	1.98	2.08	2.19
	CD	5.34	6.11	6.41	6.74

The highest value of plant height was noticed at the 60 DAS stage under the germplasm JS 20-116 which was significantly higher than all the other germplasms . In plant height the same pattern was recorded as measured at maturity. In the germplasm JS 20-116, the maximum plant height i.e. 62.33, was recorded at crop maturity. It has been shown to be appreciably superior to all other germplasms. The lowest plant height was noted in PS 1569.



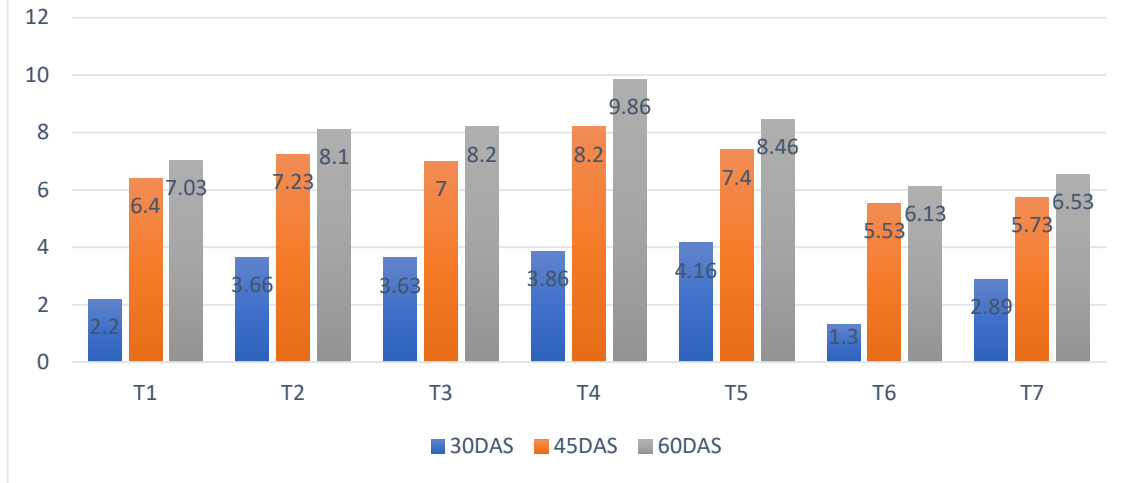
4.1.2: Branches plant⁻¹

The trend of data obtained on number of branches (Table 4.2) showed that 30 DAS germplasm JS 20-116 had reported the considerably highest number of branches per plant (4.07) followed by MACS 1520 and NRC 86 genotypes with branches number 3.95 and 3.66 respectively. In germplasm PS-1569, the minimum number of branches plant⁻¹ (1.3) at 30 DAS was reported. Nearly similar pattern for the number of branches plant⁻¹ was observed at 45 DAS. The germplasm JS 20-116 recorded appreciably superior and highest number of branches / plant (8.72) followed by the germplasm MACS 1520 and NRC 86. In plant height the same pattern was reported as measured at 60 DAS and ripeness. The largest number of branches plant⁻¹ was registered at 60 DAS (9.86) in the germplasm JS 20-116, followed by MACS 1520 and NRC 86. In the germplasms, JS 20-116 , the maximum number of branches (cm) i.e.10 was observed at crop maturity. It has been shown to be noticeably superior to all other germplasms. The lowest no. of Branches was noted in PS 1569 i.e 6.2.

Table – 4.2: Effect of different treatments on number of branches per plant of soybean at different successive stages.

	Treatments	Branches per plant (no.)			
		30 DAS	45 DAS	60 DAS	At maturity
T ₁	RVS 2011-10	2.20	6.40	7.03	7.10
T ₂	NRC 86	3.60	7.30	8.10	8.13
T ₃	DLSb 01	3.63	7.00	8.20	8.20
T ₄	JS 20-116	4.16	8.20	9.60	10.00
T ₅	MACS 1520	3.83	7.40	8.46	8.56
T ₆	PS 1569	1.30	5.53	6.13	6.20
T ₇	JS 22-12	1.42	5.73	6.33	6.30
	SEm±	0.13	0.20	0.22	0.24
	CD	0.42	0.63	0.70	0.75

Fig.4.2 Effect of different treatments on no. of branches/plant at various succeeding stages of soybean.



4.1.3: Root length plant⁻¹ (cm)

Data on plant⁻¹ root length at different stages of crop growth (30, 45, 60 DAS and at maturity). The information shows chronological progress of the plant⁻¹ root length at different points (Table 4.3).

The influence of different treatments on root length plant⁻¹ was found to be significant at 30 DAS stage after sowing, JS 20-116 (18.6 cm) developed considerably higher root length over different treatments and was found to be at par with MACS 1520 (18.26) and NRC 86 (15.8) . The least number of root length was noted under PS 1569 (11.1).

Table: 4.3: Effect of different treatments on the root length plant⁻¹(cm)at different successive stages of soybean.

	Treatment	Root length (cm)			
		30 DAS	45 DAS	60 DAS	At maturity
T ₁	RVS 2011-10	15.30	26.90	29.93	30.13
T ₂	NRC 86	15.80	27.53	29.83	30.13
T ₃	DLSb 01	15.00	23.33	28.13	28.36
T ₄	JS 20-116	18.60	28.80	32.40	31.90
T ₅	MACS 1520	18.20	27.73	29.16	31.06
T ₆	PS 1569	11.10	23.83	26.90	27.13
T ₇	JS 22-12	13.00	24.83	27.56	27.73
	SEm±	0.91	1.10	1.02	0.96
	CD	2.87	3.41	3.17	2.98

The effect of various treatments on root length per plant at the 45 DAS level was found to be significant JS 20-116 (28.80 cm) developed significantly higher root length over other treatments and was found to be at par with MACS 1520 (27.73 cm) and NRC 86 (27.53) treatments. Under PS 1569 (23.83 cm) was noted the lowest number of root length.

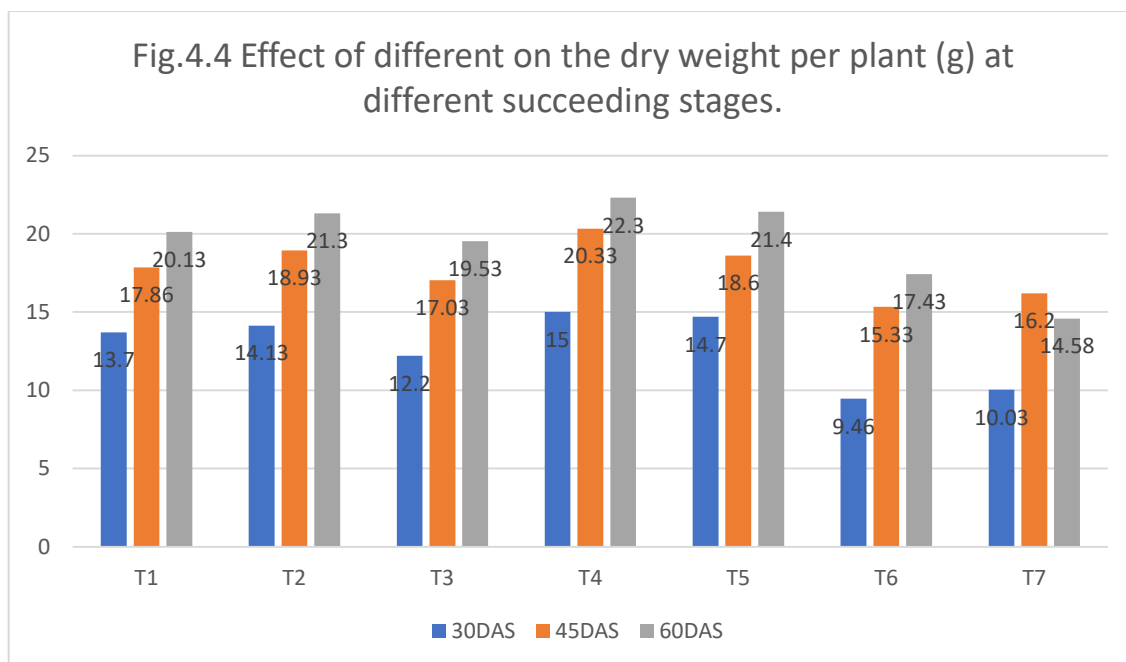
The consequence of the varying treatments on root length per plant was observed to be important at 60 DAS level. (JS 20-116) (32.4 cm) developed significantly higher root length than other treatments and was found to be at par MACS 1520 (29.93 cm) and NRC 86 (29.83 cm). Under PS 1569 (26.9 cm) the lowest number of root lengths was recorded. The effect of various treatments on root length per plant was considered important at maturity level JS 20-116 (31.9cm) had a higher root length than other treatments and was followed by MACS 1520 (31.06) . Under PS 1569 (27.13) was recorded the least number of root length

4.1.4: Dry weight plant⁻¹ (g)

Among the 7 germplasms dry weight plant⁻¹ germplasms of soybean, reported at 30, 45, 60 DAS and significantly influenced by varying treatments at maturity. The examination of dry weight/plant data (Table 4.4) showed that at 30 DAS germplasm JS 20-116 (15g) recorded the dry weightplant⁻¹ that was significantly higher than compared to others and followed by MACS 1520 and NRC 86.

Table: 4.4: Effect of different treatments on the dry weight plant⁻¹ (g) at different successive stages of soybean.

	Treatment	Dry weight plant ⁻¹ (g)			
		30 DAS	45 DAS	60 DAS	At maturity
T ₁	RVS 2011-10	13.76	17.86	20.13	21.20
T ₂	NRC 86	14.13	18.93	21.30	22.06
T ₃	DLSb 01	12.20	17.03	19.53	19.80
T ₄	JS 20-116	15.00	20.30	22.30	23.40
T ₅	MACS 1520	14.70	18.60	21.40	22.86
T ₆	PS 1569	9.46	15.30	17.43	17.66
T ₇	JS 22-12	10.03	16.20	18.33	18.73
	SEm±	0.37	0.52	0.96	0.68
	CD	1.15	1.61	2.97	2.09



The germplasm followed by MACS 1520 (14.7g) and NRC 86 (14.13g). The minimum number of dry weight $plant^{-1}$ in soybean at 30 DAS was recorded in genotype PS 1569 (9.46g). The same pattern was observed at 45 DAS for the dry weight $plant^{-1}$. The germplasm JS 20-116 showed dry weight $plant^{-1}$ significantly superior and highest (20.3g) which was followed by MACS 1520 and NRC 86. In dry weight $plant^{-1}$ the same pattern was observed as calculated at 60 DAS and ripeness. The maximum number of dry weight $plant^{-1}$ was recorded at 60 DAS in the germplasm JS 20-116 (22.3), which was followed by MACS 1520 (21.4g) and NRC 86 (21.3g). At crop maturity in the germplasm, JS 20-116 was observed the highest dry weight $plant^{-1}$ (g) i.e (22.86g) . It was found to be appreciably superior to all other germplams.

