Improving biological nitrogen fixation (BNF) capacity and productivity of kabuli chickpea (*Cicer kabulinum* L.) varieties by molybdenum and PSB applications

THESIS

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

In partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

In

AGRICULTURE
(AGRONOMY)

By

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CERTIFICATE – I

This is to certify that the thesis entitled **"Improving biological nitrogen fixation (BNF) capacity and productivity of kabuli chickpea (*Cicer kabulinum* L.) varieties by molybdenum and PSB applications"** submitted in partial fulfilment of the requirement for the **Degree in Master of Science (Agronomy)** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P) is a record of the bonafied research work carried out by **Mr. Rahul Badole, ID. No 143D04** 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. All the assistance and help received during the course of the investigation has been acknowledged by the scholar.

Place: Sehore	**Dr. R.P.SINGH)**	(**Somanagouda B. Patil**)
Date:	**Chairman, Advisory Committee**	**Co- Advisor**

THESIS APPROVED BY THE STUDENTS ADVISORY COMMITTEE

Member (Dr. M. D. Vyas) ....

Member (Dr. S.C. Gupta) ....

CERTIFICATE –II

This is to certify that the thesis entitled "**Improving biological nitrogen fixation (BNF) capacity and productivity of kabuli chickpea (*Cicer kabulinum* L.) varieties by molybdenum and PSB applications"** submitted by Mr. Rahul Badole, **ID. No 143D04**, to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfilment of the requirement for the **Degree of Master of Science (Agronomy)** in Department of Agronomy, R.A.K. College of Agriculture, Sehore has been, after evaluation, approved by the External Examiner and by the Students Advisory Committee after an oral examination on the same.

Signature

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Date:

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Date
Sehore *(Rahul Badole)*

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Legend
&	And
@	At the rate of
^{o}C	Degree Celsius
C.D.	Critical Difference
cm	Centimeter
DAS	Days after sowing
d.f.	Degree of Freedom
et al.	And others
etc	and the rest
fig.	Figure (s)
g	Gram
ha	Hectare
HI	Harvest Index
i.e.	That is
Rh.	Rhizobium
PSB	Phosphate-solubilizing bacteria
Mo	Molybdenum
V1	RVSJKG 102
V2	Phule G 0517
V3	PKV 4
kg	Kilogram (s)
kg/ha	Kilogram per hectare
MSS	Mean sum of square
mg	Milligram
m	Meter (s)
N_2	Nitrogen
NH_3	Ammonia
no	Number (s)
NS	Non significant
T	Tonnes
R.V.S.K.V.V.	Rajmata Vijaya Raje Scindia Krishi Vishwa Vidyalaya
R.A.K.	Rafi Ahmed Kidwai
RH	Relative humidity
₹	Rupees
SEm±	Standard error of mean
S.S.	Sum of Square
Viz.	Namely
√	Square root
%	Percent
±	Plus or Minus

THESIS ABSTRACT

1.	**Title of the thesis**	:	**Improving biological nitrogen fixation (BNF) capacity and productivity of kabuli chickpea (*Cicer kabulinum* L.) varieties by PSB and molybdenum applications**
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ABSTRACT

The experiment entitled "Improving biological nitrogen fixation (BNF) capacity and productivity of kabuli chickpea (*Cicer kabulinum* L.) varieties by PSB and molybdenum applications" was executed during *rabi* 2015-16 at the ICARDA – FLRP, Amlaha, Sehore (M.P.), India.

Experiment consisted of twelve treatment combinations, laid out in Factorial randomized block design with three replications. The treatment were included four inoculants *viz.,* control, Ammonium Molybdate (Mo @ 1 g/kg seed), *Rhizobium* + PSB and *Rhizobium* + PSB + Mo (1 g/kg seed) and three kabuli varieties (RVSJKG 102, Phule G 0517, PKV 4) for estimate the individual or combined effect of various treatment on BNF and crop productivity at field level.

The soil was medium clay loam (Vertisol), low in available nitrogen, medium in phosphorus and medium in available potash with pH 7.5. Various growth and yield attributing characters were studied. The experiment was conducted with following objectives:

1. To determine the effect of PSB biofertilizer and Mo on growth, yield and quality of kabuli chickpea varieties.
2. To study the effect of PSB and Mo on root nodulation behavior of kabuli chickpea varieties.
3. To work out economics of different treatments.

Effect of inoculants:

The seed inoculants with *Rh.* + PSB + Mo significantly influenced the growth attributing parameter *viz.,* plant height, primary branches and secondary branches at all crop growth stages. At maturity plant height, primary and secondary branches per plant were maximum when seed inoculated with *Rh.* + PSB + Mo, while minimum was in control. Number of root nodule and dry weight of root nodule per plant was significantly higher with *Rh.* + PSB + Mo, followed by inoculants with *Rh.* + PSB inoculants and it was at par with *Rh.* + PSB in root nodule number and also at par with Mo inoculants in nodule dry weight per plant. Crop growth rate and relative growth rate were not influenced significantly due to seed inoculants. Whereas, *Rh.* +

PSB + Mo observed maximum crop growth rate and relative crop growth followed with *Rh.* + PSB treatment. Seed inoculants were found significant effect on pods per plant, seeds per pod, seed yield per plant and seed index. Maximum yield components were found when seed inoculated with *Rh.* + PSB + Mo seed inoculants, whereas minimum was in control. Similarly seed and biological yields were highest in *Rh.* + PSB + Mo seed inoculants, whereas harvest index was maximum with *Rh.* + PSB.

Effect of varieties:

Varieties had non-significant effect on growth parameters except plant height. At all growth stages, variety RVSJKG 102 produce maximum plant height and Phule G 0517 was at par with PKV 4. Maximum number of primary and secondary branches was observed in PKV 4 followed by Phule G 0517. Nodule number and nodule dry weight per plant were influenced significantly with varieties. Maximum number and dry weight of root nodule found in variety PKV 4 followed by Phule G 0517. Crop growth rate and relative growth rate did not differ significantly in different varieties. Effect on yield component found significant, variety PKV 4 had highest number of pods, seeds per pod, seed yield per plant, while RVSJKG 102 recorded highest seed index. Seed and biological yield different according to variety and the highest values were obtained from variety PKV 4 (1625 kg/ha and 4584 kg/ha, respectively).

Economics:

The highest gross return was obtained in *Rh.* + PSB + Mo seed inoculants (126665 Rs/ha) with net profit of 107592 Rs/ha and B:C ratio (6.8). However, variety PKV 4 recorded highest gross return, net profit and B:C ratio (109771 Rs/ha, 90987 Rs/ha and 4.9, respectively).

Conclusion:

The seed inoculants with *Rh.* + PSB + Mo was found best among other inoculants in respect to BNF capacity, productivity and profitability. Variety PKV 4 produced higher values of growth and yield attributing parameters of kabuli chickpea. Treatment combination of *Rh.* + PSB + Mo with Phule G 0517 on seed index proved better combinations for higher production.

CHAPTER – I

INTRODUCTION

Pulses are widely cultivated in India especially by small holding farmers. These are low input required crops because of their legume crops ability to assimilate atmospheric nitrogen through its symbiotic association with Rhizobium sp.; thus helping in enhancing the soil quality for subsequent cereal crop cultivation. The pulse cultivation also contributes towards improvement of soil fertility and subsequently the productivity of non-leguminous crops in the rotation. Pulses efficiently complement the cereal rich food in making a wholesome meal by balancing the amino acid and micronutrient content of the diet.

Chickpea after dry beans and dry peas is the third most important food legume in the world. Its cultivation is largely done in Asia with 90% of the global area. India is the principal chickpea producing country with 83% share in the region and 65% of acreage of world. The major chickpea producing states in India are Madhya Pradesh (40%), Uttar Pradesh, Rajasthan and Maharashtra. During 2014-15 in Madhya Pradesh, chickpea was grown in 28.53 lakh hectare area and recorded production of 29.64 lakh metric tonnes with average yield of 1040 kg ha^{-1} (Anonymous, 2015).

Kabuli chickpea traditionally grown in the third week of October to first week of November on profile stored moisture. Chickpea (kabuli and desi) is valued for its nutritive seeds with high protein content. Abd EL-Rahim *et al*. (2004) found that chemical composition of raw and cooked chickpea were 8.69, 8.08 % moisture, 3.84, 2.68% ash, 21.85, 24.73 % crude protein, 4.74, 6.05 % crude fiber, 6.13, 4.82 % ether extract and 53.88%, 45.00% total hydrolysable carbohydrate.

Kabuli chickpea (*Cicer kabulinum* L.) is one of the most important pulse crops it is mainly used for preparation of chhola dish and other table purpose. It is also used as dal, besan, flour, crushed whole gram, boiled or roasted or cooked, salted or sweet preparation and green foliage as vegetables. Dal is the splited grain without its seed coat, dried and cooked into a thick soup or ground into flour for snacks and sweetmeats.

Chickpea is leguminous crop which fix nitrogen in the root nodules; and this process depend on various factors, like compatibility of *rhizobium* strain with host genotype, environments, agronomic practices and their interactions. The agronomic practices like application of molybdenum and phosphorus which play a key role in biological nitrogen fixation (BNF) by legumes.

Molybdenum is required for growth of most biological organisms including plants (Graham and Stangoulis, 2005). Generally, molybdenum is an essential micronutrient for plants and bacteria (Williams and Fraustoda Silva 2002). Meagher et al. (1991) reported the role of molybdenum in normal assimilation of nitrogen by plants is well known, because molybdenum is an essential component of nitrate reductase and nitrogenase, which control the reduction of inorganic nitrate and helps in fixing N_2 to NH_3. Thus, molybdenum is the key to nitrogen fixation by legumes. Brkics et al. (2004) and Jongruaysup *et al*. (1993) also stated that the application of molybdenum stimulated nodulation and biological nitrogen fixation (BNF), thus increasing the legume productivity.

Similarly, phosphate-solubilizing bacteria (PSB) also plays a key role in BNF in legumes. PSB stimulates plant growth through enhanced P nutrition, increasing the uptake of N, P, K, and Fe. Phosphorus biofertilizers could help increase the availability of phosphates accumulated in the soil and could enhance plant growth by increasing the efficiency of BNF and the availability of Fe and Zn through production of plant growth promoting substances (Kucey et al., 1989).

Inoculation of composite strains of *Rhizobium* with phosphorus (P) and molybdenum (Mo) gave a better yield than inoculation of a single strain of *Rhizobium*. *Rhizobium* strain with Mo also increase pods plant^{-1}and yield in chickpea (Tiwari *et al*. 1989). Aditya *et al*. (2012) reported that *Rhizobium* inoculation in combination with different micronutrients (Bo, Mo) recorded higher nodulation, plant dry weight, yields and uptake of N and P than the treatments of only micronutrients or *Rhizobium* alone.

Hence, supplementation of micronutrients along with *Rhizobium* + PSB inoculation in chickpea cultivars may increase BNF and P availability in chickpea crop and there by its productivity. ,therefore keeping in view, the importance of molybdenum and PSB on nitrogen fixation by chickpea varieties, Therefore keeping these points, in view, the present study undertaken during *winter* rabi season of 2015-16 at ICARDA-FLRP, Amlaha Farm, Sehore (M.P.), India with the following objectives.

1. To determine the effect of PSB biofertllizers and Molybdenum on growth, yield and quality of *Kabuli* chickpea varieties.
2. To study the effect of PSB and Molybdenum on root nodulation behaviour of *kabuli* chickpea varieties.
3. To work out economics of different treatments.

CHAPTER II

REVIEW OF LITERATURE

Chickpea (desi and kabuli) is an important pulse crop of India and research work has been conducted on different aspects at various places in the country. Inoculation in chickpea is one of the major factors of production, since seed inoculation in chickpea is not trade in India; hence it has not received much attention of research work, The work done in India and abroad on *Rhizobium,* Molybdenum and PSB inoculation of chickpea is given below pertaining to "Improving biological nitrogen fixation (BNF) capacity and productivity of kabuli chickpea (*Cicer kabulinum* L.) varieties by Molybdenum and PSB applications".

Effect of Inoculation on growth attributing characters of chickpea:

Pala and Mazid (1992) summarized the results of 30 on-farm trials conducted over four seasons in northwestern Syria. They concluded that the effects of Rhizobium inoculations on chickpea were very small and inconsistent.

Alagawadi and Gaur (1988) in a study on the associative effect of *Rhizobium* and phosphate solubilizing bacteria on the yield and nutrient uptake of chickpea reported that the co inoculation of *Rhizobium and* Phosphobacteria enhanced the growth parameters.

Akdag and Durzdemir (2001) reported that *Rhizobium* inoculation had significant positive effects on total plant weight nodules and nitrogen contents of above ground parts at 40 and 60 (flowering) days after sowing in chickpea.

Bandyopadhyay and Puste (2001) field trial was conducted to evaluate the prospect of growing rice (*Oryza sativa* L.) – pulse sequence under rainfed condition and study on pulse inoculated with or without *Rhizobium spp*. Seed inoculation of pulses with *Rhizobium* sp. also played a positive role towards the total crop productivity and residual soil fertility status.

Jain and Singh (2003) reported that *Rhizobium* + PSB showed 8.33, 24.75, and 10.7% higher plant height, dry matter accumulation and number of branches per plant respectively in compared to the control in chickpea.

Gull *et al.* (2004) studied the effect of mineral phosphate solubilizing bacteria on phosphorus uptake and growth of chickpea. Inoculation of chickpea with the bacteria significantly increased the plant growth, shoot phosphorus and nitrogen concentration, nodulation efficiency and nitrogenase activity of roots, showing the positive effect of phosphate solubilizing bacteria inoculation on growth and development of chickpea.

Rudresh *et al.* (2005) reported that combined inoculation of *Rhizobium,* PSB and *Trichoderma spp. s*howed increased germination, nutrient uptake, and plant height, number of branches, nodulation, yield and total biomass in chickpea over the uninoculated control.

Gupta (2007) reported significantly increase in grain yield and N uptake in chickpea due to molybdenum application @ 1 kg/ha ammonium molybdate along with *Rhizobium* + PSB.

Singh *et al.* (2008) reported that the application of S, Mo, and *Rhizobium* alone or in combination increased the vegetative growth, nodule number, grain and straw yield significantly as compared to control in black gram.

Togay *et al.* (2008) reported that inoculation with Rhizobium significantly increased Plant height, first pod height, number of branches, pods and seeds per plant, grain Yield and biological yield in chickpea.

Namvar and Sharifi (2011) observed that the rhizobium inoculation as biofertilizer and mineral nitrogen (N) fertilizer affected significantly the morphological traits of chickpea (*Cicer arietinum* L.). Plants whom larger growth period produced higher biological and grain yield compared to plants that had shorter growth period.

Thomas and Ann (2011) conducted a field experiment to evaluated the effect of different methods of p application, bio-inoculants and micronutrients (Mo + B) on growth and yield of kabuli chickpea (*Cicer kabulinum*) and they observed that the bio inoculants Trichoderma + PSB was the best having recorded significantly superior growth, yield attributes and yield. Application of Mo + B also significantly influenced nodulation, dry weight, yield attributes and yield.

Gupta and Gangwar (2012) reported highest net return in chickpea cultivation with the use of RDF+*Rhizobium*+PSB+1g ammonium molybdate/kg seed in black soil.

Shukla *et al*. (2013) carried out a field experiment to study the performance of chickpea (*Cicer arietinum* L.) as influenced by FYM, biofertilizers castor cake and levels of nitrogen and phosphorus during 2008-09. Application of FYM + castor cake and FYM + Rhizobium + Azotobacter + PSB gave the similar maximum values. Application of 100% RDF gave significantly the highest values for all the growth and yield attributes.

Effect of variety on growth attributing character:

Meena and Baldev (2013) conducted a field experiment during winter (*rabi*) seasons of 2010-11 and 2011-12 at farmer's field of Nayagoan, Kota, Rajasthan to evaluate performance of 5 chickpea varieties (GNG 469, GNG 663, RSG 973, RSG 888 and Dahod yellow). Among the genotypes, 'GNG 469' recorded significantly higher values of plant height, branches/plant and seed index than 'Dahod yellow' and 'GNG 663' but remained on par with 'RSG 973' and 'RSG 888' except in seed index, which was recorded highest seed index (22.1 g) over rest of the genotypes. Whereas, highest significant pods/plant, seed and straw yield was recorded in 'RSG 973' remained at par with 'RSG 888' and 'GNG 469' except in pods/ plant was significant over 'GNG 469'. Among all the genotypes, 'RSG 888' recorded significantly higher seeds/pod over rest of the genotypes except 'RSG 973'.

Ozalkhan et *al.* (2010) studied the effect of relation between some plant growth parameters, Leaf Area Index (LAI), Net Assimilation Rate (NAR), Relative Growth Rate (RGR) and Crop Growth Rate (CGR) with biomass and grain yield of chickpea (*Cicer arietinum* L.) at four growth stages (slow vegetative growth stage , linear vegetative growth stage, Flowering stage and grain filling stage. linear vegetative growth stage, flowering stage and grain filling stage ; RGR through slow vegetative growth stage ; NAR and CGR during flowering stage.

Sekhon and Singh (2008) conducted a field experiment to study the effect of row spacing’s (30 and 45 cm) and seed rates (30, 40 and 50 kg/ha) on the performance of genotypes ('GPF 2' and 'GNG 469') of desi chickpea (*Cicer arietinum* L.). Bold - seeded genotype, i.e., GNG 469 recorded higher 100 - seed weight (22.81 g) and lower pods per plant than the small- seeded (14.85 g) genotype 'OPF 2'. The cultivar 'GNG 469' produced higher grain yield at 50 kg/ha seed rate, whereas 40 kg/ha seed rate was sufficient for 'GPF 2'.

Effect of Inoculation on yield attributing characters of chickpea:

Chandra and Kothari (2002) observed that the soil application of 1.0 kg Mo/ha and seed treatment with 0.5 g Mo/kg seed increased the grain yield, protein content, and number of nodules per plant of chickpea.

Gangwar and Dubey (2012) reported that application of recommended dose of fertilizer in chickpea along with Rhizobium inoculation and application of PSB as well as seed treatment with ammonium molybdate 2 g/kg could be used and it was found to be the best treatment among all the other treatments.

Gupta (2007) reported significant increase in grain yield and N uptake in chickpea due to molybdenum application @ 1 kg ha^{-1} ammonium molybdate along with *Rhizobium* + PSB.

Gupta and Namdeo (1997) found that seed inoculation with Rhizobium either alone or in combination with PSB or 5 t FYM / ha produced significantly higher grain yield, nodules dry weight of chickpea (JG-74) over the un-inoculated control.

Gupta and Sahu (2012) studied the effect of micronutrients viz., iron, boron, zinc, molybdenum and joint application of all micronutrient *viz.,* Fe + B + Zn + MO, alone and in combination with *Rhizobium* + PSB inoculation on symbiotic traits, grain yield and uptake of N, P, K, S, Zn, Fe, and B by chickpea crop grown with one irrigation in Vertisol and reported the beneficial effect of Zn and Mo on symbiotic traits, grain yield and nutrient uptake in chickpea.

Johansen *et al.* (2005) concluded that adding Mo in seed priming solution through *Rhizobium* inoculums found effectively giving yield responses of 37-90%.

Khan *et al.* (2014) reported that applied molybdenum influenced yield and yield parameters when Mo (0.5 kg ha^{-1}) was used in chickpea.

Kushwaha (2007) reported that the dual inoculation of *Rhizobium* and PSB resulted significant increase in yield attributes *viz.,* plant height branches /plant, seed/plant, seed index, grain and straw yield of chickpea.

Roy *et al*., (2006) reported Molybdenum (Mo) plays an important role in increasing chickpea yield through its effects on the plant itself and on the nitrogen-fixing symbiotic process because Mo is directly involved in N_2-fixation by legumes.

Sarawgi *et al.* (1999) reported highest yield (Mean 1.39 t/ha) of chickpea when seeds were treated with PSB, *Rhizobium* and trace element like molybdenum and iron.

Singh *et al.* (1992) reported that application of manganese and molybdenum in combination with *Rhizobium* significantly increased yields, seed protein and soil available N. The best treatment was 10 kg Mn and 1 kg Mo per ha together with *Rhizobium.*

Solaiman (1999) reported that the highest plant height and shoot dry weight of chickpea was obtained with the inoculants plus 1.5 kg Mo/ha. Seed yield per plant increased by 22 % over the control with the same Mo rate.

Tiwari *et al.,* (1989) observed that Inoculation of composite strain of Rhizobium with phosphorus and molybdenum gave a better yield than inoculation of a single strain of Rhizobium.

Poonia and Pithia (2014) determine that the inoculation treatments influenced significantly the chickpea plant height, nodules/ plant and therefore, the seed yield. The highest chickpea seed yield (1882 kg/ha) was produced with combination of RDF + ammonium molybdate (1.0 g/kg seed) + Rhizobium + PSB over control (1538 kg/ha) and remained equal with RDF + ammonium molybdate (2.0 g/kg seed) + Rhizobium + PSB (1832 kg/ha) and RDF + Rhizobium + PSB (1805 kg/ha) and produced 22.4, 19.1 and 17.4% more seed yield over control.

Shil *et al*. (2007) conducted field experiment on chickpea they observed that the combined application of both boron and molybdenum were found superior to their single application even though boron played major role in augmenting the yield.

Singh *et al.* (2015) reported that impact of Sulphur, Boron with or without Rhizobium inoculation on chickpea (*Cicer arietinum* L.) Single application of sulphur could not show any significant effect on grain quality. The interaction of S×B indicate that combined use of 60 kg S + 2.5 kg B/ha is optimum to attain higher yield.

Valenciano *et al.* (2010) reported that chickpea (*Cicer arietinum* L.) respond to Zn, B and Mo application at five concentration (0, 1, 2, 4 and 8) mg Zn/pot, two concentrations (0 and 2) mg B/pot and same of Mo were added. The mature plants fertilized with Zn, with B and Mo had a greater dry matter production and harvest index (H.I.) improved with the Zn application and with the Mo application. Zn application was more efficient when it was applied with both B and Mo.

Effect of variety on yield attributing character:

Khan *et al*. (2004) reported that genotype "CM7-1" was found physiologically efficient strain with maximum harvest index (37.33%) followed by genotype "CM 1571-1-A" with harvest index of 35.73%. Genotype "90206" produced maximum biological yield (7463 kg/ha) followed by genotypes "CM31-1" and "E 2034" with biological yield of 7352 and 7167 kg/ha, respectively.

Mansur *et al* (2006) conducted a field experiment to know the effect of plant densities and phosphorus levels on seed yield and protein content of chickpea genotypes. The chickpea genotype ICCV-2 recorded 32% higher seed yield (1840 kg/ha), 7% higher nitrogen uptake [64.94 kg/ha] and 4% protein content [23.7%] compared to BG-267 (1384 kg/ha, 60.33 kg/ha and 22.60% respectively).

Goyal *et al*. (2010) carried out a field experiment to study on growth and yield of Kabuli chickpea (*Cicer arietinum* L.) genotypes under different plant densities and fertility levels. Genotype ‘Phule G 95333’ recorded higher growth and yield attributes, grain and straw yield than genotype ‘Phule G 0515’. 33 plants/m^2 showed that significantly higher grain and straw yield, whereas number of pods/ plant and grain yield/plant were higher with 22 plants/m^2.

Kanoun *et al.* (2015) assessed 14 kabuli type chickpea genotypes for seed yield in four stations over three successive years (2010-2013) at west highlands of Iran. The mean seed yield of genotypes averaged over environments showed that FLIP 00-39C and SEL 99 TH 150454 had the highest (1163.58 kg/ha) and the lowest seed yield (759.07 kg/ha), respectively.

Mhase *et al.* (2006) reported that the eighteen chickpea cultivars were evaluated for performance under rainfed and late sown conditions. Average grain yield under normal sowing was 2120 kg/ha, and this was reduced by 68.07% under late sown conditions. Redaction in grain yield under rainfed condition was due to reduction in pod number/plant (36.6%), plant height (26.9%), and branches per plant (20.8%). The genotypes, Phule G 9425-3 and Phule G 9414-7 showed the highest tolerance efficiency with the lowest susceptibility index under rainfed and irrigated conditions.

Sabgpour *et al*. (2010) studied seed yield stability in chickpea (*Cicer arietinum* L.) genotypes in autumn planting in dryland conditions. Genotype FLIP 93-93 and S96019 with 1193 and 1181 kg/ha produced the highest seed yield.

Sekhon and Singh (2008) reported that the kabuli genotypes, GLK 21143 and BG 1053 were at par in grain yield while GLK 21159 was a poor yielder. The plant height, primary as well as secondary branches and number of pods per plant were higher in GLK 21143 and BG 1053 than GLK 21159.

Samad *et al*. (2015) conducted field experiment with eight chickpea varieties to determine the relationship yield and its components using correlation and path-coefficient analysis Correlation studies revealed that seed weight per plant expressed positive significant correlation with number of primary branches at maximum flower, number of secondary branches at maximum flower, number of pods per plant, pod weight per plant and number of seeds per plant at genotypic level. In phenotypic level, seed yield showed positive significant correlation with number of pods per plant, pod weight per plant and number of seeds per plant.

Ovais *et al*. (2015) were observed High genotypic and phenotypic coefficients of variability for seed yield (q/ha), number of pods/plant, 100-seed weight, protein content and seed yield/plant. High value of genetic advance was recorded for number of pods per plant, biological yield/plant and harvest index and highest genetic gain was recorded for number of pods per plant. Hence, these characters indicate the presence of a considerable proportion of total variability due to genetic causes.

Effect of inoculation on nodulation of chickpea:

Jain *et al* (1995) reported that Rhizobia inoculation resulted in a significant increase in the total number of nodules (64 nodules /plant at 40 DAS in 1986/87) and weight of nodules (1.475mg) as compared with the control (16 nodules and 0.36 mg).

Sarawgi *et al.,* (1999) observed that the seed treatment of chickpea with Mo and Fe can synergize the effect of applied phosphorus, PSB and rhizobium in terms of yield and nodulation.

Solaiman (1999) reported significant increase in the number of total and effective nodules per plant, dry weight of nodules per plant by *Rhizobium* inoculation in chickpea.

Jain and Singh (2003) found that chickpea cv. JG-315 on seed inoculation with *Rhizobium* and /or Phosphorus solubilizing bacteria (PSB) markedly increased nodulation, pods/plant, seed and stover yield. Seed inoculation with *Rhizobium* and PSB increased seed yield by 15 and 10% respectively, compared with no inoculation. Combined inoculation of *Rhizobium* and PSB produced the highest mean seed yield of 1.63 t/ha.

Gupta (2004) reported increase in nodules/ plant, nodule dry weight/ plant seed yield, protein in seed and N and P with inoculation of *Rhizobium* and PSB in chickpea.

Gupta (2004) studied the effect of methods of microbial inoculation of *Rhizobium* and phosphorus-solubilizing bacteria (PSB) on chickpea (*Cicer arietinum* L.). They observed that dual inoculation of chickpea with Rhizobium and PSB, exercised either as seed-inoculation or as soil-inoculation, significantly increased the root-nodulation, seed yield, seed-protein content, uptake of nitrogen and phosphorus, and the population of soil rhizosphere *Rhizobium* and PSB as compared to the control.

Gupta (2006) reported that seed inoculation with *Rhizobium* and PSB individually and with *Rhizobium* + PSB together significantly increased the nodule number, nodule dry weight per plant and also the average grain yield of chickpea by 16.7%, 11.90% and 24.3 % respectively over control.

Gupta and Gangwar (2012) reported that the application of ammonium molybdate @ 1.0 g/kg seed along with *Rhizobium* + PSB inoculation at the recommended levels of fertilizer application enhances chickpea nodulation, growth, N and P uptake and also the grain yield of chickpea by 32.4% over RDF only.

Gangwar and Dubey (2012) reported that the application of recommended dose of fertilizer in chickpea along with *Rhizobium* inoculation and application of PSB as well as seed treatment with ammonium molybdate 2 g/kg could be used and it was found to be the best treatment among all the other treatments.

Das *et al.* (2012) in a study on the effect of P levels and bacterial inoculation reported that the application of 30 kg P_2O_5 /ha significantly enhanced plant height, number of branches per plant, number of nodules per plant, pods per plant, seeds per pod, test weight, seed yield (1263 kg/ha) straw yield (3336 kg/ha), biological yield (4734 kg/ha), harvest index of chickpea.

Effect of Inoculation on quality of chickpea:

Zai *et al.* (1999) found that *Rhizobium* inoculation had significant positive effect on growth, nitrogen content and uptake in shoot, yield and yield attributes and seed protein content in chickpea.

Alam *et al.* (2001) observed that the *Rhizobium* inoculation had a significant effect on the seed yield and seed protein content in chickpea.

Elsheikh *et al.* (2001) reported that inoculation with *Rhizobium* in pulses significantly increased the protein content.

Gupta (2001) reported that dual inoculation in chickpea with *Rhizobium* and PSB either as seed or soil inoculation significantly increases the nodulation, grain yield, crude protein, N and P uptake and soil *Rhizobium* as well as PSB population over control.

Singh *et al.* (2014) in a study on the effect of some micronutrients on content and uptake of nutrients in chickpea stated that the maximum content of protein and uptake of nitrogen, phosphorus, iron, molybdenum and zinc was observed with the combined application of all three micronutrients (Fe, Zn and Mo) with *Rhizobium* inoculation.