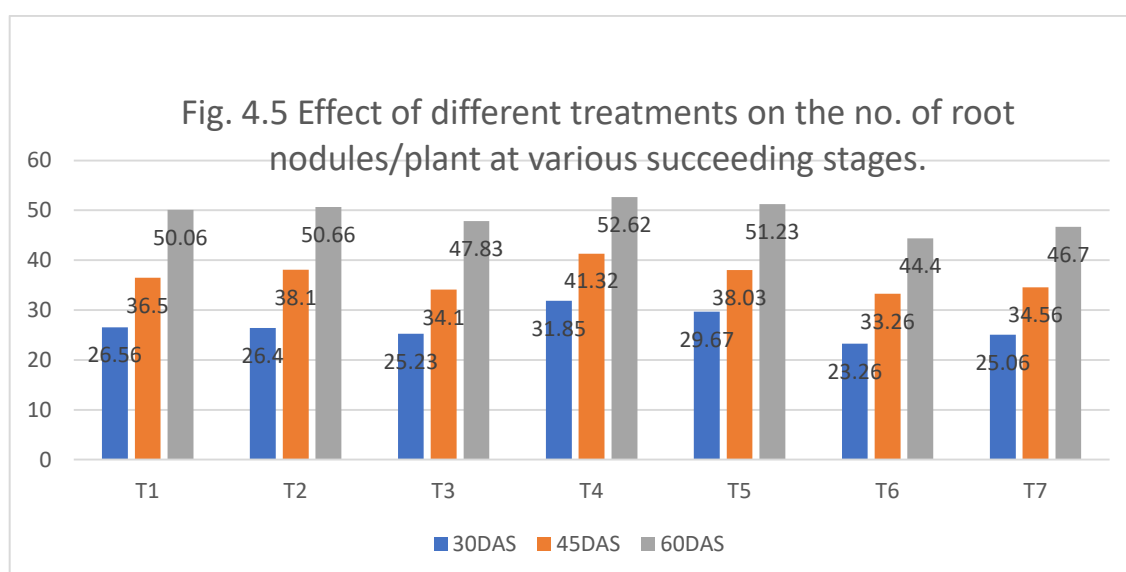
4.1.5: Number of root nodules $plant^{-1}$

Among 7 soybean germplams, the highest number of nodules $plant^{-1}$ (Table 4.5) was noted under the germplasm JS 20-116 (31.85), which was significantly higher than all other germplams at 30 DAS followed by MACS 1520 (29.67) and NRC 86 (26.4). Minimum number of root nodules was noted under the germplasm PS 1569 (23.26). A similar trend for the number of root nodules $plant^{-1}$ was followed at 45 DAS level. The highest number of nodules $plant^{-1}$ was reported at 45 DAS under the germplasm JS 20-116 (41.32) , which was significantly superior to all the other germplasms. The similar pattern was observed in number of nodules $plant^{-1}$ as measured at 60 DAS. The maximum

number of nodules plant⁻¹ was reported in the germplasm JS 20-116 (52.62) and at par with MACS 1520 (51.23) and NRC 86 (50.66) and .The minimum number of root nodules per plant PS 1569 (44.4) .

Table:4.5: Effect of different treatments on the number of root nodules plant⁻¹ at different successive stages of soybean.

	Treatments	Number of root nodules per plant		
		30 DAS	45 DAS	60 DAS
T ₁	RVS 2011-10	26.56	36.50	50.06
T ₂	NRC 86	26.4	38.10	50.66
T ₃	DLSb 01	25.23	34.10	47.83
T ₄	JS 20-116	31.85	41.32	52.62
T ₅	MACS 1520	29.67	38.03	51.23
T ₆	PS 1569	23.26	33.26	44.40
T ₇	JS 22-12	25.06	34.56	46.7
	SEm±	1.28	1.05	1.23
	CD	3.96	3.25	3.79



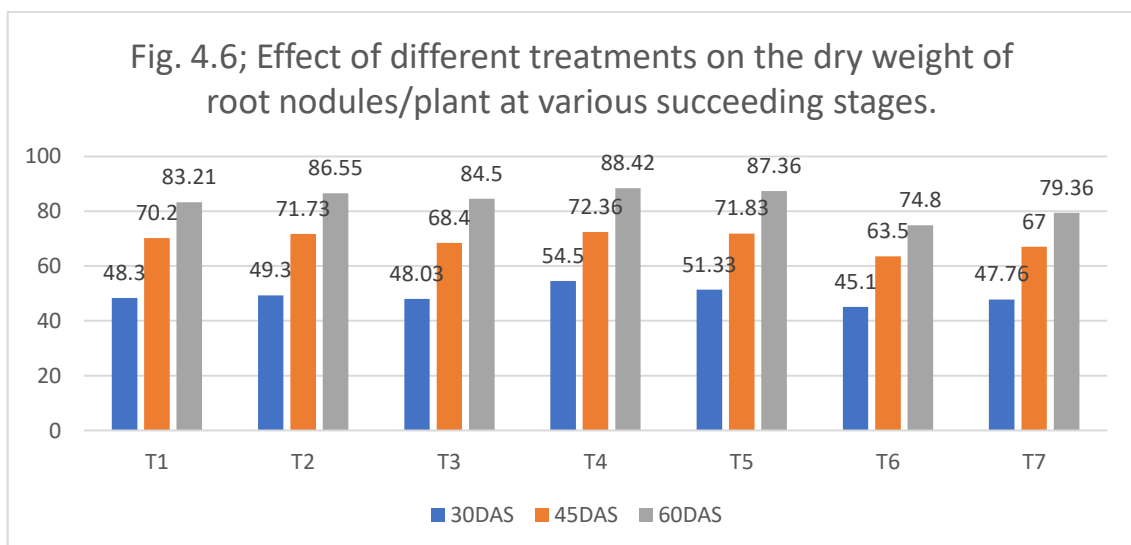
4.1.6: Dry weight of root nodules plant⁻¹ (mg) :

Particulars on the plant⁻¹ dry weight root nodule at various crop growth periods (30, 45 and 60 DAS) revealed chronological increase of root nodules from 30 DAS to 60 DAS for dry weight plant⁻¹. Dry weight of the root nodules was found to be significantly varied under different germplasms at various stages of crop growth (Table 4.6).

Table: 4.6: Effect of different treatments on the dry weight of root nodules per plant(mg) at different successive stages of soybean.

	Treatments	Dry weight of root nodules per plant (mg)		
		30 DAS	45 DAS	60 DAS
T ₁	RVS 2011-10	48.30	70.20	83.21
T ₂	NRC 86	49.30	71.73	86.55
T ₃	DLSb 01	48.03	68.40	84.50
T ₄	JS 20-116	54.50	72.36	88.42
T ₅	MACS 1520	51.30	71.83	87.36
T ₆	PS 1569	45.10	63.50	74.80
T ₇	JS 22-12	47.76	67.00	79.36
	SEm±	1.43	1.85	2.79
	CD	5.04	5.7	8.61

At 30 DAS, a major difference was reported in the dry weight of root nodules plant⁻¹. The maximum dry weight value of root nodules per plant was observed under the germplasm JS 20 -116 (54.5mg) and found to be followed by MACS 1520 (51.3mg) and NRC 86 (49.3mg). The lowest dry weight of nodules was noted in PS 1569 (45.1mg). At 45 DAS the substantially higher dry weight of root nodules per plant was recorded by JS 20-116 (72.36mg) followed by MACS 1520 (71.83 mg). The lowest dry weight of root nodules per plant was reported in PS1569 (67mg), the similar pattern in Dry weight of root nodules per plant was observed at 60 DAS. The maximum no. of dry weight of nodules per plant was observed at 60 DAS (88.42mg) in the genotype JS 20-116, followed by MACS 1520 and NRC 86..



4.2: Post-harvest studies

4.2.1: Pods plant⁻¹

One of the significant and important yield attributing characters is the number of pods plant⁻¹ which determines the seed yield of soybean crop. The number of pods per plant influences directly the number of seeds plant⁻¹, and consequently the final yield of grain. The data in Table 4.7 revealed a significant variation on no of pods per plant in different genotypes.

The maximum number of pods plant⁻¹ was reported in the JS 20-116 (50.3) germplasm which was significantly higher than all other germplasms followed by the MACS 1520 (49.3) and NRC 86 (47.6) germplasms. In the PS 1569 germplasm the minimum number of pods per plant was reported i.e.(37.46).

4.2.2: Number of seeds pod⁻¹

Due to the impact of different soybean genotypes under study, a major difference was noted on average number of seeds pod⁻¹. The germplasm JS 20-116 was substantially superior with a maximum number of seeds per pod (2.93 pod⁻¹) over all other germplasm followed by the MACS 1520 (2.85 pod⁻¹) and NRC 86 (2.82 pod⁻¹).The number of seeds per pod was reported in genotype PS 1569 (1.96 pod⁻¹).

4.2.3: Seed index (g)

The data on seed index (100-seed weight) of soybean are presented in Data perusal of the Table 4.7 shows that the JS 20-116 genotype registered the highest seed index (12.03 g), which was significantly higher than .all the other genotypes followed by MACS 1520 (11.37 g) and NRC 86 (10.7 g). The lowest seed index was recorded under the genotype PS 1569 (7.72g).

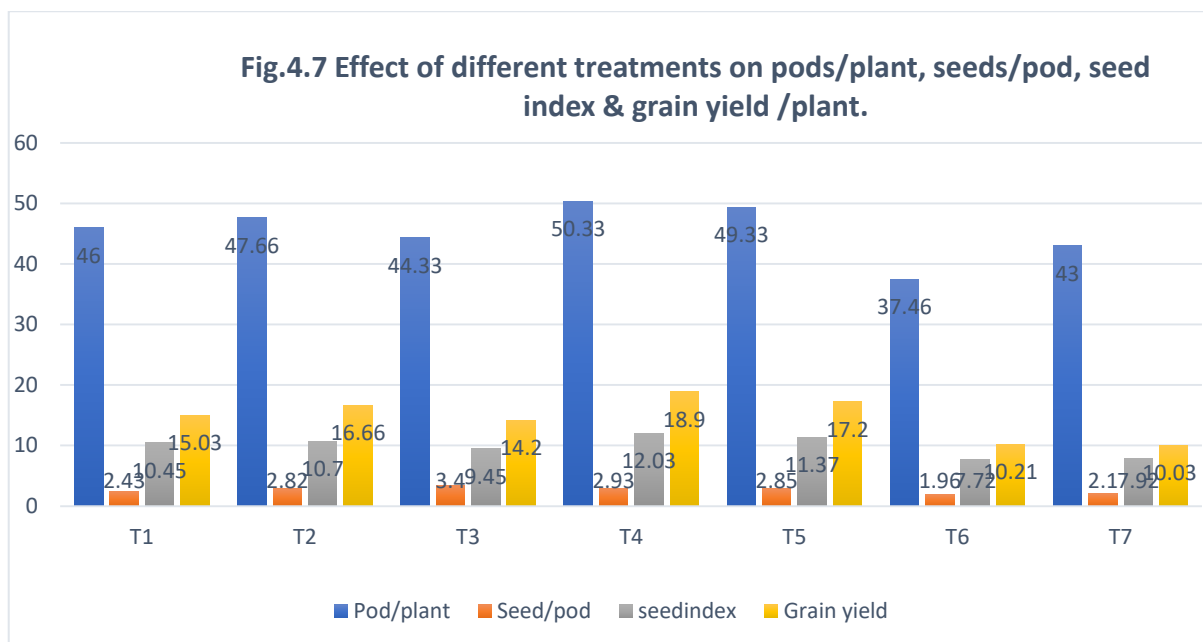
4.2.4: Grain yield plant⁻¹ (g)

Seed yield data per plant are the most important characters from which the dominance of specific germplasms can be measured. The review of the Table 4.7 data reveals the significant variation in the per plant seed yield of soybean due to the effect of different germplasms. The various germplasms significantly affected the grain yield per plant.

Table: 4.7: Effect of different treatments on the pods per plant, seeds per pod, seed index and grain yield per plant of soybean.

	Treatments	Pod Plant ⁻¹ (No.)	Seeds pod ⁻¹ (No.)	Seed index (g)	Grain yield plant ⁻¹ (g)
T ₁	RVS 2011-10	46.00	2.40	10.40	15.01
T ₂	NRC 86	47.60	2.80	10.70	16.60
T ₃	DLSb 01	44.30	2.20	9.40	14.22
T ₄	JS 20-116	50.30	2.90	12.00	18.91
T ₅	MACS 1520	49.30	2.80	11.30	17.20
T ₆	PS 1569	37.40	1.90	7.70	10.21
T ₇	JS 22-12	43.00	2.10	7.90	12.20
	SEm±	1.30	0.08	0.50	1.22
	CD	4.20	0.25	1.71	3.71

Critical analysis of the data revealed that the JS 20-116 germplasm provided the highest yield of grain per plant (18.9 g) which was significantly higher than the other germplasms followed by the MACS 1520 (17.2 g) and NRC 86 (16.66g) . Under the germplasm PS 1569 the lowest grain yield per plant i.e.(10.21 g).



4.2.5: Grain yield (kg plot⁻¹)

Grain yield per unit area is a significant scale for crop agronomic evaluation. Any crop yield is the end product of the biotic and abiotic factors interacting. Data noted on grain yield plot⁻¹ were analysed statistically and presented (Table 4.8).