Effect of Variety on quality of chickpea:

Ghribi *et al*.(2015) research on two chickpea cultivars (kabuli, desi) were analyzed to determine and compare their physical characteristics, chemical composition and functional properties to one another and observed that significant differences were revealed among the studied cultivars. Kabuli cultivar has significantly shown ($P \leq 0.05$) higher protein content (24.51%), fiber content (21.86%) and lower Water Holding Capacity (WHC) compared to the desi cultivar.

Gaur *et al.* (2016) found result in field experiment Thus, an increment in protein content is expected to have a negative effect on seed size and grain yield. However, careful selection of transgressive segregates with high protein content along with moderate seed size and utilizing diverse sources of high protein content will be useful in developing chickpea cultivars with high protein content and high grain yield. Inheritance of protein content and its relationships with seed size, grain yield and other traits in chickpea.

CHAPTER - III

MATERIALS AND METHODS

The materials used and the techniques adopted for the study were considered as the most important ones. Therefore, the ensuring account has been prepared in the same light. A detailed account of the material employed and methods followed during the course of investigation is embodied in this chapter.

3.1 Experimental site:

The experimental work was conducted in the field No. 11 at Food Legumes Research Platform (FLRP), ICARDA, Amlaha, Sehore, (M.P.), India on chickpea during 2015 on 728.64 m^2 area having uniform topography, normal fertility status and soil homogeneity.

3.1.1 Soil

The field selected for the purpose of investigation had typical medium black cotton soil (Vertisol). In order to know the fertility status of the soil, the soil samples were taken from 0 – 20 cm depth after the layout (before sowing) of the experimental field from different places selected at random with help of soil auger. The composite sample was analyzed and the results of chemical analysis are shown in the Table 3.1.

Table 3.1: Mechanical analysis physio-chemical properties of soil of experimental site.

S.No.	Constitution	Quantity (%)	Method of determination
1.	Sand	21.5	International Pipette method
			(Piper, 1950)
2.	Silt	31.8	-do-
3.	Clay	42.6	-do-
4.	Inert matter	2.5	-do-

3.1.2 Climate and weather condition

FLRP,ICARDA, Amlaha is situated 60 km from Bhopal on Bhopal-Indore NH 86 road in sub-tropical zone of Vindhyan Plateau of Madhya Pradesh, North of 23º 07’ 0’’ latitude and East of 76º 54’ 0’ ’longitude with an altitude of 469 m from Above Sea Level (ASL). The average rainfall varies from 1000 to 1200 mm concentrated mostly from June to September. The mean annual maximum and minimum temperature are 40.16ºC and 18.5ºC, respectively. The summer months are hot and May is the hottest month having a maximum temperature up to 43.52º C. Winter month experienced mild cold with an average temperature from 8.74º C to 16.56º C. January is the coldest month as temperature reaches up to 4º C. Meteorological data recorded during the period of experimentation are given in Table 3.2 and depicted in Fig. 1.

Table 3.2: Meteorological data during the crop season (October, 2015 to March 2016)

Month	Standard week No.	Week	Temperature (°C)		Relative humidity (%)	Rainfall (mm)	Number of rainy days
			Max.	Min.			
	40	28-4	33.9	19.9	73.42	0.0	0
October	41	5-11	34.98	19.37	74.57	0.0	0
	42	12-18	34.28	19.05	73.85	0.0	0
	43	19-25	34.24	20.47	73.71	0.0	0
	44	26-1	27.84	17.92	67.42	20	1
	Average		**41.31**	**24.17**	**72.59**		
November	45	2-8	30.8	18.58	70.42	0.0	0
	46	9-15	31.05	17.12	70.57	0.0	0
	47	16-22	29.45	14.08	69.14	0.0	0
	48	23-29	27.77	15.85	67.42	0.0	0
	Average		**29.76**	**16.40**	**69.38**		
December	49	30 -6	28.42	13.62	68	1.5	1
	50	7-13	27.08	11.38	66.57	0.0	0
	51	14-20	22.58	6.77	62.14	0.0	0
	52	21-27	21.72	5.92	61.28	0.0	0
	Average		**24.95**	**9.42**	**64.49**		
January	53	28-3	27.97	10.05	67.57	0.0	0
	1	4-10	26.67	9.81	66.14	0.0	0
	2	11-17	26.22	11.61	65.71	0.0	0
	3	18-24	18.31	8.35	60.71	15	1
	4	25-31	26.94	9.61	66.42	0	0
	Average		**25.22**	**9.88**	**65.31**		
February	5	1-7	26.78	11.45	66.42	0.0	0
	6	8-14	26.97	11.68	66.28	0.0	0
	7	15-21	29.98	16.97	69.42	0.0	0
	8	22-28	29.57	12.21	69.28	0.0	0
	Average		**28.32**	**13.07**	**67.85**		
March	9	29-6	32.48	17.10	72	5	0
	10	7-13	33.01	17.44	72.42	0.0	0
	11	14-20	31.94	17.28	71.57	0.0	0
	12	21-27	35.70	18.20	75.14	0.0	0
	Average		**33.28**	**17.50**	**72.78**		
					G.T.	41.5	3

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

The weekly meteorological data viz. rainfall, temperature, relative humidity and no of rainy days during crop season were recorded in meteorological observatory of R.A.K. College of Agriculture, Sehore.

The data in Table 3.2 indicates that during the crop season the May was the hottest while December and January were the coolest months, maximum and minimum rainfall, ranged from 1.5 mm to 20.0 mm. The maximum and minimum temperature during crop season, ranged from 18.31℃ to 35.70℃ and 5.92℃ to 20.47℃, respectively, while relative humidity varied from 60.71% to 75.14% respectively.

3.1.3 Cropping history of the experimental field:

The crops grown in the experimental field during the preceding one year are presented in Table 3.3.

Table 3.3 Cropping history of the experimental field

Year	Kharif season	Rabi Season
2014-15	Soybean	Lentil
2015-16	Soybean	Chickpea Present Experiment

3.1.4 Collaboration with other department:

1. Department of Soil Science and Agricultural Chemistry, R.A.K. College of Agriculture, Sehore (M.P.)
2. Department of Statistics, R.A.K. College of Agriculture, Sehore (M.P.).
3. FLRP, ICARDA, Amlaha , Sehore (M.P.), India

3.2 Experimental details:

The present experiment was carried out with 12 treatment combination consisted 4 inoculants and 3 varieties, replicated 3 times in randomized complete block design .The details of layout plan and experiment are as follows:

Design : Factorial Randomized Complete Block Design

Number of replications : 03

Treatments : 12 (4 × 3)

Plot size- Gross : 4 m × 3.6 m

Net : 3 m × 3 m

Spacing between plots	:	0.8 m
Spacing between Replication	:	1.2 m
Spacing between rows	:	30cm
Number of rows/plot	:	10 rows
Total experimental area	:	728.6 m^2
Seed rate	:	120 kg/ha
Spacing	:	30 × 10 cm
Date of sowing	:	26/11/2015
Date of harvesting	:	04/03/2016
Date of threshing	:	06/03/2016

Table 3.4: Details of the treatments

Factor- A : Inoculants- 4	
1. Control	I1
2. Molybdenum (Mo) seed treatment	I2
3. *Rhizobium* + PSB seed treatment	I3
4. *Rhizobium* + PSB + Mo seed treatment	I4
Factor- B: Varieties- 3	
1. RVSJKG 102	V1
2. PHULE G 0517	V2
3. PKV 04	V3

Table 3.5: Treatment combinations

T1- $I_1 + V_1$	T4- $I_2 + V_1$	T7- $I_3 + V_1$	T10- $I_4 + V_1$
T2- $I_1 + V_2$	T5- $I_2 + V_2$	T8- $I_3 + V_2$	T11- $I_4 + V_2$
T3- $I_1 + V_3$	T6- $I_2 + V_3$	T9- $I_3 + V_3$	T12- $I_4 + V_3$

3.3 Characteristics of genotypes:

(a) Phule G 0517:

This variety is semi spreading growth habit with broad leaves. Seeds are ivory white colour. It is an extra-large seeded (59.4 g/100 seeds) kabuli variety. It matures in 100 to 110 days. Its average yield is 18q/ha. It is tolerant to *Fusarium* wilt. Year of release/notification was 2010 from area of adoption Zone/State Maharashtra, Madhya Pradesh

Karnataka and released from MPKV (Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra).

(b) PKV Kabuli - 4:

It has semi spreading growth habit with broad leaves. Seed colour is ceramic white and seeds are extra-large (55.4 g/100 seeds). It matures in 100-110 days and is tolerant to wilt, dry root rot and BGM. Its average yield is 18-20q/ha. Year of release/notification in 2010 from Area of adoption Zone/State Maharashtra, Madhya Pradesh and released from PDKV (Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola, Maharashtra).

(c) RVSJKG 102 :

Whitish extra bold seeded variety having average seed size of 58.0 g/100 seed. Early maturity (104 days) and average yield 1200-1500 kg/ha. Year of release/notification in 2012 from Area of adoption Zone/State Madhya Pradesh and released from RVSKVV (Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya), Gwalior, M.P.).

3.4 Soil sampling and analysis:

Before planting, one composite soil sample from the experimental site was collected in a zigzag pattern from the depth of 0-30 cm from fifteen spots. Uniform volume of soil was obtained in each sub-sample by vertical insertion of an auger. The soil was air dried, ground by using a pestle and a mortar and allowed to pass through a 2 mm sieve. Working samples were obtained from each submitted samples and analyzed for organic carbon, total N, soil pH, available phosphorus, cation exchange capacity (CEC and textural analysis using standard laboratory procedures at R.A.K. College of Agriculture Analytical Service Laboratory**.**

3.5 Cultivation practices:

3.5.1 Field preparation:

After the harvest of soybean crop during the month of October 2015, one tillage operation was done by tractor, there after pre sowing irrigation (palewa) was given on 03.11.2015, cross bukharing was done after attainment of workability, the field was prepared by pata and leveler.

3.5.2 Seed treatment:

Before sowing, the seeds were treated as per treatment.

3.5.3 Method of sowing:

The sowing was done by bullock drawn Dufan at the depth of 3 to 4 cm uniformly. The sowing of experiment crop was carried out on 26th November 2015 maintaining row spacing of 30 cm. The required quantity of seed was placed in furrows by hand and covered with soil immediately.

3.5.4 Seed rate:

At the rate of 120 kg/ha seed was used for sowing.

Table 3.6: Schedule of the field operations

S.No.	Operation	Date	Remark
1	Field operations (a) Ploughing (b) Bukharing by Desi Bakhar (c) Levelling by bullock drawn leveler	 01/11/2015 09/11/2015 12/11/2015	By tractor drawn plough
2	Layout of the experiment	22/11/2015	Manual
3	Sowing	26/11/2015	By bullock drawn Dufan
4	First irrigation	30/12/2015	
5	Intercultural operation	05/01/2016	By Khurpi & hand hoe
6	Harvesting	04/03/2016	Manual
7	Threshing	06/03/2016	Manual

3.5.5 Intercultural operation:

Weeds like Bathua (*Chenopodium album)*, Senji (*Melilotus indica*) Motha (*Cyperus rotundus*), Gajar grass (*Partheniun hysterophorus*), Hiran khuri (*Convolvulus arvensis*), and Satyanasi (*Argemone mexicana*) were predominant in the field after sowing. They were kept under control at the stage of 35-40 DAS by hand weeding and hoeing.

3.5.6. Harvesting and Threshing

The harvesting of the experiment was done on 04/03/2016. To avoid the border effect, border rows were first harvested before the harvest of net plot. The produce of each plot was tied in bundles and weighed with the help of spring balance. The produce of each plot was recorded in kg/plot and yield/ha was worked out.

3.5.7 Details of observations recorded:

The detailed of observation recorded during the course of investigation or studying the effect of various treatments are given here in the Table 3.5.

Table 3.7: Observation recorded during the crop period

S.No.	Observation	Size of sample	Stage
A.	Pre-harvest studies		
1.	Height of plant (cm)	3 tagged plant	40,60,80 DAS and at maturity
2.	Number of branches /plant	-do-	40,60,80 DAS and at maturity
3.	Dry weight/plant	-do-	40, 60 DAS and at maturity
4.	Number of Root nodules / plant	-do-	40,60 DAS
5.	Dry weight of nodules/plant (mg)	-do-	40,60 DAS
B.	Post-harvest studies		
1.	Number of pods/plant	3 tagged plant	At maturity
2.	Number of seeds/pod	-do-	At maturity
3.	Seed yield /plant (g)	-do-	At maturity
4.	Seed index (g)	-do-	At maturity
5.	Seed yield/plot	Per plot	At maturity
6.	Straw yield/plot	Per plot	At maturity
7.	Biological yield	Per plot	At maturity
C.	Data to be calculated		
1.	Seed yield/ha (kg)		At maturity
2.	Straw yield/ha (kg)		At maturity
3.	Harvest index (%)		At maturity

3.6 Crop data collection and measurement:

3.6.1 Phenological and growth parameter:

(a) Plant height (cm)

In each net plot five plants were selected randomly for periodic observation. The height was recorded at 40, 60, 80 DAS and at physiological maturity in all the plots. Height of each selected plant was measured in centimeters with the help of meter scale from the ground surface level to the main stem apex.

(b) Number of primary branches per plant :

The average number of basal primary branches emerged directly from the main shoot was counted at 40, 60, 80 DAS and at maturity from three randomly taken plants at physiological maturity and reported as average number of primary branches per plant.

(c) Total and effective Number of root nodules

This was determined by counting from three plants at 40 and 60 DAS randomly taken from destructive sampling of the non-border rows of each plot at flowering. Roots were carefully exposed with the bulk of root mass and nodules. The nodules were separated from the soil washed and the total numbers of nodules were determined by counting. Then, effective and non-effective nodules were separated by their colors where a cross section of an effective nodule made with a pocket knife showed a pink to dark-red color, whereas a green color indicated non-effective nodulation.

(d) Dry weight / plant (g.)

The dry weight per plant was also recorded from randomly selected three plants in each plot at 40, 60 DAS and at physiological maturity, plants were oven dried and their weight was recorded, with the help of electronic balance.

(e) Dry weight of effective root nodules (mg) :

Dry weight of effective root nodules per plant were recorded at 40 and 60 DAS. Isolated effective root nodules were kept in an oven for 24 hours at 70˚C temperature and subsequently the dry weight of nodules was recorded.

3.6.2 Physiological parameters:

(1) Crop growth rate (CGR, g/m^2/day):

It is the rate of dry matter production per unit ground area per unit time (Watson, 1952). It was calculated by using the following formula and expressed as g/m^2/day.

$$\text{CGR} = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

Where, W_2 and W_1 are dry matter of preceding and succeeding stages and t_2 and t_1 represent the time period at which W_1 and W_2 were recorded. P is the ground area.

(2) Relative growth rate (RGR, g/g/day):

Relative growth rate (RGR) is also a measure used to quantify the speed of plant growth. It is measured as the mass increase per above ground biomass per day, for example as g g^{-1} d^{-1}. It is considered to be the most widely used way of estimating plant growth.

It expresses the dry weight increase in time interval in relation to the initial weight and is expressed in g/day. It is also called efficiency index. It is proposed by Fisher (1921).

$$\text{RGR} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where, W_2 and W_1 are the dry weight (g) at time t_1 and t_2 respectively.

3.6.3 Yield components and yield:

(a) Number of pods per plant

Number of pods in each plant was counted after crop harvesting and mean of 25 plants was calculated.

(b) Number of grains per pod.

Numbers of grains in each plant were counted after harvesting and mean of 25 plants was calculated

(c) Seed yield/plant (g)

Seed yield (g) of each plant was recorded and mean of 25 plants was calculated.

(d) Seed index

Hundred seed weight was recorded by weighing 100 randomly taken dry seeds from the harvested net plot using a sensitive balance and the weight was adjusted to 10% seed moisture content.

(e) Seed yield kg/plot

It was determined from the net plot, and the seed yield was adjusted to moisture level of 10%. Finally, yield per plot was converted to per hectare basis and the average yield was reported in kg ha^{-1}

(f) Straw yield kg/plot

Grain weight (kg) of each plot was subtracted from the dry bundle weight of that plot to obtain the stover yield (kg) per plot.

(g) Biological yield (kg/plant)

At proper maturity whole plants were harvested along with grains and after sun dried the biomass of each selected plant was weighed in grams to determine biological yield (g) per plant.

3.6.4 Parameters to be calculated

(a) Seed yield (kg ha^{-1})

Total yield of each plot was recorded in kg at the time of harvesting and converted in to kg per hectare by multiplying with conversion factor 1111.1.

(b) Straw yield (kg ha^{-1})

Grain weight (kg) of each plot was subtracted from the dry bundle weight of that plot to obtain the stover yield (kg) per plot and converted in to kg per hectare by multiplying with conversion factor.

(c) Harvest index (%):

Harvest index per plot was recorded as the ratio of dry seed yield per plot to the above ground dry biomass yield per plot taken at physiological maturity

Harvest index was calculated by equation:

HI = Ye / Yb

Where,

HI= Harvest Index

Ye= Economical yield

Yb= Total above ground dry biomass

3.7 Soil analysis

3.7.1 Soil analysis for NPK before sowing and at harvesting

(a) Available nitrogen:

The available nitrogen in soil was determined by alkaline permanganate method as explained by Subbiah and Asija in 1956.

(b) Available phosphorus:

The estimation of available P_2O_5 was done by using Olsen's extract (0.5 m sodium bicarbonate solution of pH 8.5) as described by Olsen *et al*. (1954).

(c) Available potassium:

The available amount of potassium was determined by using neutral ammonium acetate as mentioned by Black in 1965.

Table 3.8: Initial soil fertility status of experimental field

S. No.	Particulars	Content	Level	Method adopted
1.	Organic carbon (%)	0.48%	Medium	Walkey and Black method (1934)
2.	Available Nitrogen (kg/ha)	149.8	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
3.	Available Phosphorus (kg/ha)	6.40	Medium	Olsen's procedure (Olsen *et al.*. 1954)
4.	Available Potash (kg/ha)	346.5	High	Flame Photometer (Black 1965)
5.	Soil pH	7.6	Normal	Glass electrode pH meter in 1:2:5 soil water suspension (Piper, 1950)
6.	Electrical conductivity (dsm^{-1})	0.49	Normal	Solubridge method (Jackson, 1973)

Table 3.9: At harvesting soil fertility status of experimental field:

S.No	Particulars	Content	Level	Method adopted
1.	Organic carbon (%)	0.68	Medium	Walkey and Black method (1934)
2.	Available Nitrogen (kg/ha)	255	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
3.	Available Phosphorus (kg/ha)	12.1	Medium	Olsen's procedure (Olsen *et al.*. 1954)
4.	Available Potash (kg/ha)	541	High	Flame Photometer (Black 1965)
5.	Soil pH	6.9	Neutral	Glass electrode pH meter in 1:2:5 soil water suspension (Piper, 1950)
6.	Electrical conductivity (dsm^{-1})	0.18	Normal	Solubridge method (Jackson, 1973)

3.8 Economics of the treatments

Recommendation and adoption of any practices by different treatment depends upon its economics. Therefore, it becomes essential to work out economics of the treatments tested for judging the best treatments under study, for getting higher net profit per hectare.

3.8.1 Cost of cultivation (₹ ha^{-1})

It was worked out from the summation of cost of expenditure incurred on preparation of experimental field, sowing, intercultural operation, inputs applied, harvesting, daily wages, etc. in rupees in a hectare.

3.8.2 Gross Monetary Returns (₹ ha^{-1})

It is calculated by adding the prevailing market rates of grain and straw obtained in different treatments.

3.8.3 Net Monetary Returns (₹ ha^{-1})

It is obtained by subtracting cost of cultivation from gross returns. It is good indicator of suitability of a cropping system since this represents the actual income of the farmer.

Monetary returns for different treatments were calculated with the help of prevailing market rates of output and inputs.

Net monetary return = Gross monetary return-Total cost of cultivation

3.8.4 Benefit cost ratio:

Recommendation and adoption of any practice by cultivators depend upon its economics. Therefore it is essential to work out the economics of the experiment conducted for judging the optimum level of cost benefit ratio of various treatments. The cost of cultivation is summing of the cost incurred from the field preparation to winnowing /cleaning of the produce. Benefit cost is calculated by the following formula:

$$\text{Benefit cost ratio} = \frac{\text{Gross return (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

3.9 Statistical analysis

The data pertaining to various growth and yield parameters as well as values of economic return were subjected to analysis of variance prescribed for factorial randomized block Design by the method given by Panse and Sukhatme (1967). The "F" test was performed for judging the significance of the treatment mean squares. The significant differences between means were judged by using critical difference (C.D.) at 5% level of probability.

Table 3.10 The skeleton of the analysis of variance

Source of variation	DF	SS	MSS	F cal	F tab	SEm±	CD 5%
Replication	2						
Variety (V)	2						
Inoculants (I)	3						
V X I	6						
Error	22						
Total	35						

In case of "F" test was significant, standard error and critical differences were calculated by formula.

(1) Variety

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

$$CD = SEm\pm \sqrt{2} \times t_{(18\ df)} \text{ at } 5\%$$

$$CV\% = \frac{\sqrt{EMS}}{GM} \times 100$$

(2) Inoculants

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

$$CD = SEm\pm \sqrt{2} \times t_{(18\ df)} \text{ at } 5\%$$

(3) V x I interaction

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

$$CD = SEm\pm \sqrt{2} \times t_{(18\ df)} \text{ at } 5\%$$

Where:

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

CHAPTER IV

RESULTS

This chapter deals with the interpretation of the significant finding obtained from the present investigation entitled "Improving biological nitrogen fixation (BNF) capacity and productivity of kabuli chickpea (*Cicer kabulinum* L.) varieties by molybdenum and PSB applications" carried out during *rabi* season of 2015-16. The data relating to growth characters, yield attributing parameters and yield have been analyzed statistically. The results of treatments seed inoculants with PSB and Mo have been summarized in appropriate Table and have also been depicted by bar diagrams and figures.

4.1. Pre-harvest studies

To characterize the growth and development of kabuli chickpea in different stages, the following observations were recorded.

4.1.1 Plant height (cm):

Plant height is an important character of the vegetative phase and indirectly influences the yield components .The plant height was periodically recorded 20 days interval starting from 40 days, up to maturity stage. The analyzed data is presented in Table 4.1, Appendix-I and depicted in Fig 4.

Table 4.1: Plant height (cm) as influenced by seed inoculants and different varieties.

Treatments	40 DAS	60 DAS	80 DAS	Maturity
A. Seed inoculants : 04				
I1 : Control	28.1	37.1	47.7	47.7
I2 : Molybdenum seed inoculants	29.1	37.7	48.5	48.5
I3 : *Rh.* + PSB seed inoculants	29.8	38.4	49.1	49.1
I4 : *Rh.*+ PSB + Mo seed inoculants	32.6	41.7	50.7	50.7
SEm±	1.1	0.6	0.6	0.6
CD @ 5%	3.2	1.7	1.9	1.9
B. Varieties : 03				
V1 : RVSJKG 102	32.2	40.5	50.3	50.3
V2 : PHULE G 0517	29.3	38.4	48.1	48.1
V3 : PKV 4	28.2	37.3	48.7	48.7
SEm±	1.0	0.5	0.6	0.6
CD @ 5%	2.8	1.5	1.6	1.6

Data indicated that the plant height under all the treatment increased up to 80 DAS and thereafter constant. The periodical increment was almost uniform up to 80 DAS.

Amongst the four seed inoculants, *Rh.*+ PSB + Mo seed inoculation recorded significantly maximum plant height as compared to the other inoculant treatments, but it was at par with *Rh.* + PSB seed inoculants at all successive growth stages, whereas *Rh.* + PSB seed inoculants and molybdenum seed inoculants found non-significant differences on plant height with control at all growth stages.

The variation in plant height in different variety were significant at different stages of plant growth. RVSJKG 102 gave significantly higher plant height then PHULE G 0517 and PKV 4 at all stage except 80 DAS and at maturity where it was found at par with PKV 4 and Phule G 0517, respectively.

The interaction in between variety and seed inoculation (V×I) did not show any significant effect on plant height at all successive growth stage.

4.1.2. Number of Primary Branches per plant:

The number of Primary branches per plant at different growth stages is presented in Table 4.2, depicted in Fig. 4 and Appendix-II. It is revealed from the data that the number of primary branches per plant continuously increased up to 80 DAS under all treatments and thereafter it was constant up to maturity stage.

Table 4.2: Number of primary branches per plant influenced by seed inoculants and different varieties.

Treatments	40 DAS	60 DAS	80 DAS	Maturity
A. Seed inoculants : 04				
I1 : Control	1.86	2.28	2.61	2.61
I2 : Molybdenum seed inoculants	2.18	2.59	2.67	2.67
I3 : *Rh.* + PSB seed inoculants	2.41	2.70	2.92	2.92
I4 : *Rh.*+ PSB + Mo seed inoculants	2.49	3.11	3.34	3.34
SEm±	0.15	0.10	0.14	0.14
CD @ 5%	0.44	0.30	0.42	0.42
B. Varieties : 03				
V1 : RVSJKG 102	2.02	2.53	2.88	2.88
V2 : Phule G 0517	2.37	2.67	2.88	2.88
V3 : PKV 4	2.32	2.82	2.90	2.90
SEm±	0.13	0.09	0.12	0.12
CD @ 5%	NS	NS	NS	NS

The number of primary branches per plant were significantly influenced by inoculation at all stage, number of primary branches continuously increase 40 to 80 DAS and constant at maturity stage.

Treatment *Rh.*+ PSB + Mo seed inoculants found number of higher primary branches over control at all growth stages but it was non-significant with *Rh.* + PSB seed inoculants at 40 DAS and maturity.

The effect of variety on primary branches was found non-significant at all 40, 60, 80 DAS and Maturity stage. Highest number of primary branches recorded in PKV 4 at all stage of plant followed by Phule G 0517 except 40 DAS.

The interaction between seed inoculants and variety (I × V) was found non-significant at 40, 60, 80 and at maturity stage.

4.1.3. Number of Secondary Branches per plant:

Secondary branching is one of the most important characters which have direct effect on grain yield. The number of secondary branches per plant at different growth stages is presented in Table 4.3, depicted in Fig. 5 and Appendix-III. It is obvious from the data that the number of secondary branches per plant continuously increased up to 80 DAS under all treatments and thereafter it was remained constant rate of increases.

Table 4.3: Number of secondary branches per plant influenced by seed inoculants and different varieties.

Treatments	40 DAS	60 DAS	80 DAS	Maturity
A. Seed inoculants : 04				
I1 : Control	4.14	4.82	5.10	5.14
I2 : Molybdenum seed inoculants	4.30	5.37	5.61	5.64
I3 : *Rh.* + PSB seed inoculants	4.44	5.19	5.36	5.41
I4 : *Rh.*+ PSB + Mo seed inoculants	4.84	5.63	6.04	6.10
SEm±	0.15	0.18	0.16	0.20
CD @ 5%	0.43	0.53	0.47	0.57
B. Varieties : 03				
V1 : RVSJKG 102	4.30	5.08	5.40	5.47
V2 : Phule G 0517	4.37	5.36	5.57	5.59
V3 : PKV 4	4.63	5.32	5.62	5.67
SEm±	0.13	0.16	0.14	0.17
CD @ 5%	NS	NS	NS	NS

The number of secondary branches per plant at maturity period was analyzed statistically and reveals that inoculation had significant effect on secondary branches per plant at all growth stages.

The data indicated that the highest number of secondary branches per plant were recorded at all growth stages in *Rh.*+ PSB + Mo seed inoculants which was significantly higher over control and, at par with Molybdenum Seed inoculant at 40 and 60 DAS. The control had lowest no. of secondary branches per plant.

The variation in number of secondary branches in different variety was non-significant at all the stages of observations. However, the maximum number of secondary branches were recorded at all growth stages in PKV 4 followed by PHULE G 0517 and RVSJKG 102.

It was also observed that Seed inoculation and Variety interaction (I× v) does not found any significant effect on number of secondary branches at all stages of growth.

4.1.4. Number of root nodules per plant:

The variation in number of root nodules by different seed inoculation was recorded significant effect at all stages of observation (Table 4.4, Fig 6 and Appendix-IV).

Table 4.4 Number of root nodules per plant influenced by seed inoculants and different varieties

Treatments	40 DAS	60 DAS
A. Seed inoculants : 04		
I1 : Control	23.1	34.5
I2 : Molybdenum seed inoculants	26.3	36.1
I3 : *Rh.* + PSB seed inoculants	29.8	37.2
I4 : *Rh.* + PSB + Mo seed inoculants	32.4	41.5
SEm±	2.1	1.3
CD @ 5%	6.2	3.8
B. Varieties : 03		
V1 : RVSJKG 102	27.1	36.2
V2 : Phule G 0517	28.2	37.6
V3 : PKV 4	28.5	38.2
SEm±	1.8	1.1
CD @ 5%	NS	NS

Data indicated that the increase of root nodules per plant was significantly higher due to seed inoculants with *Rh.* + PSB + Mo (32.4 and 41.5 at both 40 and 60 DAS, respectively) and it was at par with *Rh.* + PSB and Mo seed inoculants at 40 DAS.

Variety effect on number of nodule recorded non-significant at both stages of observation. Variety PKV 4 recorded highest no. of root nodules at both the stages of observation followed by Phule G 0517 and RVSJKG 102. Seed inoculants and variety interaction (I × V) effect on nodule number found non-significant.