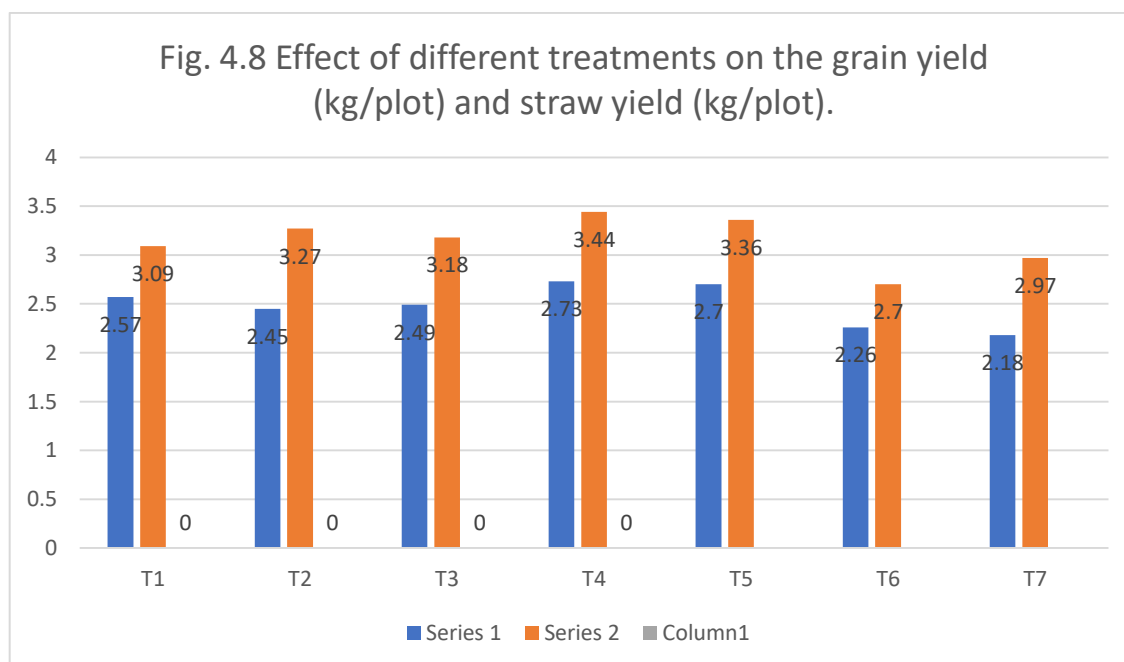
Table: 4.8: Effect of different treatments on the grain yield (kg plot⁻¹) and Straw yield (kg plot⁻¹).

	Treatments	Grain yield (kg/plot)	Straw yield (kg/plot)
T ₁	RVS 2011-10	2.57	3.09
T ₂	NRC 86	2.45	3.27
T ₃	DLSb	2.49	3.18
T ₄	JS 20-116	2.73	3.44
T ₅	MACS 1520	2.70	3.36
T ₆	PS 1569	2.26	2.70
T ₇	JS 22-12	2.18	2.97
	SEm±	0.16	0.09
	CD	0.49	0.28

The maximum grain yield kg plot⁻¹ (2.73 kg plot⁻¹) was found under the JS 20-116 and followed by MACS 1520 (2.70 kg plot⁻¹) and NRC 86 (2.45 kg plot⁻¹) was achieved.

4.2.6: Straw yield (kg plot⁻¹)

The exhibit that the highest straw yield kg plot⁻¹ (3.44kg plot⁻¹) was obtained under JS 20-116 and found followed by MACS 1520 and NRC 86 respectively. PS 1569 (2.70 kg plot⁻¹) was obtained with minimum straw yield plot⁻¹.



4.2.7: Grain yield (kg ha⁻¹)

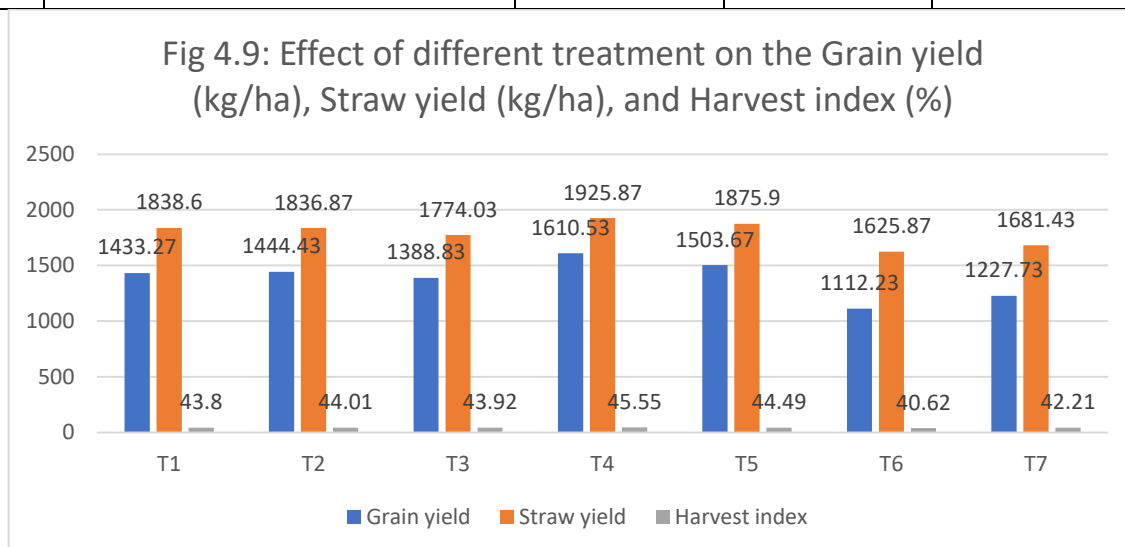
Statistically evaluated data collected on grain yield ha⁻¹ revealed the impact of different treatments. Further Data review (Table 4.9) revealed that germplasm JS 20-116, produced the maximum yield of grain (1610.53 kg/ha), however it was followed by MACS 1520 (1503.6kg/ha) and NRC 86 (1444.43 kg ha⁻¹). Minimum grain yield was recorded under the PS 1569(1112.23 kg ha⁻¹)

4.2.8: Straw yield (kg ha⁻¹)

The data showed that the effect of different treatments on straw yield kg ha⁻¹ was noted to be significant. The highest straw yield observed under JS 20-116 (1925.87 kg ha⁻¹), which was substantially higher than all other germplasms and found followed by MACS 1520 (1875.90kg ha⁻¹) and NRC 86 (1336.86 kg ha⁻¹). The PS 1569 minimum straw yield (1625.87kg ha⁻¹).

Table: 4.9: Effect of different treatments on the grain yield (kg/ha), Straw yield (kg/ha) and harvest index (%) of soybean.

	Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)
T ₁	RVS 2011-10	1433.27	1838.60	43.80
T ₂	NRC 86	1444.43	1836.87	44.01
T ₃	DLSb 01	1388.83	1774.03	43.92
T ₄	JS 20-116	1610.53	1925.87	45.55
T ₅	MACS 1520	1503.67	1875.90	44.49
T ₆	PS 1569	1112.23	1625.87	40.62
T ₇	JS 22-12	1227.73	1681.43	42.21
	SEm±	30.58	36.65	0.73
	CD	94.23	112.95	2.27



4.2.9: Harvest index (%)

The harvest index is significantly affected by the various germplasms. The DLSb 01 germplasm registered the maximum and significantly superior harvest index (46.04). While, the germplasm NRC 86 (45.67) , MACS1520 (45.07) were noted to be at par. The minimum harvest index was found under the PS 1569 (43.36).

4.3: Chemical analysis

4.3.1: Nutrient content

Nitrogen content (%) in seed

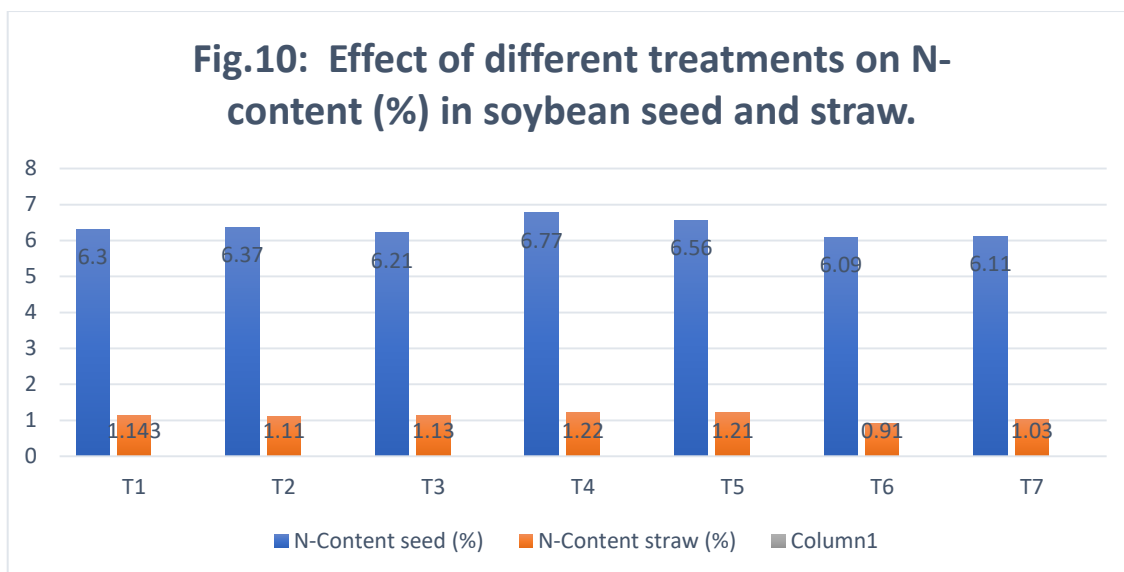
Significant variation was observed in the nitrogen content of seeds amongst the various treatments (Table 4.10). High nitrogen content in seed was found in JS 20-116 treatment (6.77%) , which was followed by treatment MACS 1520 (6.56%) and NRC 86 (6.37%). The minimum nitrogen content of seeds was noted in PS 1569 (6.09%).

Table-4.10: Effect of different treatments on N-content (%) in soybean seed and straw.

	Treatments	N-Content seed (%)	N-Content Straw (%)
T ₁	RVS 2011-10	6.30	1.14
T ₂	NRC 86	6.37	1.11
T ₃	DLSb 01	6.21	1.14
T ₄	JS 20-116	6.77	1.22
T ₅	MACS 1520	6.56	1.21
T ₆	PS 1569	6.09	0.91
T ₇	JS 22-12	6.11	1.03
	SEm±	0.13	0.02
	CD	0.42	0.07

Nitrogen content (%) in straw

Due to different treatments, the nitrogen content in straw differed significantly and the highest nitrogen content was observed in straw under treatment JS 20-116 (1.22%), which was substantially higher than other treatments and followed by MACS 1520 (1.21%) and NRC 86 (1.4). Minimum nitrogen content was reported under PS 1569 (0.91).