4.1.5 Dry weight of root nodules per plant (mg):

The data on dry weight of root nodules per plant recorded at 40 and 60 DAS under different treatments are presented in Table 4.5, Fig. 7 and Appendix-V.

Table 4.5: Dry weight of root nodule influenced by seed inoculants and different varieties

Treatments	40 DAS	60 DAS
A. Seed inoculants : 04		
I1 : Control	70.7	83.1
I2 : Molybdenum seed inoculants	72.7	86.7
I3 : *Rh.* + PSB seed inoculants	75.2	89.8
I4 : *Rh.*+ PSB + Mo seed inoculants	76.3	93.5
SEm±	1.3	2.2
CD @ 5%	4.0	6.3
B. Varieties : 03		
V1 : RVSJKG 102	72.9	86.7
V2 : Phule G 0517	73.8	88.4
V3 : PKV 4	74.4	89.6
SEm±	1.2	1.9
CD @ 5%	NS	NS

The data indicates by application of seed inoculants significant increase nodule dry weight under different treatments at both stages. Significantly highest root nodule dry weight recorded under *Rh.*+ PSB + Mo seed inoculants followed by in *Rh.* + PSB seed inoculants as against control, however *Rh.*+ PSB + Mo seed inoculants and *Rh.*+ PSB were found non-significant differences in each other.

As regards varieties nodule dry weight showed non-significant. However, PKV 4 recorded highest dry weight of root nodule at both stages.

The interaction effect between varieties and seed inoculation (V x I) at 40 and 60 DAS were found non-significant on dry weight of root nodule.

4.1.6 Dry weight / plant (g):

The data on plant dry weight (g/plant) recorded at 40 and 60 DAS and physiological maturity stage under different treatments are presented in Table 4.6, Fig.8 and Appendix-VI.

Table 4.6: Dry weight per plant influenced by seed inoculants and different varieties.

Treatments	40 DAS	60 DAS	At maturity
A. Seed inoculants : 04			
I1 : Control	1.9	3.5	10.4
I2 : Molybdenum seed inoculants	2.5	4.0	10.6
I3 : *Rh.* + PSB seed inoculants	2.9	4.3	11.3
I4 : *Rh.*+ PSB + Mo seed inoculants	3.1	4.5	12.2
SEm±	0.2	0.2	0.3
CD @ 5%	0.6	0.5	0.9
B. Varieties : 03			
V1 : RVSJKG 102	2.5	3.9	10.9
V2 : Phule G 0517	2.6	4.1	11
V3 : PKV 4	2.7	4.2	11.5
SEm±	0.2	0.1	0.25
CD @ 5%	NS	NS	NS

Dry matter accumulation was influenced significantly due to various treatment. Seed inoculation found significant effect on dry weight per plant. *Rh.* + PSB + Mo seed inoculants) treatment found significantly higher plant dry weight over control at all stages, but it was at par with *Rh.* + PSB seed inoculants and molybdenum seed inoculants at 40 and 60 DAS.

There is non-significant effect observed variety on dry matter accumulation. Minimum dry matter accumulated by variety PKV 4 increased dry mater accumulation at all growth stages followed by variety Phule G 0517.

Interaction effect of Variety and seed inoculants (V×I) were Non-significant effect recognized on plant dry matter at all growth stages.

4.1.7 Crop growth rate

The crop growth rate of different periods of the crop growth stages is presented in Table 4.7, Fig. 9 and Appendix-VII.

Table 4.7: Crop growth rate (g/m^2/day) influenced by seed inoculants and different varieties

Treatments	40 - 60DAS	60 - 80 DAS
A. Seed inoculants : 04		
I1 : Control	2.6	11.5
I2 : Molybdenum seed inoculants	2.4	11.1
I3 : *Rh.* + PSB seed inoculants	2.3	11.7
I4 : *Rh.*+ PSB + Mo seed inoculants	2.4	12.8
SEm±	0.3	0.7
CD @ 5%	NS	NS
B. Varieties : 03		
V1 : RVSJKG 102	2.3	11.6
V2 : Phule G 0517	2.5	11.5
V3 : PKV 4	2.5	12.2
SEm±	0.3	0.6
CD @ 5%	NS	NS

Crop growth rate are the most important phenomena to evaluated growth of plant at all stage interval.

Data indicated that there was no significant effect of variety and inoculants on crop growth rate. However, inoculation of *Rh.* + PSB + Mo and *Rh.* + PSB found relatively similar growth rate at all interval period. All variety found similar growth at both stage of plant.

The interaction effect of Variety and Inoculant (V × I) found non-significant on crop growth rate at all stages of plant.

4.1.8 Relative growth rate (g/g/day)

The relative growth rate of chickpea at different periods of crop growth stages is presented in Table 4.8, Appendix-VII and depicted in Fig. 10. Relative growth rate recorded at 40-60 and 60-80 days interval showed that RGR was minimum at early growth stage and there after it increased with advancement of time and were found statistically non-significant under all the treatments of seed inoculants and variety.

There was non-significant effect of variety, inoculants and their interaction (V × I) on relative growth rate of crop.

Table 4.8: Relative growth rate (mg/g/day) influenced by seed inoculants and different varieties.

Treatments A. Seed inoculants : 04	40 - 60DAS	60 - 80 DAS
I1 : Control	0.078	0.346
I2 : Molybdenum seed inoculants	0.071	0.333
I3 : *Rh.* + PSB seed inoculants	0.069	0.350
I4 : *Rh.*+ PSB + Mo seed inoculants	0.071	0.385
SEm±	0.010	0.020
CD @ 5%	NS	NS
B. Varieties : 03		
V1 : RVSJKG 102	0.068	0.349
V2 : Phule G 0517	0.074	0.344
V3 : PKV 4	0.075	0.367
SEm±	0.009	0.018
CD @ 5%	NS	NS

Post-harvest studies:

4.2 Yield attributing characters:

The various yield attributing characters were recorded at maturity are described here under.

4.2.1 Pods per plant (No.):

The number of pods per plant is one of the important yield attributes which have direct correlation with seed yield. The observation on this attribute was recorded at maturity. A perusal of data Table 4.9, Appendix-VIII and Fig.10 showed that the numbers of pods per plant was affected significantly by seed inoculants and different varieties.

Inoculation of chickpea with *Rh.* + PSB + Mo seed inoculants produce significantly maximum number of pods (34.2) per plant as compared to no inoculation or control (26.7). There was significant difference between seed inoculants Molybdenum seed inoculants (29.6), *Rh.* + PSB seed inoculants (32) and *Rh.* + PSB + Mo seed inoculants (34.2) treatment which were superior over control.

Variety PKV 4 produce significantly maximum number of pods per plant (31.5) whereas minimum number of pods per plant was observed in variety

RVSJKG 102 (29.8). Statistically the variety PKV 4 found at par with Phule G 0517.

The interaction between seed inoculants and variety (V×I) was found non-significant effect on pods per plant.

Table 4.9: Yield and yield attributing traits influenced by seed inoculants and varieties

Treatments	Pods / plant (No.)	Seeds / pod (No.)	Seed yield / plant (g)	Seed index (g)
A. Seed inoculants : 04				
I1 : Control	26.7	1.06	17.5	50.7
I2 : Molybdenum seed inoculants	29.6	1.07	17.9	52.6
I3 : *Rh.* + PSB seed inoculants	32	1.07	18.4	55.8
I4 : *Rh.* + PSB+ Mo seed inoculants	34.2	1.08	19.9	56.7
SEm±	0.5	0.003	0.50	1.0
CD @ 5%	1.4	0.009	1.5	2.9
B. Varieties : 03				
V1 : RVSJKG 102	29.8	1.06	17.17	55.4
V2 : Phule G 0517	30.5	1.07	17.88	54.7
V3 : PKV 4	31.5	1.08	20.18	51.7
SEm±	0.4	0.003	0.43	0.9
CD @ 5%	1.2	0.008	1.3	2.5

4.2.2 Seeds per pod:

The number of seed per pod is one of the important yield attributes which has direct correlation with the grain yield. The observation on this attribute was recorded at maturity. The data on seed per pod under different treatments are presented in Table 4.9, Fig. 11 and Appendix-VIII.

It is clear from the data the effect of seed inoculation and chickpea variety found significant on seeds per pod. There was maximum number of seed per pod when seed inoculate with *Rh.* + PSB + Mo seed inoculants (1.08) it was significantly superior to rest of the treatments. While minimum number of seeds per pod found under control.

Variety PKV 4 produce maximum number of seeds per pod (1.08) whereas minimum number of seeds per pod (1.06) in variety RVSJKG 102.

Interaction effect between seed inoculants and variety (V×I) on seeds per pod was found non-significant.

4.2.3 Seed yield per plant:

The data on seed yield per plant are depicted in Table 4.9, Fig.11 and Appendix-VIII. Statistical analysis reported that there is treatments seed inoculants and variety was found significant effect on seed yield per plant.

Data in table indicated that seed yield per plant was weight maximum when inoculate with *Rh.* + PSB+ Mo seed inoculants (9.03) and also found minimum in control (6.03). There is no significant difference were observed in Seed inoculants Mo inoculants and *Rh.* + PSB seed inoculant.

Variety PKV 4 produce maximum (8.80) seed yield per plant where variety RVSJKG 102 V1 produce minimum (5.73) number of seeds per plant.

Table 4.10 Interaction effect of seed inoculation and varieties (IxV) on seed yield per plant (g)

Variety	Inoculant			
	I1	I2	I3	I4
V1: RVSJKG 102	18.6	15.3	18.3	16.5
V2: PHULE G 0517	21.4	24.3	18.4	16.6
V3: PKV 4	12.6	13.9	22.0	23.0

Interaction effect of seed inoculant and varieties (I x V) was found significant at maturity stage. Where treatment combination I1V2, I2V2, I3V3 and I4V3 found highly significant effect on seed yield per plant rest of all treatment.

4.2.4 Seed index (100 seed weight):

The data on seed index are presented in Table 4.9 Fig. 11 and Appendix-VIII**.** It evident from the data that the significant variation in seed index due to different inoculant and variety was recorded. There is *Rh.* + PSB + Mo seed inoculants (56.7) found highly significant effect over control (50.7). However it was at par with *Rh.* + PSB seed inoculants.

Interaction between seed inoculant and variety (IxV) were found significant for seed index (100 seed weight).

Table 4.11: Interaction effect of seed inoculants and varieties (IxV) on seed index (g) at maturity

Variety	Inoculant			
	I1	I2	I3	I4
V1 RVSJKG 102	54.67	52.33	59.33	55.33
V2 PHULE G 0517	48.67	56.67	54.00	59.33
V3 PKV 4	48.67	48.67	54.00	55.33

Inoculant *Rh*. + PSB with Variety RVSJKG 102 and inoculant Rh. + PSB + Mo with Phule G 0517 was significantly higher in seed index then rest of the interaction.

4.3 Parameters calculated:

4.3.1 Seed yield (kg/ha):

The seed yield is an important character and superiority of the treatment judged by its capacity to produce more seed yield it enables the investigators to select superior treatment combination. The data pertaining to seed yield (kg/ha) are presented in Table 4.12 and depicted in Fig. 12 and Appendix-IX.

The data indicated that seed yield per hectare different significantly under different seed inoculants and varieties.

Seed inoculants in chickpea with *Rh.* + PSB + Mo (1878 kg/ha) produced significantly maximum seed yield followed by *Rh.* + PSB and Mo seed inoculants over control. There was also significant difference between treatments.

Response on seed yield due to variety PKV 4 (1625 kg/ha) produced significantly maximum seed yield and it was at par with variety Phule G 0517 (1539 kg/ha), while minimum seed yield found in variety RVSJKG 102 (1435 kg/ha).

The interaction between seed inoculant and variety was found non-significant.

Table 4.12: Seed yield kg/ha, straw yield kg/ha and harvest index (%) influenced by seed inoculants and different varieties

Treatments	Seed yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
A. Seed inoculants : 04			
I1 : Control	1253	3490	35.9
I2 : Molybdenum seed inoculants	1402	4037	35.1
I3 : *Rh.* + PSB seed inoculants	1599	4315	37.2
I4 : *Rh.*+ PSB + Mo seed inoculants	1878	5224	36.1
SEm±	43	152	0.7
CD @ 5%	125	445	NS
B. Varieties : 03			
V1 : RVSJKG 102	1435	3895	37.0
V2 : Phule G 0517	1539	4321	35.9
V3 : PKV 4	1625	4584	35.4
SEm±	37	131	0.6
CD @ 5%	108	385	NS

4.3.2 Biological yield (kg/ha):

The data of biological yield are summarized in Table 4.11 and depicted in Fig. 12 and Appendix-XI. Data in the table indicates that *Rh.*+ PSB + Mo seed inoculants (5224 kg/ha) found significantly superior than rest of the treatments .Where Molybdenum seed inoculants was at par with *Rh.* + PSB seed inoculants. Minimum Biological yield recorded under control (3490 kg/ha).

Variety effect on Biological yield found also significant. Where variety PKV 4 (4584 kg/ha) produced maximum straw yield which was at par with Phule G 0517. Minimum Biological yield recorded under variety RVSJKG 102.

Interaction of seed inoculants and Variety (I×V) also found non-significant effect on straw yield.

4.3.3 Harvest Index (%):

The data on harvest index on different treatments are presented in Table 4.12 and depicted in Fig. 12. The effect of seed inoculants on harvest index was found non-significant, however, *Rh.* + PSB gave higher harvest index (37.2%).

The response of variety on harvest index was found non-significant .variety RVSJKG 102 gave higher seed index (37%).

The interaction between seed inoculants and variety was also found non-significant effect on Harvest index.

4.4 Quality analysis

4.4.1 Protein content in grains

Protein content in grains of chickpea data presented in Table 4.12, Appendix-XII and depicted in Fig 13. Data in table indicated that the seed inoculants effect on protein content in grain was found significant.

Rh.+ PSB + Mo seed inoculants found significantly maximum protein content % followed by *Rh.* + PSB seed inoculants and Molybdenum seed inoculants over control, where was *Rh.* + PSB seed inoculants and Molybdenum seed inoculants found at par with *Rh.*+ PSB + Mo seed inoculants.

Among variety, non-significant effect on protein content % was observed maximum protein content was recorded in V3 PKV 4 (21.4%), while minimum Protein content was recorded in RVSJKG -102 (20.9%).

Interaction effect of seed inoculants and Variety (I×V) on protein content in grain % was also found non-significant.

Table 4.13: Protein content % in grain influenced by seed inoculants and different varieties.