.3.2: Phosphorus content

Phosphorus content (%) in seed

Different treatments revealed significant difference in phosphorus content in seed (Table 4.11)

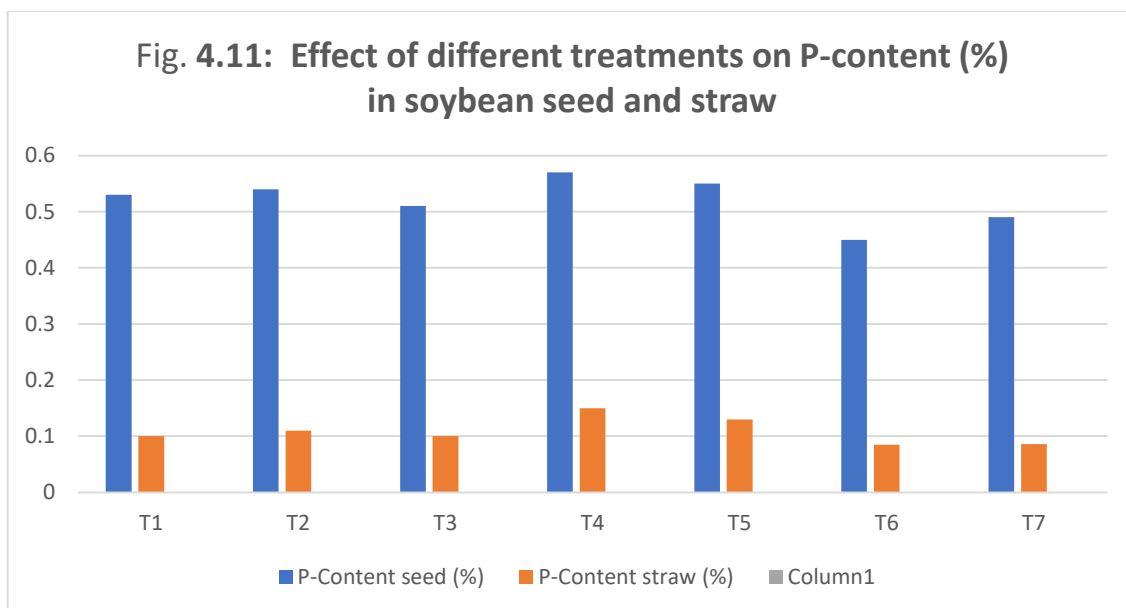
The highest phosphorus content in seed recorded under JS 20-116 (0.57%) which was significantly higher than recorded under other treatments followed by MACS 1520 (0.55) and NRC 86 (0.54%). The lowest phosphorus content of seeds (0.45%) was found under the PS 1569 Treatments.

Phosphorus content (%) in straw

The data on P-content in straw are shown in table 11

Table-4.11: Effect of different treatments on P-content (%) in soybean seed and straw

	Treatments	P-content seed (%)	P-content straw (%)
T ₁	RVS 2011-10	0.53	0.10
T ₂	NRC 86	0.54	0.11
T ₃	DLSb 01	0.51	0.10
T ₄	JS 20-116	0.57	0.15
T ₅	MACS 1520	0.55	0.13
T ₆	PS 1569	0.45	0.08
T ₇	JS 22-12	0.49	0.08
	SEm±	0.01	0.01
	CD	0.03	0.03



The phosphorus content in straw differed significantly among different treatments and the maximum percent of phosphorus in straw was reported under JS 20-116 (0.15%) followed by MACS 1520 (0.13%) and NRC 86 (0.11%). The minimum percent of phosphorus in straw was obtained in PS 1569 (0.085%), which was substantially lower than all treatment.

4.3.3: Potassium content

Potassium content (%) in seed

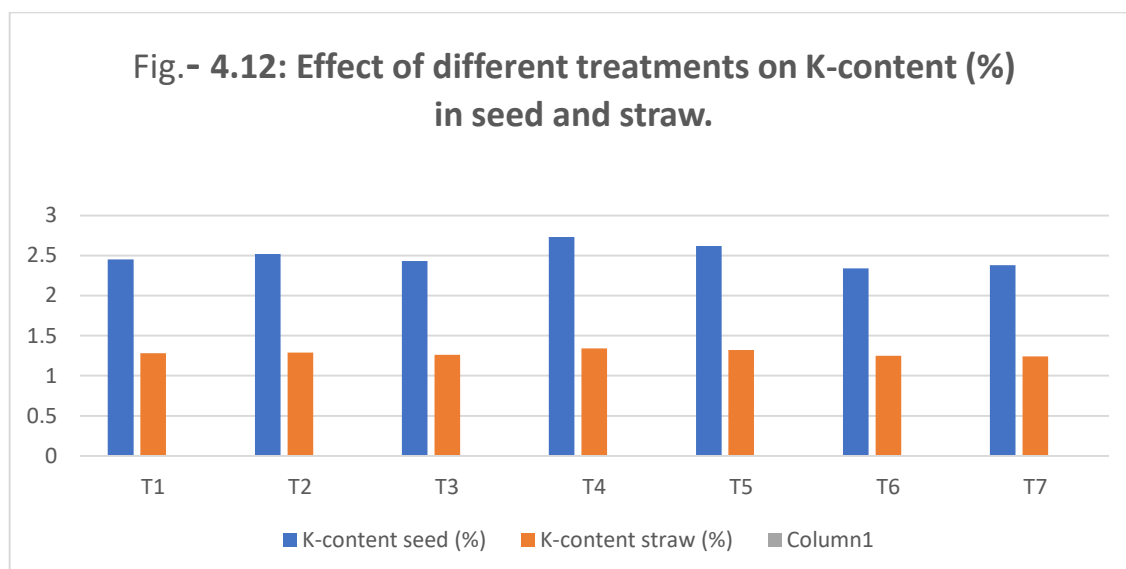
The Trend of data on K-content in seed is shown in table 4.12 and in figure 4.12. Difference in K content in seed among the various treatments was noted or. Highest K content was found in seed of JS 20-116 (2.73%) treatment, which was followed by MACS 1520 (2.62%) and NRC 86 (2.52%) treatment. The minimum content of potassium in seed was obtained in PS 1569 (2.34%).

Table- 4.12: Effect of different treatments on K-content (%) in seed and straw.

	Treatments	K-content seed (%)	K-content straw (%)
T ₁	RVS 2011-10	2.45	1.28
T ₂	NRC 86	2.52	1.29
T ₃	DLSb 01	2.43	1.26
T ₄	JS 20-116	2.73	1.34
T ₅	MACS 1520	2.62	1.32
T ₆	PS 1569	2.34	1.25
T ₇	JS 22-12	2.38	1.24
	SEm±	0.08	0.01
	CD	0.24	0.03

Potassium content (%) in straw

The variations in K content in straw were observed significant due to different treatments (Table 4.12) and fig.12. K content in straw was higher in treatment JS 20-116 (1.34%) and it was followed by MACS 1520 (1.32%) and NRC 86 (1.29%). The minimum content of potassium in straw was obtained in JS 22-12 (1.24%), which was substantially lower than all treatment.



4.3.4: Sulphur content

Sulphur content (%) in seed

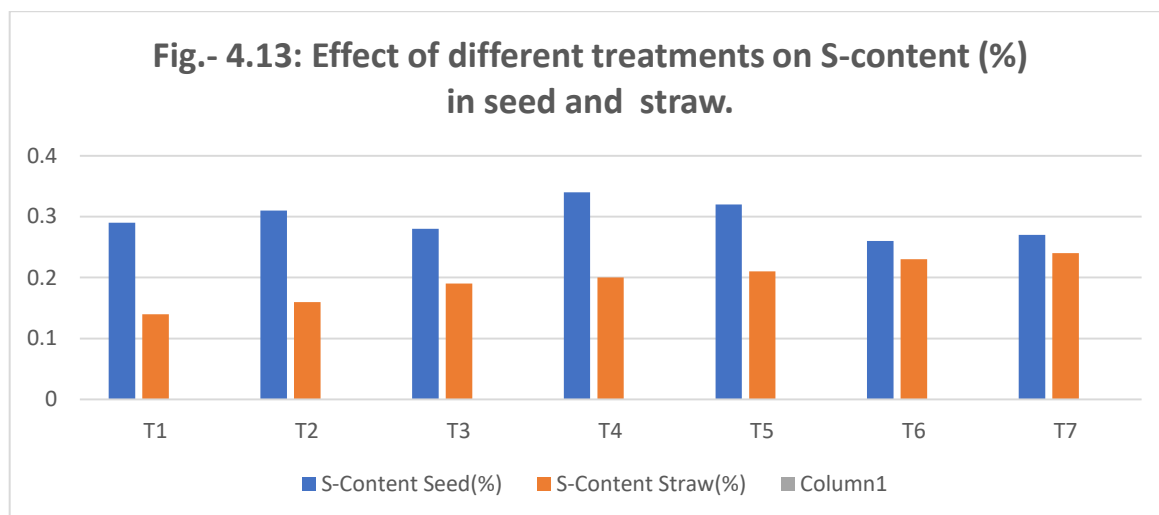
Significant difference amongst various treatments was noted for S content in seed (Table 4.13). Maximum seed S content was found in JS 20-116 (0.34%) treatment, followed by MACS 1520 (0.32%) and NRC 86 (0.31%) treatment. Minimum content of S was obtained in seed of PS 1569 (0.26 %), which was substantially lower than all treatment.

Table- 4.13: Effect of different treatments on S-content (%) in seed and straw.

	Treatments	S-content seed (%)	S-content straw (%)
T ₁	RVS 2011-10	0.29	0.20
T ₂	NRC 86	0.31	0.21
T ₃	DLSb 01	0.28	0.19
T ₄	JS 20-116	0.34	0.24
T ₅	MACS 1520	0.32	0.23
T ₆	PS 1569	0.26	0.14
T ₇	JS 22-12	0.27	0.16
	SEm±	0.008	0.005
	CD	0.02	0.01

Sulphur content (%) in straw

The data on S-content in straw are showed in table 4.13 and S content in straw was more in treatment JS 20-116 i.e (0.24 %) and it was followed by MACS 1520 and NRC 86. The Minimum Sulphur content in straw was obtained in PS 1569 (0.14) .



4.3.5: Nitrogen uptake in seed and straw (kg ha⁻¹)

N-uptake in seed

Data concern to nitrogen uptake by soybean seed is presented in table 4.14. The highest uptake of nitrogen in seed (85.82 kg ha⁻¹) was reported under treatment JS 20-116, which was significantly superior to the rest of the treatments and was found to be followed by MACS 1520 (84.46 kg ha⁻¹) and NRC 86 (83.65 kg ha⁻¹). The lowest uptake of nitrogen was recorded in PS 1569 (56.02 kg ha⁻¹).

Table: 4.14: Effect of different treatments on N-uptake by straw and seed and total uptake (kg ha⁻¹).

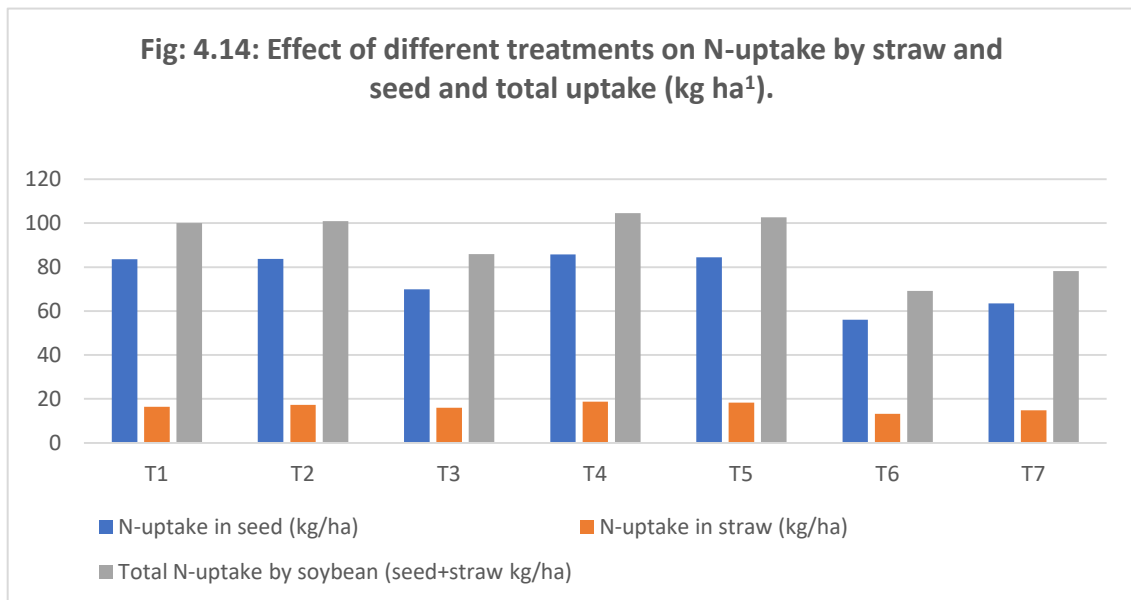
	Treatments	N-uptake in seed (kg ha ⁻¹)	N-uptake in straw (kg ha ⁻¹)	Total N uptake by soybean (seed+straw kg ha ⁻¹)
T ₁	RVS 2011-10	83.56	16.46	100.02
T ₂	NRC 86	83.65	17.24	100.89
T ₃	DLSb 01	69.83	16.00	85.83
T ₄	JS 20-116	85.82	18.79	104.61
T ₅	MACS1520	84.46	18.27	102.73
T ₆	PS 1569	56.02	13.19	69.21
T ₇	JS 22-16	63.41	14.75	78.16
	SEm±	3.69	1.12	4.81
	CD	11.39	3.46	14.85

N-uptake in straw

Data concern to nitrogen uptake by soybean straw is showed in table 4.14. Under JS 20-116 treatment, the nitrogen intake in straw was found to be optimum (18.79 kg ha^{-1}) and was slightly higher than the MACS 1520 (18.27 kg ha^{-1}). Least N-uptake in straw (13.19 kg ha^{-1}) was reported under Treatment PS 1569.

Total N-uptake in seed and straw

Total uptake of nitrogen in seed+straw, are showed in table 4.14. The highest total N uptake ($104.61 \text{ kg ha}^{-1}$) was recorded under the treatment JS 20-116, and was found followed by the treatment MACS 1520 ($102.73 \text{ kg ha}^{-1}$) and NRC 86 ($100.89 \text{ kg ha}^{-1}$) least total N-uptake was found under PS 1569 .



4.3.6: Phosphorus uptake in seed and straw (kg ha^{-1})

P-uptake in seed

The trend of data on phosphorus uptake by soybean seed is shown in table 4.15 having the maximum phosphorus uptake of 11.01 kg ha^{-1} reported under treatment JS 20-116, was substantially higher than the rest of the treatment and followed by MACS 1520 (9.7 kg ha^{-1}) and NRC 86 (8.81 kg ha^{-1}). The lowest uptake of phosphorus (5.66 kg ha^{-1}) was reported in .PS 1569.

Table: 4.15: Effect of different treatments on P-uptake by straw, seed and total uptake (kg ha⁻¹).

	Treatments	P-uptake in seed (kg ha ⁻¹)	P-uptake in straw (kg ha ⁻¹)	Total P-uptake by soybean (straw+seed, kg ha ⁻¹)
T ₁	RVS 2011-10	8.12	1.71	9.83
T ₂	NRC 86	8.81	2.09	10.90
T ₃	DLSb 01	7.20	1.43	8.63
T ₄	JS 20-116	11.01	4.13	15.14
T ₅	MACS 1520	9.70	2.34	12.04
T ₆	PS 1569	5.66	1.09	6.75
T ₇	JS 22-12	6.65	1.79	8.44
	SEm±	0.26	0.10	0.36
	CD	0.80	0.33	1.13

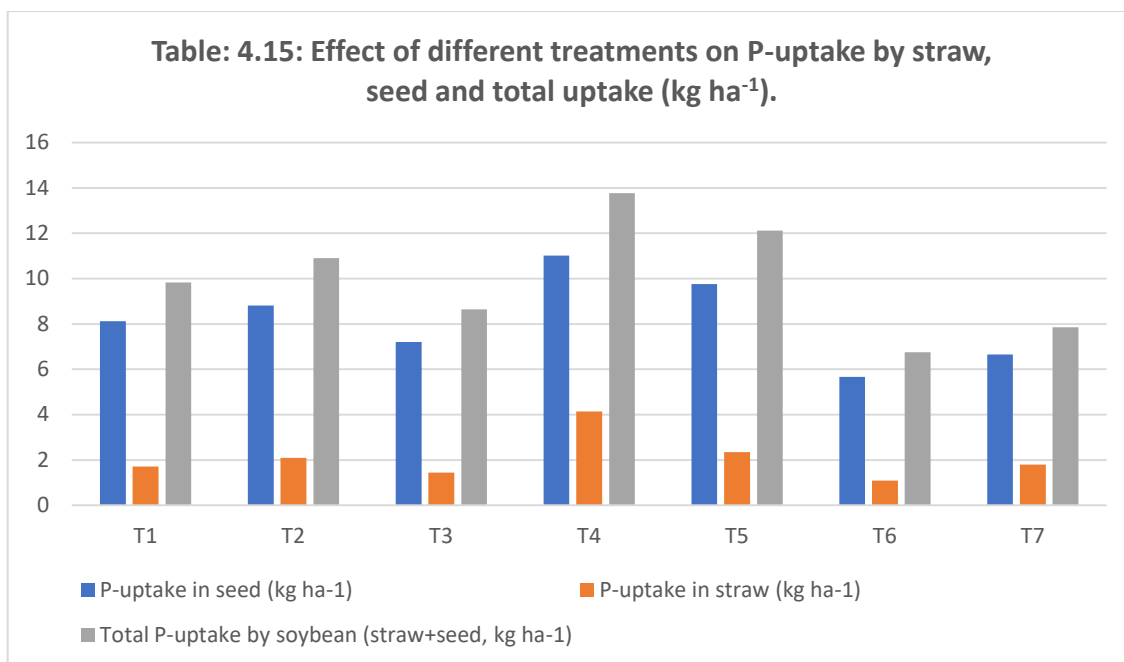
P-uptake in straw

The trend of data on phosphorus uptake by soybean seed is shown in table 4.15. Soybean straw use up phosphorus was found to be important. Treatment of JS 20-116 noticed the highest P-uptake in soybean straw (4.135kg ha⁻¹), which was significantly superior to other treatments followed by MACS 1520 (2.34 kgha⁻¹) and NRC 86 (2.09 kgha⁻¹). Minimum P-uptake under treatment PS 1569 (1.09 kg ha⁻¹) was noted.

Total P-uptake in seed and straw

The data on total (straw + seed) P-uptake by soybean crop are shown in table 4.15.

The total uptake by soybean seed + straw was significantly affected by the different treatments. The highest (13.77kg ha⁻¹) total P-uptake (seed + straw) was observed in the treatment JS 20-116 , which was substantially superior to rest other treatments and followed by MACS 1520 (12.11 kg ha⁻¹) and PS 1569 (6.75 kg ha⁻¹). Less P-uptake was recorded under PS 1569 (6.7kg ha⁻¹).



4.6 Potassium uptake in seed and straw (kg ha⁻¹)

4.6.1 K-uptake in seed

Data on potassium uptake by soybean seed are showed in table 4.16 indicating the highest potassium uptake of 41.13 kg ha⁻¹ was recorded under the treatment JS 20-116 which was significantly higher than the rest of the treatments and followed by MCS 1520 having 38.19 kg ha⁻¹ and NRC 86 having 35.07 kg ha⁻¹. The least potassium uptake was recorded at 66.68 kg ha⁻¹ in PS 1569.

K-uptake in straw

The data on K-uptake by straw as influenced by various treatments presented in table 4.16. Soybean straw potassium consumption was also found to be optimum under JS 20-116 having 44.07 kg h⁻¹ and was substantially maximum than other treatments and followed by MACS 1520 having 41.55 kg h⁻¹ and NRC 86 having 39.38 kg h⁻¹, the lowest potassium intake was noted at PS 1569 having 31.15 kg h⁻¹.

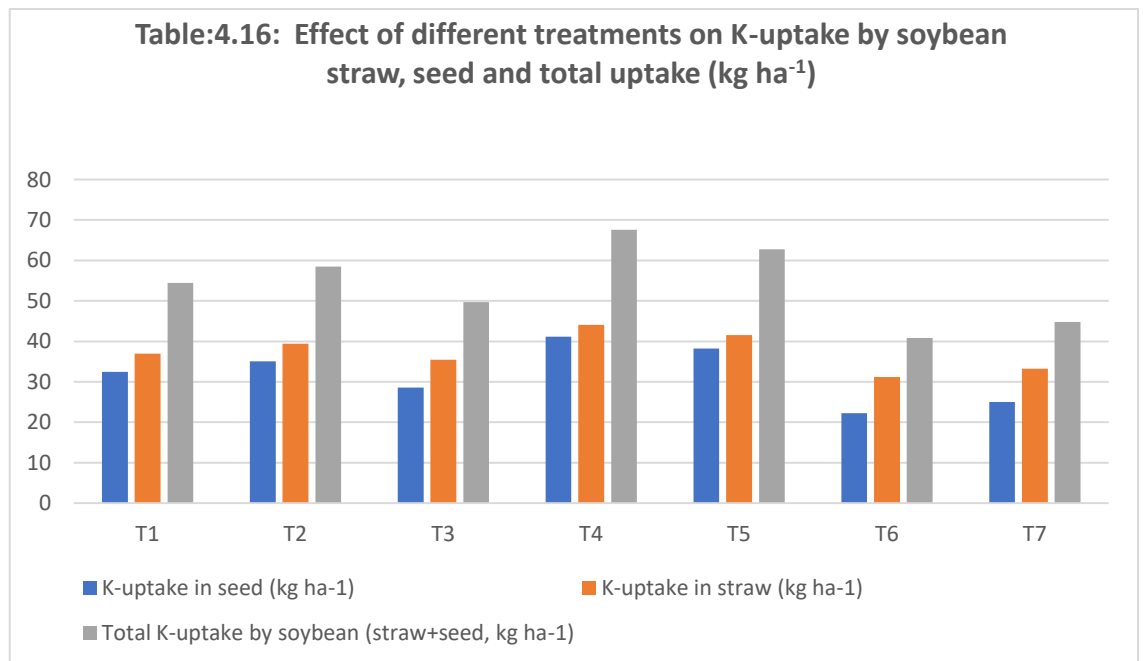
Table:4.16: Effect of different treatments on K-uptake by soybean straw, seed and total uptake (kg ha⁻¹)

	Treatments	K-uptake in seed (kg ha ⁻¹)	K-uptake in straw (kg ha ⁻¹)	Total K-uptake by soybean (straw+seed, kg ha ⁻¹)
T ₁	RVS 2011-10	32.43	36.99	68.42
T ₂	NRC 86	35.07	39.38	74.45
T ₃	DLSb 01	28.54	35.45	63.99
T ₄	JS 20-116	41.13	44.07	85.20
T ₅	MACS 1520	38.19	41.55	79.74
T ₆	PS 1569	22.22	31.15	53.37
T ₇	JS 22-12	25.00	33.26	58.26
	SEm±	1.59	0.76	2.35
	CD	4.92	2.34	6.74

Total K-uptake in seed and straw

The data on total (straw + seed) K-uptake by soybean crop are shown in table 4.16.

The highest (67.61 kg ha⁻¹) total K-uptake (seed +straw) was recorded in the treatment JS 20-116 which was significantly superior to rest of the treatments and followed by MACS 1520 having 62.75 kg ha⁻¹ and NRC 86 having 58.46 kg ha⁻¹. The minimum potassium uptake of 40.85 kg ha⁻¹ was noted in PS 1569.



4.3.8: Sulphur uptake in seed and straw (kg ha⁻¹)

S-uptake in seed

The trend of data on Sulphur uptake by soybean seed is shown in (table 4.17) having highest Sulphur uptake of 4.67 kg ha⁻¹ observed under treatment JS 20-116 which was significantly superior to the other treatments, followed by treatment MACS 1520 having 4.12 kg ha⁻¹ and NRC 86 having 3.90 kg ha⁻¹. However, the lowest Sulphur uptake (2.19 kg ha⁻¹) was noted under PS 1569.

Table: 4.17: Effect of different treatments on S-uptake by soybean straw, seed and total uptake (kg ha⁻¹)

	Treatments	S-uptake in seed (kg ha ⁻¹)	S-uptake in straw (kg ha ⁻¹)	Total S-uptake by soybean (straw + seed, kg ha ⁻¹)
T ₁	RVS 2011-10	3.36	2.88	6.24
T ₂	NRC 86	3.90	3.12	7.02
T ₃	DLSb 01	3.00	2.68	5.68
T ₄	JS 20-116	4.67	4.09	8.76
T ₅	MACS 1520	4.12	3.57	7.69
T ₆	PS 1569	2.19	1.82	4.01
T ₇	JS 22-12	2.63	2.52	5.15
S	SEm±	0.14	0.17	0.31
	CD	0.45	0.55	1.00

S-uptake in straw

The trend of data on S-uptake by straw are shown in table 4.17. Getting the highest S-uptake in straw of JS 20-116 having (4.09 kg ha⁻¹), which was substantially superior to the other treatments and followed by MACS 1520 having 3.57 kg ha⁻¹ and NRC 86 having 3.12 kg ha⁻¹. The least (1.82 kg ha⁻¹) S uptake was noted in PS 1569.