Treatments	Protein content %
A. Seed inoculants : 04	
I1 : Control	20.0
I2 : Molybdenum seed inoculants	21.4
I3 : *Rh.* + PSB seed inoculants	21.2
I4 : *Rh.*+ PSB + Mo seed inoculants	22.2
SEm±	0.44
CD @ 5%	1.3
B. Varieties : 03	
V1 : RVSJKG 102	20.9
V2 : Phule G 0517	21.2
V3 : PKV 4	21.4
SEm±	0.38
CD @ 5%	NS

Economics:

The economics of various treatments was worked out by taking market rates of various production inputs and produce into account during the research period. The highest net profit (107592Rs.ha-1) and B:C (1:5.8) ratio obtained with *Rh.* + PSB + Mo seed inoculants and lowest profit was recorded with control (66041 Rs/ha).

According to the data from Table 4.14 that highest gross return (109771 Rs/ha) and net profit (90987 Rs/ha) were recorded with variety PKV 4 and lowest gross return was recorded with genotype RVSJKG 102 (96566 Rs/ha) and net profit (77782 Rs/ha). The B: C ratio was found minimum (1:3.2) with variety RVSJKG 102.

Table 4.14: Economics of the various treatments

Treatments A. Seed inoculants : 04	Gross return	Total cost of cultivation	Net profit	Benefit cost ratio
I1 : Control	84536	18495	66041	3.6
I2 : Molybdenum seed inoculants	94942	18975	75967	4.0
I3 : *Rh.* + PSB seed inoculants	107513	18593	88919	4.8
I4 : *Rh.*+ PSB + Mo seed inoculants	126665	19073	107592	5.8
B. Varieties : 03				
V1 : RVSJKG 102	96566	18784	77782	3.2
V2 : Phule G 0517	103905	18784	85121	3.6
V3 : PKV 4	109771	18784	90987	3.9

CHAPTER V

DISCUSSION

The results presented in the earlier chapter are discussed here for interpretation of finding with possible explanation in the light of scientific reasoning evidences as for the observed variations.

Pre-harvest studies

5.1 Growth attributing characters

5.1.1 Plant height, number of primary and secondary branches:

Growth attributing characters *viz.*, plant height, and number of primary and secondary branches are the important parameters which contributed to yield of crop. This parameters showed significant increase due to supplementation of various seed inoculants *Rhizobium* (*Rh.*), Phosphate Solubilizing Bacteria (PSB) and Molybdenum (Mo) application at various stages of plant growth. However different varietal effect on growth attributing character was found non-significant except plant height. Seed inoculation with *Rh.*, PSB, and Mo might have favoured the microbial activity and mineral nutrition in crops which resulted better plant height, number of primary branches and secondary branches at various stages of crop growth under this treatment. Significant increase in plant height, primary branches and secondary branches with use of *Rh.* + PSB + Mo seed inoculants might be due to enhanced nitrogen fixation by increased nitrogenase and nitrate reductase activities due to Mo seed inoculation along with *Rh.* + PSB. The results were similar kind in chickpea have also been reported by Shukla *et al.* (2013), The similar kind of results also reported by Dutta and Bandyopadhyay (2009) and Ahmed et al. (2010).

However, variety effect was also found non-significant effect on growth attributing character except plant height at all growth stages of plant, RVSJKG 102 produced taller plants at all stages, whereas number of primary branches and secondary branches produce maximum in PKV 4. The differential behavior of Kabuli chickpea varieties with respect to these characters could be explained solely by the variation in their genetic makeup and adaptability to soil and climatic conditions. The results are in close conformity with the findings of Sekhon *et al.* (2008), Ozalkhan (2010) and Shamsi (2011).

5.1.2 Number and dry weight of root nodules per plant:

The application of the inoculants affect the nodulation, significant effect of inoculation with PSB and Mo was observed maximum total number of nodules per plant. For that parameter, the highest number of nodules per plant and nodule dry weight were recorded when the seeds were inoculated with *Rh.* + PSB + Mo (I4) at all growth stages. The significant positive effect of high rates of inoculation (high number of rhizobia per seed) have been demonstrated (Date, 2001).high number of viable cells on the seed are an important criterion for good nodulation. The results are in close conformity with Dutta and Bandyopadhyay (2009), Ahmed et al. (2010), Dubey and Gangwar (2012).

Variety influence on nodule number and nodule dry weight was not significant. The highest nodule number and nodule dry weight was produced by the variety PKV 4 followed closely by the Phule G 0517 and the RVSJKG 102 respectively. This result is in line with the finding of Sekhon *et al.* (2008), Ozalkhan (2010) and Shamsi (2011) in chickpea varieties inoculation.

5.1.3 Dry weight per plant, CGR (Crop growth rate) and RGR (Relative growth rate):

The analysis of variance indicates that the effect of seed inoculants was found non-significant on Plant dry weight and also non-significant effect on CGR and RGR. The seed inoculation with *Rh.* + PSB + Mo recorded highest dry weight per plant at various stages of crop growth which might be due to enhanced microbial activities through inoculated rhizobia along with molybdenum application which favorably increase the dry weight per plant. Whereas *Rh.* + PSB + Mo (I4) seed inoculants found maximum crop growth and relative growth rate followed by rest inoculants. The result of similar kind was also reported by Alagawadi and Gaur (1988).

Variety effect on plant dry weight, CGR and RGR was found non-significant. Dry weight was produced maximum with PKV 4 followed by Phule G 0517 and RVSJKG 102. This shows that, the varieties studied had equal crop growth and plant dry weight potential. This is because the conditions of growth were similar, so producing similar dry matter attest to the fact that, the growth potentials were similar growth condition is indication of similar potential (Sekhon *et al.* (2008), Ozalkhan (2010) and Shamsi (2011).

5.2 Yield components of chickpea:

5.2.1 Pods per plant, seeds per pod, seed yield per plant and seed index

Yield components *viz.,* pods per plant, seeds per pod, seed yield per plant and hundred seed weight showed significant effect with seed inoculation. *Rh.* + PSB + Mo seed inoculants showed highest number of pods, seeds per pod, seed yield and seed index. *Rh.* + PSB+ Mo seed inoculants effect on yield character, it might also be due to adequate availability of N and P which might have facilitated the production of primary and secondary branches and plant height which might in turn have contributed for the production of higher number of total, pods, seeds per pod, seed yield per plant and hundred seed weight. Inoculation had a significant effect on growth, N contents and uptake in shoots increased its size in order to intercept light for photosynthesis, yield and yield components of chickpea. This may probably be due to the cumulative effect of phosphorus in the processes of cell division and balanced nutrition. The present result was in conformity with (Singh *et al.* 2008) who reported that the seeds and nutritional quality of legumes is greatly influenced by application of PSB and Mo.

Variety effect on yield component were found also significant. Variety PKV 4 produced all yield component maximum except seed. Whereas minimum effect on yield component produce by RVSJKG 102 .Variation in yield component by variety may be due to genetic capability of variety and natural habit also climatic effect on plant. Similar result were found with Goyal *et al*. (2010), Mansur *et al* (2009).

5.2.2 Seed yield, biological yield and Harvest index %:

The result of analysis of variance revealed that yield attributing character except harvest index % of chickpea was significantly affected by the seed inoculation and variety. The highest grain and biological yield was recorded by *Rh.* + PSB + Mo seed inoculation followed by the *Rh.* + PSB seed inoculants whereas maximum harvest index % was found with *Rh.* + PSB.

The observed yield and biological yield improvements when inoculation with *Rh.* + PSB + Mo might be due to the increased N from atmospheric nitrogen fixation from effective nodule formation in the vicinity of root zone and P availability by seed inoculants with PSB as result of improvements observed for the yield traits discussed above. In line with this result Dubey and Gangwar (2012).

Chickpea varieties produce statistically similar seed-yield and straw yield .Variety PKV 4 produced the highest seed yield of 1625 kg/ha. Phule G 0517 and RVSJKG 102 varieties produced grain yield of 1539 and 1435 kg/ha respectively. There was varietal difference in these varieties and this was non-significant. RVSJKG 102 variety had the highest 100 seed weight of 37.0 g. The grain yield obtained in this study is lower compared with the potential yield reported of these varieties. The result agrees with the work done by Khan *et al*. (2004), Kanouni *et al.* (2015) who reported varietal difference in chickpea.

5.1.3 Quality parameters (protein %):

There was significant effect was found in protein content in grain due to seed inoculation where was non-significant on protein % due to variety. Protein content in grain was maximum recorded when seed inoculants with *Rh.* + PSB + Mo application. Where treatment difference between I3 and I2 found at par with each other. I4 found best which might be due to enhanced N_2-fixation by Mo application with *Rh.* + PSB which contributed higher N to the seed. *Rh.* increase nodulation where Mo increases the nitrogenase activity in the root nodule which enhances N_2-fixation and there by N and crude protein content in seed. These results are in similar findings with of Singh *et al.* (2014) and Das *et al.* (2013).

The chickpea varieties effect found non-significant in protein content %. Among varieties, maximum was recorded in PKV 4 partially followed by Phule G 0517. Besbes *et al*. (2015) reported that the Kabuli cultivar has significantly shown ($P \leq 0.05$) higher protein content (24.51%), fiber content (21.86%) and lower Water Holding Capacity (WHC) compared to the Desi cultivar (Ghribi et al. (2015)). It was due to Grain yield, evidence of relationship of protein content with seed yield were found with Gaur et al. (2016) study.

5.3 Economics of chickpea cultivation:

Production of grain legume is increasing due to their vast use in different situation including food, feed and industrial demands. Considering the increasing needs for human consumption of plant products and the economic constraints of applying inoculants in different varieties of chickpea.

The agronomic data in previous chapter which the recommendations are based must be relevant to the farmer own agro ecological conditions and the evaluation of previous chapter data must be consistent with the farmers goal and socio economics circumstance (CIMMYT, 1988)

Based on the partial budget procedure , the variable cost including the *Rh.* , PSB and Mo price at a time of sowing (26 Nov.2016) and the price of the current (march to April 2016) chickpea grain data were taken from office of Trade and Transportation marketing case team of Sehore district. Labour cost per treatment was recorded and used for this analysis. Cost and benefits which were taken as net benefit.

In previous chapter data indicated the economic analysis of chickpea as affected by the effect of seed inoculation and variety. It is clear from the budget summary of economic analysis, the highest net returns (107592 Rs/ha) was obtained from seed inoculation with *Rh.* + PSB + Mo followed by seed inoculation with *Rh.* + PSB (88919 Rs/ha). Even though the highest cost of fertilizer, the use of inoculation with *Rh.* + PSB + Mo and variety PKV 4 appears to be a priority for small holder farmers growing in kabuli chickpea in this area.

CHAPTER VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary:

The experiment entitled "Improving BNF capacity and productivity of kabuli chickpea (*Cicer kabulinum* L.) varieties by PSB and molybdenum applications" was executed during *rabi* 2015-16 at the ICARDA-FLRP, Amlaha, Sehore (M.P.), India,

Experiment consisted of twelve treatment combination, laid out in Factorial randomized block design with three replications. The treatment included were four inoculants, control, Ammonium Molybdate (Mo @ 1g/kg seed treatment), *Rh.* + PSB and *Rh.* + PSB + Mo (1g/kg seed treatment) in three kabuli varieties (RVSJKG 102, Phule G 0517 and PKV 4) for estimate the individual or combined effect of various treatment on production at field level.

The soil condition of the experimental field was good health with proper drainage system, soil status tested in Soil science laboratory (Deptt. of soil Science and Agriculture Chemistry at R.A.K. College of Agriculture, Sehore (M.P.). Soil was medium clay loam (Vertisol), low in available nitrogen, medium in phosphorus and medium in available potash with pH 7.5. Various growth and yield attributing characters were studied. The important results of this investigation are summarized below:

6.1.1 Effect of inoculants:

1. The seed inoculants with *Rh.* + PSB + Mo significantly influenced the growth attributing parameter *viz.,* plant height, primary branches and secondary branches at all crop growth stages. At maturity plant height, primary and secondary branches per plant were maximum when seed inoculants with *Rh.* + PSB + Mo, while minimum in control.
2. Number of root nodule and dry weight of root nodule per plant significantly maximum when seed inoculants with *Rh.* + PSB + Mo, followed by inoculants with *Rh.* + PSB inoculants and it was at par with I3 in nodule number and at par with I2 in nodule dry weight per plant.

3. Crop growth rate and relative growth rate varied non-significantly influenced by seed inoculants. Where I4 effect found maximum crop growth rate and relative crop growth followed by I3.
4. Seed inoculants were found significant effect on pods/plant, seeds per pod, seed yield per plant and seed index. Maximum yield components were found when seed inoculants with *Rh.* + PSB + Mo seed inoculants (I4) where minimum in control (I1) in all component of yield.
5. Seed and biological yields, harvest index % different according to seed inoculants and highest values were recorded when inoculated with *Rh.* + PSB + Mo in seed yield and Biological yield, where harvest index % was maximum when inoculants with *Rh.* + PSB (I3).

6.1.2 Effect of varieties:

1. Different variety non-significantly influenced on growth parameters except like Plant height. At all growth stages variety RVSJKG 102 produce maximum plant height, where Phule G 0517 at par with PKV 4 at all stages of growth. Maximum no. of branches primary and secondary count in PKV 4 followed by Phule G 0517.
2. Nodule number and nodule dry weight per plant found non-significant effect due to variety. Maximum number and dry weight of root nodule found in variety PKV 4 followed by Phule G 0517.
3. Crop growth rate and relative growth rate did not differ significantly in different varieties. PKV 4 recorded in higher Crop growth and relative growth rate. Where minimum growth rate recorded in variety RVSJKG 102.
4. Variety effect on yield component found significant. Variety PKV 4 had highest number of pods, seeds per pod, seed yield per plant where RVSJKG 102 highest seed index recorded.
5. Seed and Biological yields different according to variety and highest values were obtained from variety PKV 4(1625 kg/ha and 4584 kg/ha, respectively). The Harvest index % were not influence significantly due to variety. Maximum harvest index % recorded in variety RVSJKG 102 (37%).

6.2 Economics:

The economics of various treatments highest gross return in inoculants *Rh.* + PSB + Mo seed inoculants (I4) (126665 Rs/ha) with net profit (107592 Rs/ha) and highest B:C ratio (6.8). Same as it is highest gross return, net profit and B:C ratio recorded in variety PKV 4 respectively (109771 Rs/ha) (90987 Rs/ha) and (4.9).

6.3 Conclusion:

The following conclusion can be drawn on the basis of results obtained:

1. The seed inoculant with Rh. + PSB + Mo (I4) was found best among other inoculants in respect to productivity and profitability.
2. Variety PKV 4 produced higher values of growth and yield attributing parameters and seed and straw yields of kabuli chickpea.
3. Varieties Phule G 0517 inoculated with *Rh.* + PSB and treated with Mo proved better combination for higher production and yield component.

6.4 Suggestion for future work:

In the light of experience gained during the course of investigation and result obtained it was felt that the following points should be taken under considerations in future studies.