Total S-uptake in seed and straw

The data on total (straw + seed) sulphur uptake by soybean crop are shown in, (table 4.17).

Total S-uptake (seed + straw) was the highest (8.77kg ha⁻¹) reported under treatment JS 20-116, which was substantially superior to the rest of treatments, followed by MACS 1520 having 7.69 kg ha⁻¹ and NRC 86 having 7.03 kg ha⁻¹ and the minimum sulphur uptake of 4.01 kg ha⁻¹

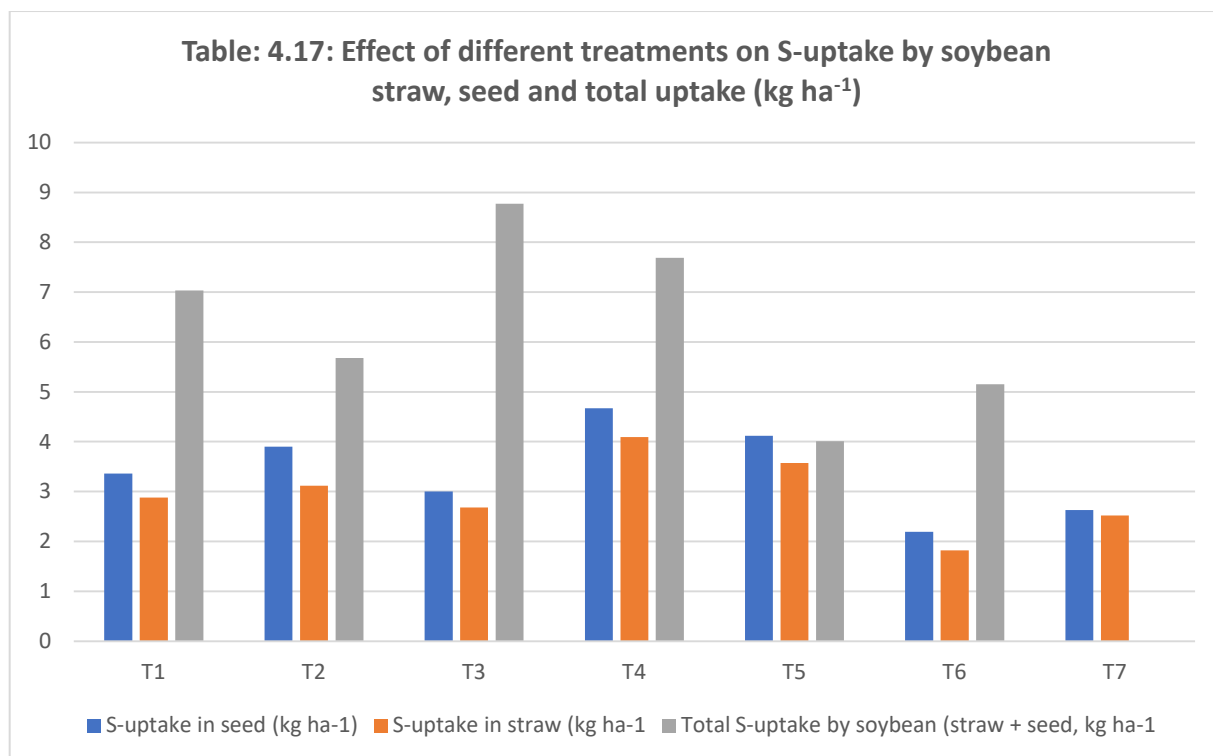


Table: 4.18: Effect of different treatments on available N, P, K and S in the soil after crop harvesting (kg ha⁻¹).

	Treatments	Available in the soil after harvest of crop (kg ha ⁻¹)			
		N	P	K	S
T ₁	RVS 2011-10	243.08	11.20	413.81	10.15
T ₂	NRC 86	245.26	12.75	415.91	10.37
T ₃	DLSb 01	221.18	10.23	403.78	9.70
T ₄	JS 20-116	246.85	14.16	421.10	11.79
T ₅	MACS 1520	245.40	13.73	420.02	11.01
T ₆	PS 1569	200.10	9.64	375.72	8.75
T ₇	JS 22-12	206.55	9.83	389.90	9.14
	SEm±	2.60	0.43	1.75	0.46
	CD	8.02	1.33	5.41	1.42

Available nitrogen balance in the soil

The data on available nitrogen content in the soil after harvesting of the soybean crop is given in table .

It was found that the highest available nitrogen content of 246.85 kg ha⁻¹ was noted in Treatment JS 20-116 , which was followed by MACS 1520 having 245.40 kg ha⁻¹ and NRC 86 having 245.26 kg ha⁻¹. Whereas the lowest N was recorded under the treatment PS 1569 having (200.1 kg ha⁻¹).

Available phosphorous content balance in soil

Available P in soil after crop harvesting was significantly affected by different treatments. It is clear from the data that available phosphorus content were substantially influenced by various treatments or not. However 14.16 kg

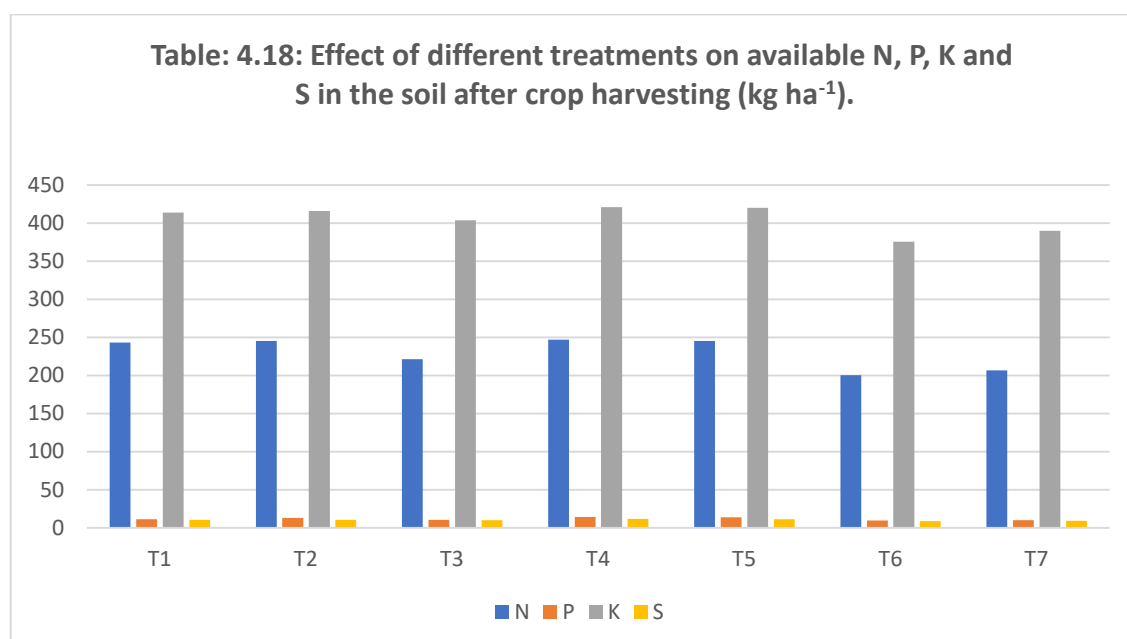
ha⁻¹P was maximum values under treatment JS 20-116 which was followed by MACS 1520 having 13.73 kg ha⁻¹ and NRC 86 having 12.75 kg ha⁻¹. Whereas the minimum P (9.64 kg ha⁻¹) was found under Ps 1569.

Available potassium content balance in the soil

Different treatments greatly affected the availability of potassium in soil after crop harvest . Available potassium content was maximum under treatment JS 20-116 having 421.1 kg ha⁻¹ and which was followed by MACS 1520 having 420.02 kg ha⁻¹ and NRC 86 having 415.91 kg ha⁻¹ . Whereas lowest K content (375.72 kg ha⁻¹) was noted under PS 1569 .

Available sulphur balance in the soil

Data presented in table .indicate that different treatments significantly affected the content of available Sulphur in soil. Data show that the highest (11.79 kg ha⁻¹) available Sulphur content values in JS 20-116 which was followed by MACS 1520 having (11.01 kg ha⁻¹) and NRC 86 having (10.37 kg ha⁻¹) and lowest value (8.23 kg ha⁻¹) in PS 1569 treatment.



4.3.9: Protein content in seed

It is an important biochemical character, documented in the seeds after the crop harvest via biochemical analysis. It is shown in Table. The highest and substantial protein content (41.5%) in seed was noted in the JS 20-116 germplasm which was followed by MACS 1520 (41.13) and NRC 86

(41.06).The lowest protein content reported in the germplasm PS 1569 (39.03%).

Table:4.19: Effect of different treatments on protein content (%) in seed of soybean

S. No.	Treatments	Protein content in seed (%)
T ₁	RVS 2011-10	40.66
T ₂	NRC 86	41.06
T ₃	DLSb 01	40.23
T ₄	JS 20-116	41.50
T ₅	MACS 1520	41.13
T ₆	PS 1569	39.03
T ₇	JS 22-12	40.06
	SEm±	0.43
	CD	1.33

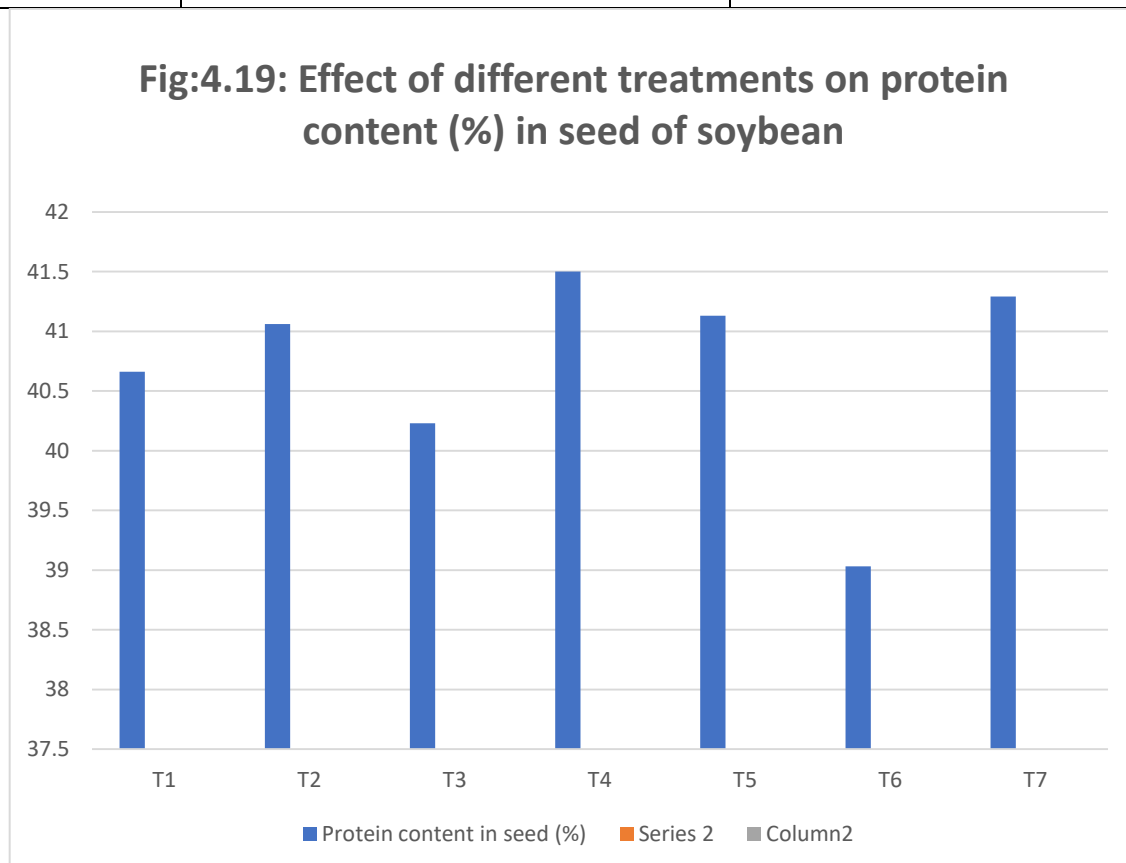


Table: 4.20: Effect of different treatments on dehydrogenase activity of soil

	Treatments	Dehydrogenase activity (TPF $\mu\text{g } 24 \text{ hr}^{-1} \text{ g}^{-1}$)
T ₁	RVS 2011-10	62.43
T ₂	NRC 86	69.01
T ₃	DLSb 01	65.27
T ₄	JS 20-116	75.66
T ₅	MACS 1520	73.90
T ₆	PS 1569	58.75
T ₇	JS 22-12	61.34
	SEm \pm	1.94
	CD	5.99

The dehydrogenase activity of soil after crop harvesting was significantly influenced by different germplasms treatments. The highest dehydrogenase activity was observed in the treatment JS 20-116 and was observed to be followed by MACS 1520 and NRC 86 While the lowest was found in PS 1569 (58.75 TPF $\mu\text{g } 24 \text{ hr}^{-1} \text{ g}^{-1}$).

Table:4.21: Effect of treatments on average bacterial and fungi population in soil

	Treatments	Bacteria (CFU X 10 ⁶ gm ⁻¹ soil) population	Fungi (CFU X 10 ⁴ gm ⁻¹ soil) Population
T ₁	RVS 2011-10	7.11	5.65
T ₂	NRC 86	7.53	5.80
T ₃	DLSb 01	6.82	5.20
T ₄	JS 20-116	8.60	6.57
T ₅	MACS 1520	7.90	6.11
T ₆	PS 1569	6.50	4.10
T ₇	JS 22-12	6.60	4.63

The result represented in table 4.21 show that the soil bacterial population after harvesting the crop . The highest number of bacterial population was recorded under the application of treatment JS 20-116 i.e. 8.6 (CFU X 10⁶gm⁻¹ soil) which was followed by MACS 1520 i.e.7.9 (CFU X 10⁶ gm⁻¹ soil) and NRC 86 i.e 7.53 (CFU X 10⁶ gm⁻¹ soil) and the least number of bacterial population was observed in PS 1569 i.e. 6.5 (CFU X 10⁶ gm⁻¹ soil) .

It is noticed from the table 4.21 that the fungi population was influenced by the numerous treatments. Application of treatment JS 20-116 was recorded the maximum number of fungi population 6.57 (CFU X 10⁴ gm⁻¹soil) in the soil. And the minimum number of fungi population 4.1 (CFU X 10⁴ gm⁻¹ soil) was noted under the treatment PS 1569.

Economics

The economics of various treatments was concluded by taking into account the market rates of various production inputs over control and produced during the analysis (Table 4.22).

The maximum net return (₹74652.8) was noted in JS 20-116 which was followed by treatments MACS 1520 (₹67917.4), NRC 86 (₹63393.2) and the least net return was noted in PS 1569 (₹33566.6). The highest B: C ratio 1:3.9 was noted with the application of JS 20-116 which was followed by MACS 1520 i.e 1:3.6 and NRC 86 i.e 1:3.5 and the least B:C ratio was noted in 1:3.5.

Table: 4.22: Economics of various combined treatments of soybean.

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Gross return (₹)	Cost of cultivation (₹)	Net profit (₹)	B:C ratio
RVS 2011-10	1066.6	1424.0	68268.0	25196.8	43071.2	1:2.7
NRC 86	1111.1	1336.8	70676.5	25196.8	45479.7	1:2.8
DLSb 01	1055.5	1240.7	67050.0	25196.8	41853.2	1:2.6
JS 20-116	1155.5	1459.2	73707.0	25196.8	48510.2	1:2.9
MACS 1520	1120.3	1375.9	71345.7	25196.8	46148.9	1:2.8
PS 1569	845.5	1092.5	54011.2	25196.8	28814.3	1:2.1
JS 22-12	961.0	1148.1	61107.9	25196.8	35911.1	1:2.4

CHAPTER – V

DISCUSSION

The discussion of present investigation entitled "**Evaluation of Soybean Germplasm for Symbiotic Traits, Nutrient Content and Yield Under Native Rhizospheric Condition in Clay Loam Soil**" are presented in this chapter.

The experimental results obtained from the study are summarised in the previous chapter and in this chapter predictable explanations is attempted which is backed by data generated in present study and available in literature.

5.1 Pre-harvest studies

5.1.1: Plant height (cm)

It is noticed that in JS 20-116 the maximum plant height was observed at all crop stages (i.e.30, 45, 60 DAS and at maturity) which is superior to other treatments. A periodic observation of soybean genotypes at plant height (cm) showed that plant height gradually increased to 60 DAS until crop maturity and its active phase of growth is in between 30 and 60 days because of better soil organic carbon enrichment and mineral nutrition in crops. Same result also reported by Mohammad Abbas *et al.* (1994), Veni and Murthy (2003), Hakkimet *et al.* (2005), Baghel and Singh (2009), and Malviya and Jain (2020), Jaiwal and Jain (2021) .

5.1.2: Number of branches plant⁻¹

Due to significant increases in supplementation of many nutrients, the highest number of branches plant⁻¹ was noted in the germplasm JS 20-116 in all stages of soybean crop. It was followed by the germplasm MACS 1520 and NRC 86. Same result have also been reported by Soni (1984), Singh and Sharma (1985) Baghel and Singh (2009), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.1.3: Root length plant⁻¹ (cm)

The highest root length plant⁻¹ was reported under the JS 20-116 germplasm which is substantially superior and followed by the MACS 1520 and NRC 86 germplasm. Least root length per plant has been observed under the PS 1569 germplasm because of fair nutrient availability and good soil physical conditions in the field such response may be assigned. Though, the results are in close conformity of the results reported by Prasad and Hajare (1992) and Mohammad Abbas *et al.* (1994), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.1.4: Dry weight (g) plant⁻¹

The maximum dry weight plant⁻¹ was noted at all phases in JS 20-116, and due to the beneficial impact of organic matter on soil physical condition and nutrients available and the minimum observed in the germplasm PS 1569. Same report of result also given by Mondal *et al.* (2014) Vyas and Kushwaha (2014), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.1.5: Number of root nodules plant⁻¹

During the analysis the maximum number of root nodules plant⁻¹ under germplasm JS 20-116 was reported may be due to genetic potential of germplasm, which may be due to better root system nodules and PS 1569 reported minimum number of root nodules. The similar results have also been reported by Choubey and Nema (1996), Baghel and Singh (2009), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.1.6: Dry weight of root nodules plant⁻¹ (mg)

Under germplasm JS 20-116 the maximum dry weight of root nodules plant⁻¹ was reported. It has been found to be followed by the MACS 1520 and NRC 86 germplasm due to the beneficial effect of nutrient utilization in soil, soil organic carbon and nutrient status and the minimum dry weight of root nodules was reported under the PS 1569 germplasm. The same results have also been reported by Choubey and Nema (1996), Baghel and Singh (2009), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.2: Post harvest studies

5.2.1: Number of Pods plant⁻¹

The highest number of pods plant⁻¹ was noticed under the JS 20-116 germplasm, which was significantly higher than all other germplasms and found to be followed by the MACS 1520 and NRC 86 germplasms Under germplasm PS 1569 the lowest number of pods plant⁻¹ was reported. Though the similar results have also been reported by Sharma and Sharma (1991), Mohammad Abbas *et al.* (1994), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.2.2: Number of seeds pod⁻¹

The JS 20-116 germplasm was significantly superior to all other germplasms with the maximum number of seeds pod⁻¹ (2.93 pod⁻¹) and minimum number of seeds pod⁻¹ which could be prefer to a favorable effect of applying physical condition to soil microbial activity and balancing nutrition to crops resulting in enhanced N-fixation, photosynthesis, protein synthesis and an increase in seed per pod and minimum number of seeds pod⁻¹ found under germplasms 1569 (1.96 pod⁻¹). Similar finding have also been reported by Choudhary and Singh (1996), Malviya and Jain (2020), Jaiswal and Jain (2021)

5.2.3: Seed index

The JS 20-116 (12.03g) germplasm noticed the highest seed index, which was considerably higher than all the other germplasm followed by MACS 1520 and NRC 86, which may be because of the many physiological processes supported which ultimately represented the seed index, the lowest reported in the germplasm 1569 (7.72g). The similar type of result found in legumes was also been reported by. Mohammad Abbas *et al.* (1994) Adam and Weaver (1998) Rocha *et al.* (2001), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.2.4: Seed yield plant⁻¹

Seed yield data plant⁻¹ are the most essential characters from which the dominance of specific genotypes is measured over others. JS 20-116 germplasm resulted the highest yield of seed plant⁻¹ (31.97 gm plant⁻¹), significantly higher than the other germplasm which was followed by MACS 1520 and NRC 86, which may be due to several physiological activities being

assisted and there by better nutrient accessibility that ultimately reflected seed yield. The lowest yield obtained in the germplasm PS 1569 i.e.(10.04 gm plant⁻¹) The same pattern of results have also been reported by Bhosle *et al.* (1995), Parmar and Nema (2002) Thakur and Vyas (2005), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.2.5: Seed and straw yields (kg plot⁻¹)

The maximum seed yield per plot (2.86 kg) and straw yield per plot (2.58 kg) were reported in JS 20-116 followed by MACS 1520 and NRC 86, respectively. This may be attributed to the improved impact of soil availability of nutrients to increase soybean seed and straw yields. In PS 1569 minimum seed yield per plot i.e. (1.67kg) and straw yield i.e. (1.94 kg) were reported. Similar result have also been reported by Thakur and Vyas (2005) Samaiya *et al.* (2007), Malviya and Jain (2020), Jaiswal and Jain 2021.

5.3: Yield of soybean

5.3.1: Grain and straw yields (kg ha⁻¹)

Grain and straw yields produced a substantial difference due to the cultivation of various soybean genotypes in medium clay loam soil.

Germplasm JS 20-116, provided the highest yield of grain (1592.5 kg ha⁻¹) and yield of straw i.e. (1433.2 kg ha⁻¹), which was substantially higher than other germplasms. It was followed by MACS 1520 and NRC 86 germplasm. In the case of straw yield the similar pattern has been observed as in the case of seed yield. This response was accredited due to improved plant growth because of better nutrient attainability and thus increased growth characters and absorption of nutrients to enhance crop grain and straw yield. The minimum grain and straw yield is observed in PS 1569 i.e. 925.6 kg ha⁻¹ and 1075.8 kg ha⁻¹. Though the similar findings have also been report by the Taware *et al.* (1997), Vyas and Khandwe (2014), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.3.2: Harvest Index (%)

The JS 20-116 germplasm noticed the highest and significantly superior harvest index (52.65%) followed by the MACS 1520 and NRC 86 . . Under the germplasm PS 1569, the minimum Harvest index (46.36 per cent) was found. This may be characterized to enhancing plant growth and higher nutrient utilization per plant. Similar result have also been reported by Patidar (2006), Panchariya and Lidder (2000), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.4: Effect of different treatment on NPKS content (%) in seed and straw

The Important variation was observed in the nitrogen content of seed and straw in soybean germplasm. Maximum nitrogen content in seed was found under JS 20-116, which was followed by the MACS 1520 and NRC 86, and the lowest in PS 1569 Germplasm. In the case of P content, the highest seed and straw content recorded under JS 20-116 was considerably higher than that reported in other treatments which reported substantial and comparatively better P-content in both seed and straw. Maximum K content in seed and straw was found under JS 20-116, which was followed by MACS 1520 and NRC 86. Same result was recorded for sulphur content in seed and straw. These treatments were superior to all the other treatments. The same results have also been reported by Vaskela and Jain (2009), Malviya and Jain (2020), Jaiswal and Jain 2021.