1. In order to confirm the validity of results the experiment may be repeated over years and location with more accuracy.
2. The investigation may be tested with some other promising varieties.
3. In future, some other level of ammonium molybdate (1.5 g or 2 g/kg) Inoculation may be used.

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APPENDICES

Appendix-I: Analysis of variance for plant height (mean square)

		Plant height (cm)			
Source of variance	**DF**	**40 DAS**	**60 DAS**	**80 DAS**	**Maturity**
Replication	2	2.00	37.1	47.7	47.7
Variety (V)	2	51.9*	37.7*	48.5*	48.5*
Inoculants (I)	3	33.6*	38.4*	49.1*	49.1*
Interaction(V*I)	6	27.4	41.7	50.7	50.7
Error	22	10.9	0.6	0.6	0.6

Appendix–II: Analysis of variance for primary branches /plant (no.) (mean square)

		Primary Branches /Plant (no.)			
Source of variance	**DF**	**40 DAS**	**60 DAS**	**80 DAS**	**Maturity**
Replication	2	0.603	0.623	0.013	0.013
Variety (V)	2	0.430	0.252	0.001	0.001
Inoculants (I)	3	0.728*	1.062*	0.998*	0.998*
Interaction(V*I)	6	0.118	0.032	0.146	0.146
Error	22	0.200	0.093	0.182	0.182

Appendix–III: Analysis of variance for secondary branches /plant (no.) (mean square)

		Secondary branches /plant (no.)			
Source of variance	**DF**	**40 DAS**	**60 DAS**	**80 DAS**	**Maturity**
Replication	2	0.26	0.05	0.01	0.69
Variety (V)	2	0.37	0.26	0.15	0.15
Inoculants (I)	3	0.81*	1.04*	1.46*	1.48*
Interaction(V*I)	6	0.11	0.39	0.28	0.77
Error	22	0.19	0.29	0.23	0.37

Appendix–IV: Analysis of variance for number of root nodules (mean square)

		Number of root nodules/plant	
Source of variance	**DF**	**45 DAS**	**60 DAS**
Replication	2	0.46	10.01
Variety (V)	2	5.79	12.98
Inoculants (I)	3	148.16*	80.26*
Interaction(V*I)	6	1.10	1.24
Error	22	39.59	15.14

Appendix–V: Analysis of variance for dry weight of root nodules (mg) (mean square)

		Dry weight of root nodules (mg)	
Source of variance	**DF**	**45 DAS**	**60 DAS**
Replication	2	27.22	0.84
Variety (V)	2	6.87	26.59
Inoculants (I)	3	57.05*	176.29*
Interaction(V*I)	6	0.27	2.25
Error	22	16.33	42.13

Appendix–VI: Analysis of variance for dry weight/plant (mean square)

		Dry weight / plant (g)		
Source of variance	**DF**	**45 DAS**	**60 DAS**	**Maturity**
Replication	2	0.3	0.5	1.8
Variety (V)	2	0.1	0.2	2.6
Inoculants (I)	3	2.4*	1.8*	4.6*
Interaction(V*I)	6	0.1	0.2	0.5
Error	22	0.4	0.2	0.8

Appendix–VII: Analysis of variance for crop growth rate (mean square)

		Crop growth rate (g/m^2 /day)	
Source of variance	**DF**	**40-60 DAS**	**60-80 DAS**
Replication	2	0.77	1.19
Variety (V)	2	0.17	1.96
Inoculants (I)	3	0.16	4.82
Interaction(V*I)	6	0.29	0.31
Error	22	1.06	4.10

Appendix–VII: Analysis of variance for relative growth rate (mean square)

		Crop growth rate (g/g /day)	
Source of variance	**DF**	**40-60 DAS**	**60-80 DAS**
Replication	2	0.0007	0.0011
Variety (V)	2	0.0002	0.0018
Inoculants (I)	3	0.0001	0.0043
Interaction(V*I)	6	0.0003	0.0003
Error	22	0.0010	0.0037

Appendix–VIII: Analysis of variance for pods per plant, seeds per pod, seed yield per plant and seed index (mean square)

Source of variance	**DF**	**Pods per plant**	**Seeds per pod**	**Seed yield per plant (g)**	**Seed index (g)**
Replication	2	0.9	0.00002	1.3	13.6
Variety (V)	2	8.4*	0.00105*	29.8*	47.3*
Inoculants (I)	3	94.9*	0.00047*	10.0*	70.3*
Interaction(V*I)	6	0.1	0.00006	59.8*	27.1*
Error	22	2.1	0.00002	1.3	9.0

Appendix–IX: Analysis of variance for seed yield, biological yield (mean square)

Source of variance	**DF**	**Seed yield Kg/ha**	**Biological Yield Kg/ha**	**Harvest index %**
Replication	2	41361.4	357269.7	1.6
Variety (V)	2	108398.3*	1448678.5*	7.9
Inoculants (I)	3	655758.9*	4724881.6*	6.4
Interaction(V*I)	6	9354.1	99298.1	5.8
Error	22	16269.8	207288.7	4.6

Appendix–XI: Analysis of variance for protein % (mean square)

Source of variance	DF	Protein %
Replication	2	2.62
Variety (V)	2	0.74
Inoculants (I)	3	7.86*
Interaction(V*I)	6	0.01
Error	22	1.75

Appendix-XII: Basic cost of cultivation:

S.No.	Operation	Quantity/Time	Cost(₹/ha)
1.	Field preparation and sowing		
	One ploughing	2 hr.	1020
	Leveling & harrowing	2 hr.	1020
	Sowing by hand	5 labor	875
2.	Cost of seed	120 kg	8400
3.	Irrigation charges	2 time	1200
4.	weeding	1 time/10 labor	2200
5.	Harvesting & transportation	10 labour	1900
6.	Threshing	6 labour	1380
7.	Miscellaneous		500
		Total	18495

*Excluding seed treatments

B. Cost of treatment:

Seed inoculants	Quantity/Time	Cost (₹/ha)
Rhizobium biofertilizer	600 gm	60
PSB	600 gm	38.4
Molybdenum	120 gm	480

<u>Prevailing rate input and others operational charges</u>

Charges	
Rate of tractor	@ ₹ 510/hr.
Labour charge Sowing	@ ₹ 175/day
Cost of seed inoculants *Rhizobium japonicum*	@ ₹ 15/150 g
PSB culture	@ ₹16/250g
Ammonium Molybdate	@ ₹4000/ kg
Rate of certified seed	@ ₹ 70 /kg
Labour rate for seed sowing	@ ₹175 /day
Rate of irrigation charges	@ ₹ 600/day
Weeding by labor	@ ₹ 220/day
Harvesting and transportation	@ ₹ 190/day
Rate of Chickpea grain	@ ₹ 6300/q
Rate of chickpea straw	@ ₹ 250/q

VITA

The author was born on 22nd February, 1992 in Madhya Pradesh, Barwani Distt., Anjad. He attended, He attained High School Saraswati Shishu Vidhya Mandir Anjad, and High Secondary Education at School of Excellence Barwani Respectively during 2006 to 2010.

After passing the Pre agriculture test examination (PAT) in 2010, He joined Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P), and obtained degree in Bachelor of Sciences (Agriculture) in 2014. After graduation, he joined RVSKVV, R.A.K. college of Agriculture, Sehore (M.P) for Post-graduation study leading to M.Sc. Degree in the field of Agronomy.

He is submitting his thesis for M.Sc. (Ag) Agronomy Degree for the partial fulfillment of the degree. He was allotted the research problem entitled "Improving BNF capacity and Productivity of Kabuli chickpea (Cicer kabulinum L.) varieties by PSB and Mo application." which is duly completed by him and is presented in the form of thesis.

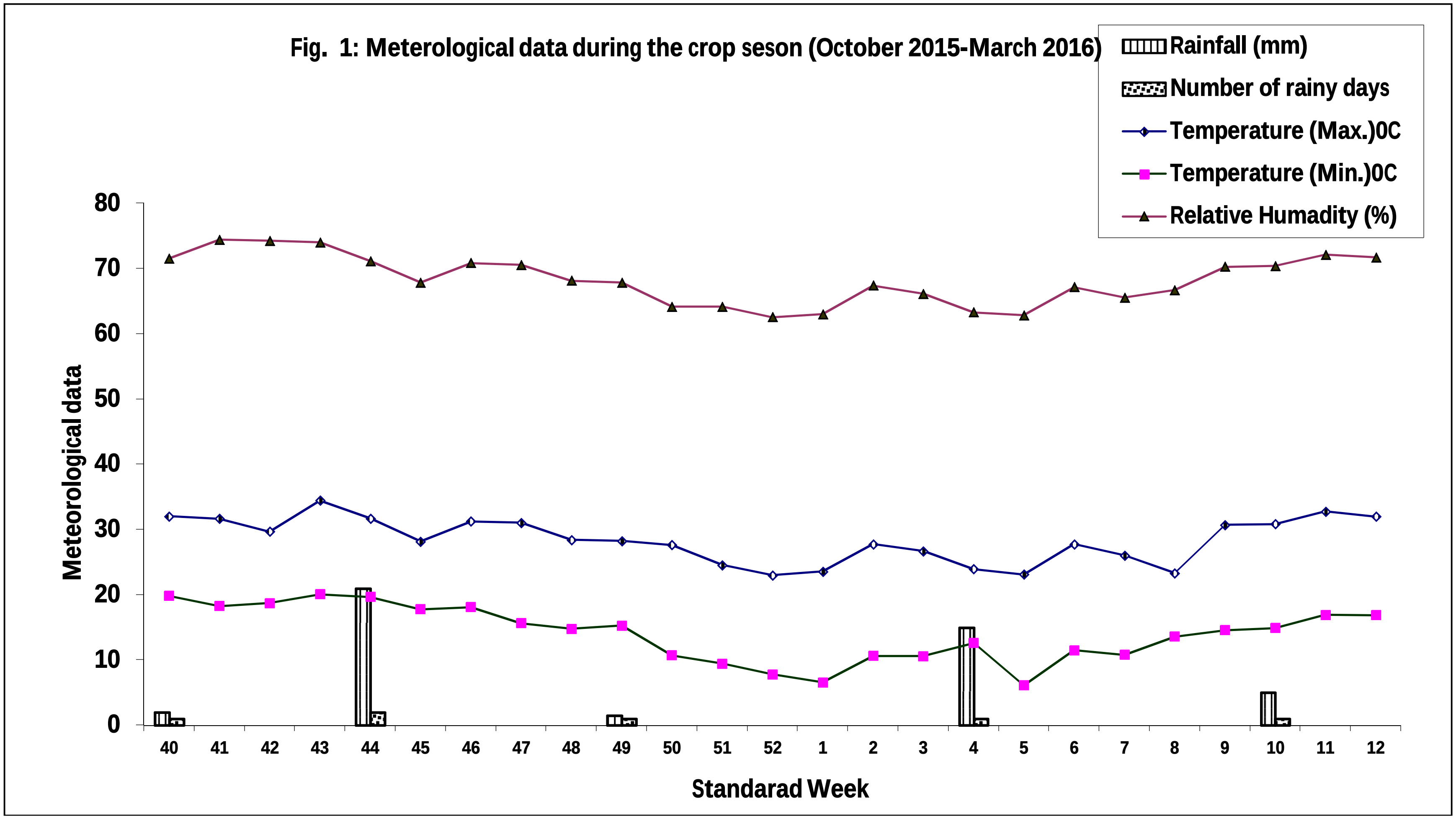
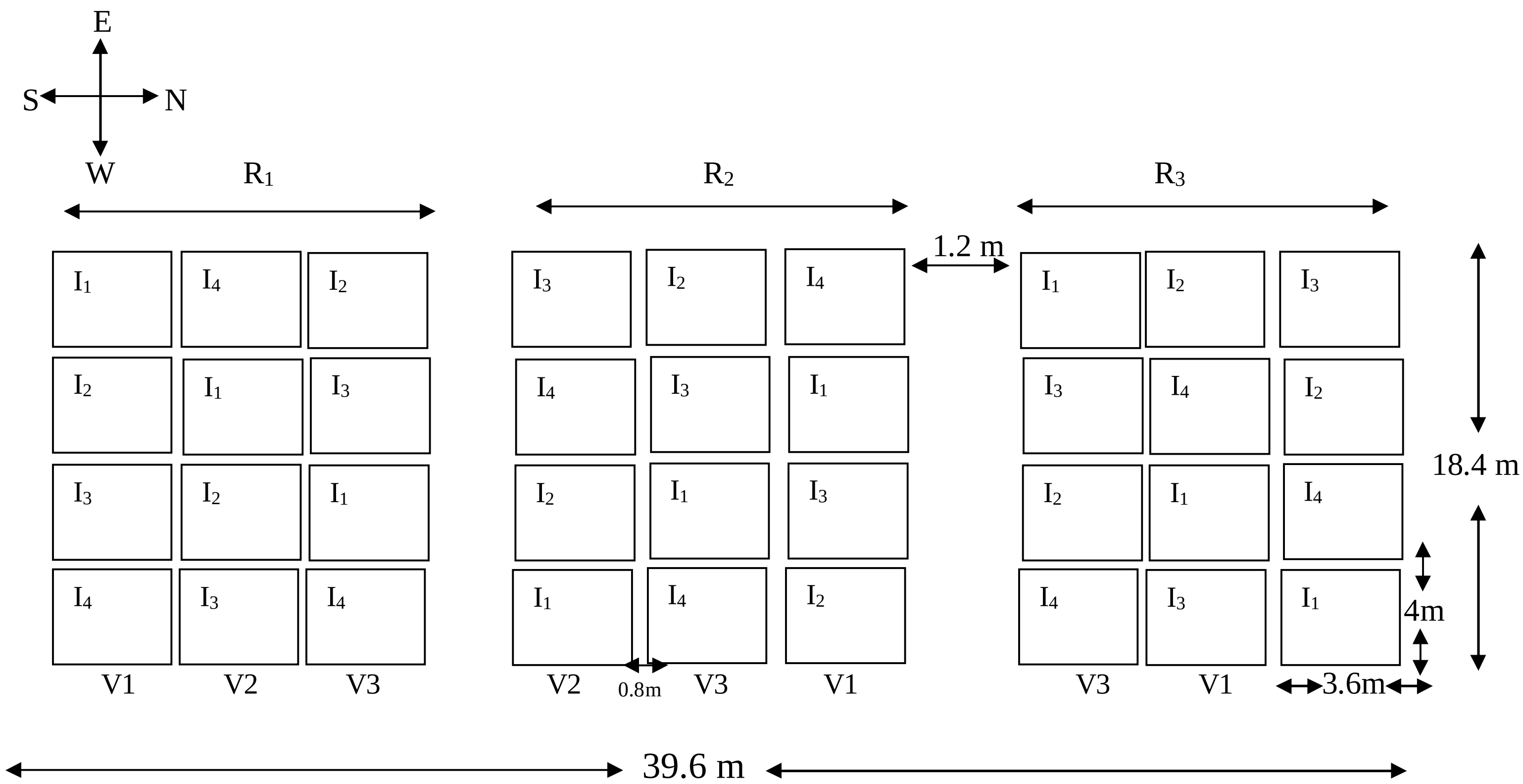