5.5: Nitrogen, Phosphorus, Potassium and Sulphur uptake by seed and straw (kg ha⁻¹)

The maximum soybean seed and straw uptake of NPKS was reported under JS 20-116 treatment which was followed by MACS 1520 and NRC 86. The minimum seed and straw consumption of NPKS was reported in PS 1569. The increased uptake of NPKS could be visualized due to better nodulation, N , P , K and S content and their uptake, hence the response of increased uptake of NPK by different soybean germplasms under study. Similar finding have also been reported by Vaskale and Jain (2009), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.6: Protein content in seeds

The highest protein content (41.5%) in seeds was recorded under germplasm JS 20-116, and it was followed by MACS 1520 and NRC 86.. This may be ascribe due to the better physical condition of the soil and better availability of nutrients to the plant. The lowest protein content was recorded in PS 1569 I.e. (39.03%). Though the results are also in the close conformity with the results as reported by Roy and Raquib (1998) Vyas and Khandwe (2014), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.7: Dehydrogenase activity

The significant and higher value of Dehydrogenase activity was noticed under treatment JS 20-116 followed by Treatment MACS 1520 and NRC 86. This acceleration in Dehydrogenase activity could be attributed due to increased microbial activities in the rhizosphere due to applied treatments. The resulting are in close agreement with the results reported by Jain and Singh (2018), Malviya and Jain (2020), Jaiswal and Jain (2021).

5.8: Economics

The comparative economics of the various treatments showed that the highest net return of Rs 73707 was obtained from the JS 20-116 germplasm. It was followed by the germplasm MACS 1520 Rs 71345.7 and NRC 86 Rs 70676.5, The lowest net return on germplasm PS 1569 was obtained i.e Rs 54011.19 The highest cost benefit ratio of the germplasm JS 20-116 (1:2.9) was received which was followed by MACS 1520 and NRC 86. This performance can be attributed to fair nutrient availability along with improved plant growth and increased nutrient uptake and yield. The lowest cost benefit ratio obtained in germplasm PS 1569 i.e. 1:2.1. The same result have also been reported by Vyas and Khandwe (2014), Malviya and Jain (2020), Jaiswal and Jain (2021).

CHAPTER - VI

SUMMARY CONCLUSION AND SUGGESTIONS FOR FUTHUER WORK

Summary

The present investigation entitled "**Evaluation of Soybean Germplam for Symbiotic traits, Nutrient Content and Yield Under Native Rhizospheric Condition in Clay Loam Soil.**" was conducted at the farm area of R.A.K., College of Agriculture, Sehore during the Kharif season of 2021-2022. In this chapter the salient findings of the investigations are summarized and meaningful conclusions have been made as under.

The experiment was laid out in Randomized Block Design with 3 replications and 7 treatments comprising of genotypes viz. RVS 2011-10, NRC 86, DLSb 01, JS 20-116, MACS 1520, PS 1569 and JS 22-12. The soil of the experimental field was medium black, low in available organic carbon, nitrogen and medium in soil available phosphorus & potassium and was normal in soil pH (7.3) and electrical conductivity (0.33 m dSm^{-1}).

The research was lead to study different growth parameters, yield attributes and absorption of nutrients in various genotypes. For all the characters tested, the variance analysis performed for all the traits presented substantial differences among the few germplasm.

The different growth characters i.e. plant height, branches, root length, dry weight of plant, nodule number and dry weight of nodules and the further yield attributing characters i.e. pod number, seeds per pod, seed index, NPK content and NPK uptake were studied to make final outlook of straw and seed yields by different genotypes.

The important results are summarized below

1. The variation in germplasms on pre harvest studies viz. Plant height, number of branches, root length, dry weight per plant, number of nodules, and dry nodular weight were obtained to be important. The best performance of JS 20-116 for capacity to nodulation was noted which was followed by MACS 1520 and NRC 86.

2. Germplasm JS 20-116 performed best for the post harvest parameters viz. pods plant⁻¹, no. of seed pod⁻¹, seed yield plot⁻¹, straw yield plot⁻¹, seed index, seed yield (kg ha⁻¹), straw yield (kg ha⁻¹), grain yield plant⁻¹(g) were found significant among genotypes. It was followed by MACS 1520 and NRC 86.
3. The harvest index (%) represented a substantial variation in the soybean germplasms and the JS 20-116 was found to have maximum Harvest index and followed by MACS 1520 and NRC 86.
4. In the study, JS 20-116 germplasm was found to have highest NPK content and their uptake followed by the germplasm MACS 1520 and NRC 86.
5. The protein content of the soybean seeds represented a major variance, and the highest protein content of JS 20-116 was found in the seeds followed by MACS 1520 and NRC 86.
6. Germplasm JS 20-116 gave the highest net return and cost benefit ratio respectively (74652.8) ha⁻¹ and 1:39) than other germplasm.

Conclusion

Among the germplasms tested, the germplasm JS 20-116 (1592.5 kg/ha) appeared largely suitable for Sehore Agro-climatic conditions in the Vindhya Plateau of Madhya Pradesh based on nodulating growth, yield attributes, NPK content and Protein content followed by MACS 1520 (1481.1 kg/ha). These promising genotypes proved to be beneficial and in the future in breeding trials.

Suggestion for further work

The current status needs to validate these results in the future, for at least two more growing seasons.

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APPENDIX

Appendix – I: Mean sum of square of plant height and no. of branches per plant at different successive stages of growth.

S.V	D.F	Plant height(cm)				Branches per plant (No.)			
		30 DAS	45 DAS	60 DAS	At maturity	30 DAS	45 DAS	60 DAS	At maturity
Rep.	2	4.943333	1.715714	5.992019	4.564585	0.11182	0.387142	0.080476	0.093333
Treat	6	61.11119	101.7841	235.0191	208.7612	4.4424	2.724285	5.225555	5.449682
Error	12	9.023333	11.79460	7.849241	8.858385	0.04393	0.125476	0.156031	0.177777

* Significant at 5% level

Appendix – II: Mean sum of square of root length and dry weight per plant at different successive stages of growth.

S.V	D.F.	Root length (cm)				Dry weight per plant (g)			
		30 DAS	45 DAS	60 DAS	At maturity	30 DAS	45 DAS	60 DAS	At maturity
Rep.	2	9.654761	10.97195	12.10047	5.37333	0.90142	0.809047	10.73476	0.030476
Treat.	6	21.32936	13.52824	10.12222	9.51158	15.1374	8.841111	9.257142	13.94095
Error	12	2.52531	3.691457	3.182698	2.80777	0.41865	0.820158	2.794761	1.392142

Appendix – III: Mean sum of square of number and dry weight of root nodules per plant at different successive stages of growth.

S.V	D.F	Number of root nodules per plant (No.)				Dry weight of root nodules per plant (mg)			
		30 DAS	45 DAS	60 DAS	At maturity	30 DAS	45 DAS	60 DAS	At maturity
Rep.	2	14.58476	2.028433	17.43857		18.8290	1.180476	24.17709	
Treat	6	25.96924	24.06897	24.9209		26.8430	31.14634	71.16207	
Error	12	4.970473	3.341883	4.543582		6.16682	10.29992	23.42727	

* Significant at 5% level

Appendix – IV: Mean sum of square of yield and yield attributing characters.

S.V	D. F.	Pods/ plant (No.)	Seeds / pod (No.)	Seed index (g)	Seed yield/ Plant (g)	Seed yield/Plot (Kg)	Straw yield/Plot (Kg)	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)
Rep.	2	35.97	0.027	0.350	0.3900	0.0008	0.2537	725.27	75869.12	27.44
Treat.	6	57.56	0.456	8.245	26.95	0.1662	0.1723	34828	50958.85	2.821
Error	12	5.701	0.020	0.928	4.357	0.0164	0.046	6086.7	15797.54	8.253

* Significant at 5% level

Appendix – V: Mean sum of square of N–content (%) and N–uptake (kg/ha) in seed and straw.

S.V.	D.F.	N–content in seed (%)	N–content in straw (%)	N – uptake in seed (kg ha ⁻¹)	N – uptake in straw (kg ha ⁻¹)	Total N - uptake seed+ straw (kg ha ⁻¹)
Rep.	2	0.0741	0.000819	44.623376	2.4918	43.18757
Treat.	6	0.1829	0.034741	437.7485	11.5727	582.902
Error	12	0.0561	0.001807	22.700548	3.800454	33.22808

* Significant at 5% level

Appendix – VI: Mean sum of square of P – content (%) and P – uptake (kg/ha) in seed and straw.

S.V.	D.F	P – content in seed(%)	P – content in straw(%)	P – uptake in seed (kg ha^{-1})	P – uptake in straw (kg ha^{-1})	Total P - uptake seed+ straw (kg ha^{-1})
Rep.	2	0.018690476	0.00117619	0.130433	0.184133.5	0.4320333
Treat.	6	0.005130159	0.00282222	10.27385	1.1516655	18.247832
Error	12	0.000434921	0.000381746	0.20430	0.0359722	0.2755556

* Significant at 5% level

Appendix – VII: Mean sum of square of K – content (%) and K – uptake (kg ha^{-1}) in seed and straw.

S.V.	D. F.	K – content in seed(%)	K–content in straw(%)	K–uptake in seed (kg ha^{-1})	K – uptake in straw (kg ha^{-1})	Total K - uptake seed +straw(kg ha^{-1})
Rep.	2	0.01895714	0.0259	6.41929	6.95431	15.162233
Treat	6	0.05608254	0.00440	143.836	22.4298	278.93896
Error	12	0.01923492	0.00038	7.65465	1.73696	14.354128

* Significant at 5% level

Appendix – VIII: Mean sum of square of S-content (%)and S-uptake (kg/ha) in seed and straw.

S.V.	D.F	S– content in seed(%)	S–content in straw(%)	S – uptake in seed (kg ha^{-1})	S – uptake in straw (kg ha^{-1})	Total S - uptake seed +straw(kg ha^{-1})
Rep.	2	0.000304762	0.000347619	0.296223	0.201951	0.125301
Treat.	6	0.002333333	0.002115873	2.850439	1.48674	8.231728
Error	12	0.000238095	0.00050873	0.085611	0.093002	0.215688

* Significant at 5% level

Appendix –IX: Mean sum of square of available N, P, K and S in soil after crop harvesting (kg/ha).

S.V.	D.F.	Available N in soil after harvest of crop (kg ha ⁻¹)	Available P in soil after harvest of crop (kg ha ⁻¹)	Available K in soil after harvest of crop (kg ha ⁻¹)	Available S in soil after harvest of crop (kg ha ⁻¹)
Rep.	2	3.577919	0.05645714	32.862533	0.4111
Treat.	6	1223.516	10.72379841	882.20	3.3353
Error	12	20.3647	0.560246032	9.275	0.6411

* Significant at 5% level

Appendix –X: Mean sum of square of DH activity and Protein content after crop harvesting (kg/ha).

S.V.	D.F.	Protein content	Dehydrogenase activity
Rep.	2	0.21142	14.166
Treat.	6	2.07714	124.82
Error	12	0.56624	11.34

* Significant at 5% level

Appendix – X: Basic cost of cultivation

S.No.	Particulars	Quantity	Cost (Rs/ha)
1	Field preparation and sowing		
	Two harrowing	6 hours	5100
	Sowing by tractor	2 hours	1700
2	Cost of seed	65 kg	5200
3	Thirum	160 gm	76.8
4	Plant protection		
	Pendimethalin	1.0 lit	380
	Chloropyriphos	1.5 lit	465
	Spraying	7 labour	1925
5	Weeding and Hoeing		
	Dicosulum	30 gm/ha	1350
	Fuziflex	750 ml/ha	900
	Spraying	6 labour	1500
6	Harvesting and Transportation	15 labour	4125
7	Threshing	9 labour	2475
	Total		25196.8

1. Rent of tractor @ ₹ 850 / hours
2. Labour charge @ ₹ 275 / day
3. Rate of certified seed @ ₹ 80 / kg
4. Cost of pandimethaline @ ₹ 380/ litre
5. Cost of chloripyriphos @ ₹ 310 / litre
6. Cost of Thirum @ ₹ 480 / kg
7. Selling cost of soybean seed @ ₹ 60/ kg
8. Selling cost of soybean straw @ ₹ 3 / kg
9. Cost of fertilizer –

Urea - 340 ₹

DAP - 1280 ₹

SSP - 320 ₹

MOP - 980 ₹

VITA

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