Fig. 1: Meterological data during the crop seson (October 2015-March 2016)
Rainfall (mm)
Number of rainy days
Temperature (Max.)0C
Temperature (Min.)0C
Relative Humadity (%)
Meteorological data
80
70
60
50
40
30
20
10
0
40
41
42
43
44
45
46
47
48
49
50
51
52
1
2
3
4
5
6
7
8
9
10
11
12
Standarad Week

Fig. 2: LAYOUT PLAN OF EXPERIMENIAL AREA

RANDOMIZED BLOCK DESIGN (Factorial)



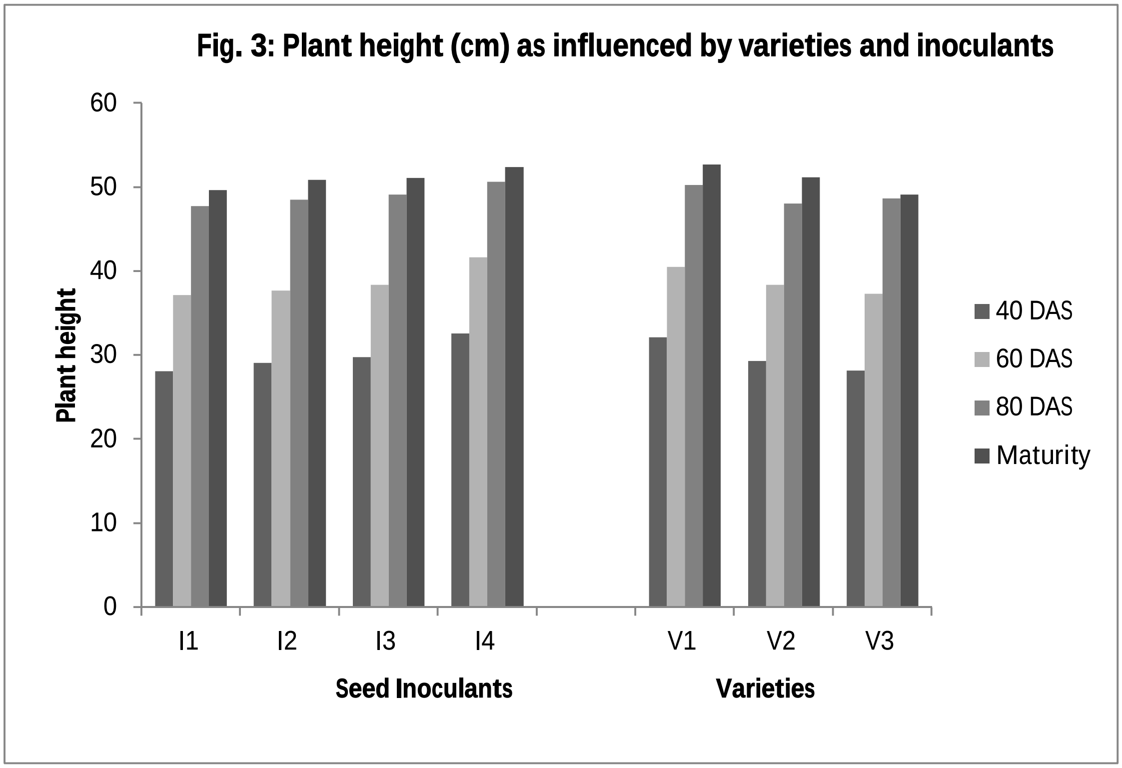


Fig. 3: Plant height (cm) as influenced by varieties and inoculants
60
50
40
30
20
10
0
Plant height
I1
I2
I3
I4
V1
V2
V3
Seed Inoculants
Varieties
40 DAS
60 DAS
80 DAS
Maturity

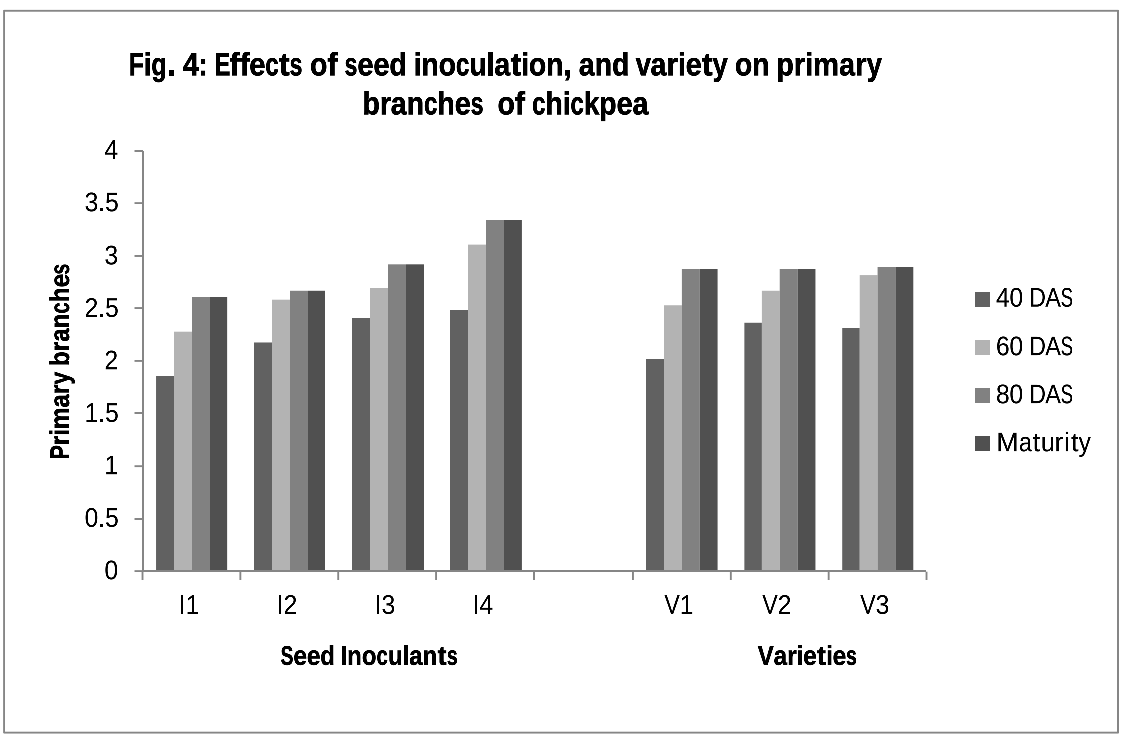


Fig. 4: Effects of seed inoculation, and variety on primary branches of chickpea
4
3.5
3
2.5
2
1.5
1
0.5
0
Primary branches
I1
I2
I3
I4
V1
V2
V3
Seed Inoculants
Varieties
40 DAS
60 DAS
80 DAS
Maturity

Fig. 5: Effects of seed inoculation and variety on secondary branches of chickpea

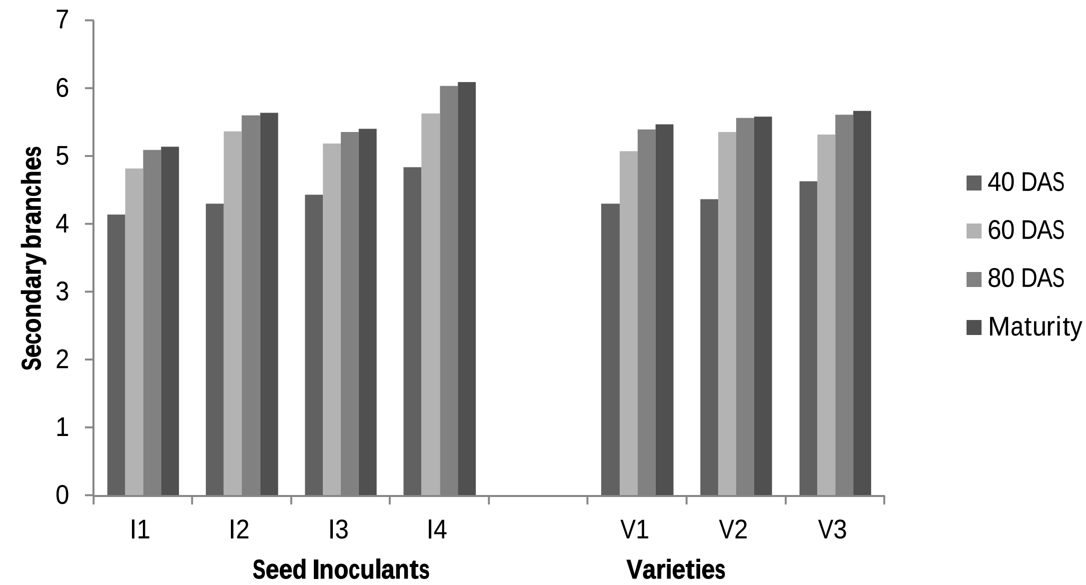


Fig. 6: Number of nodules per plant of chickpea as influenced by the seed inoculants and different varieties

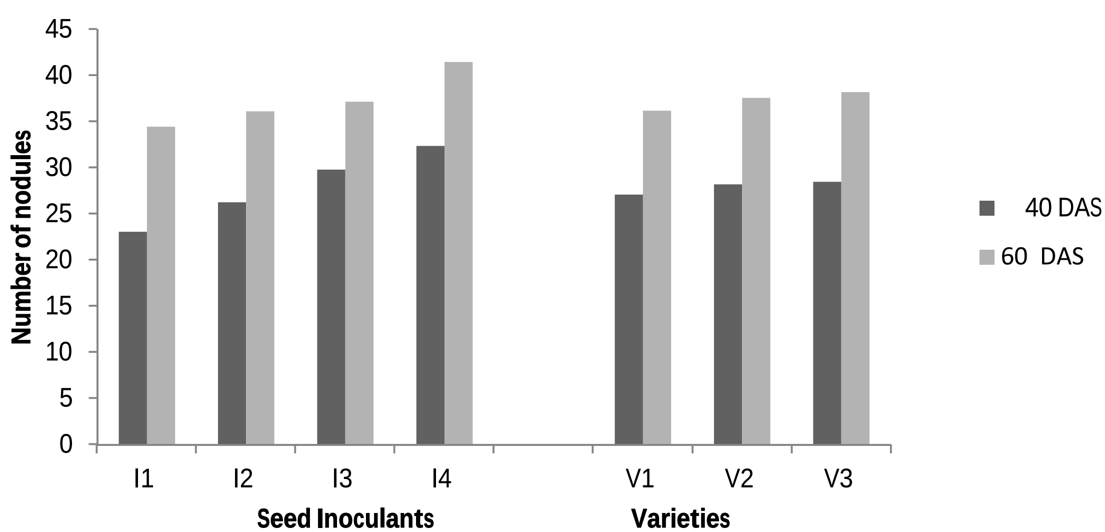


Fig. 7: Dry weight of root nodules/plant (mg) as influenced by varieties and inoculants

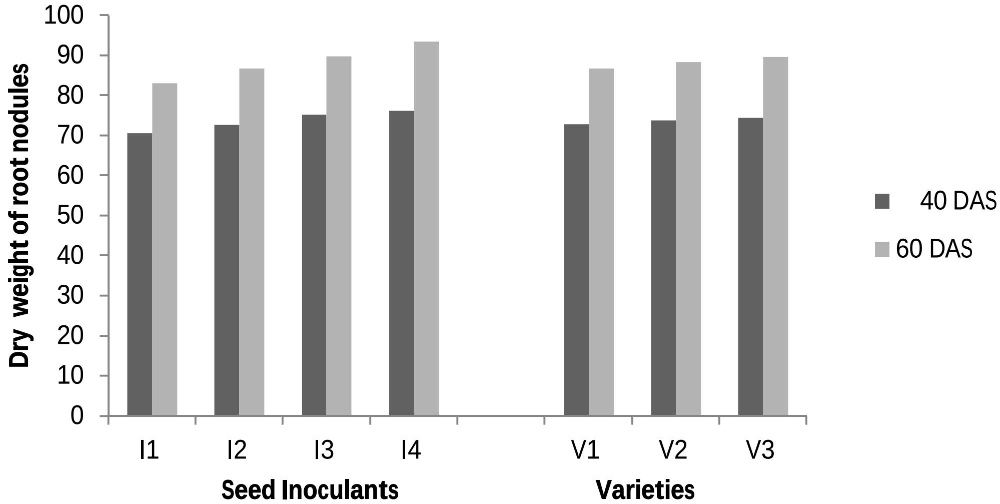
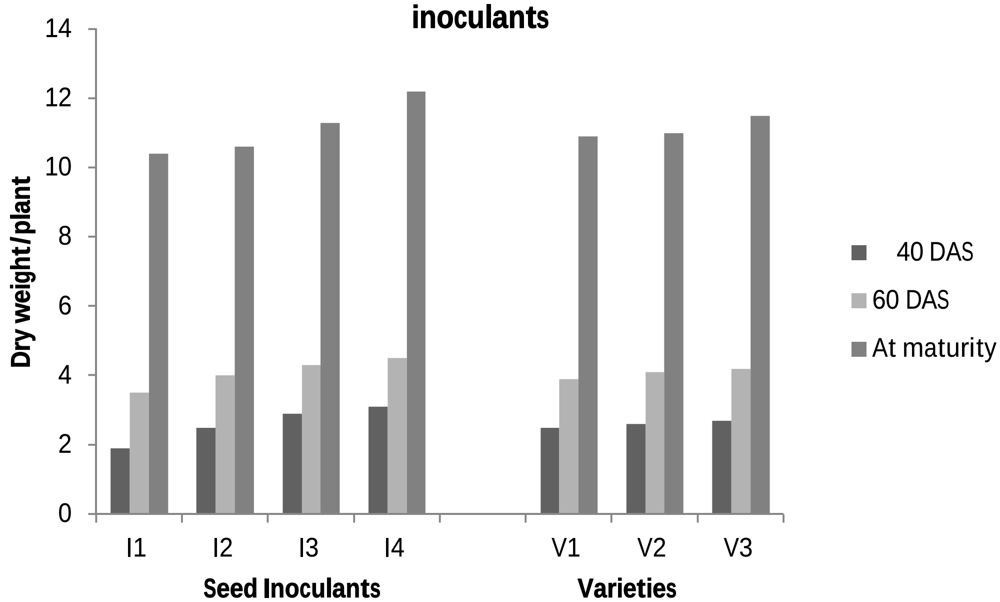


Fig. 8: Dry weight/plant (g) as influenced by varieties and inoculants



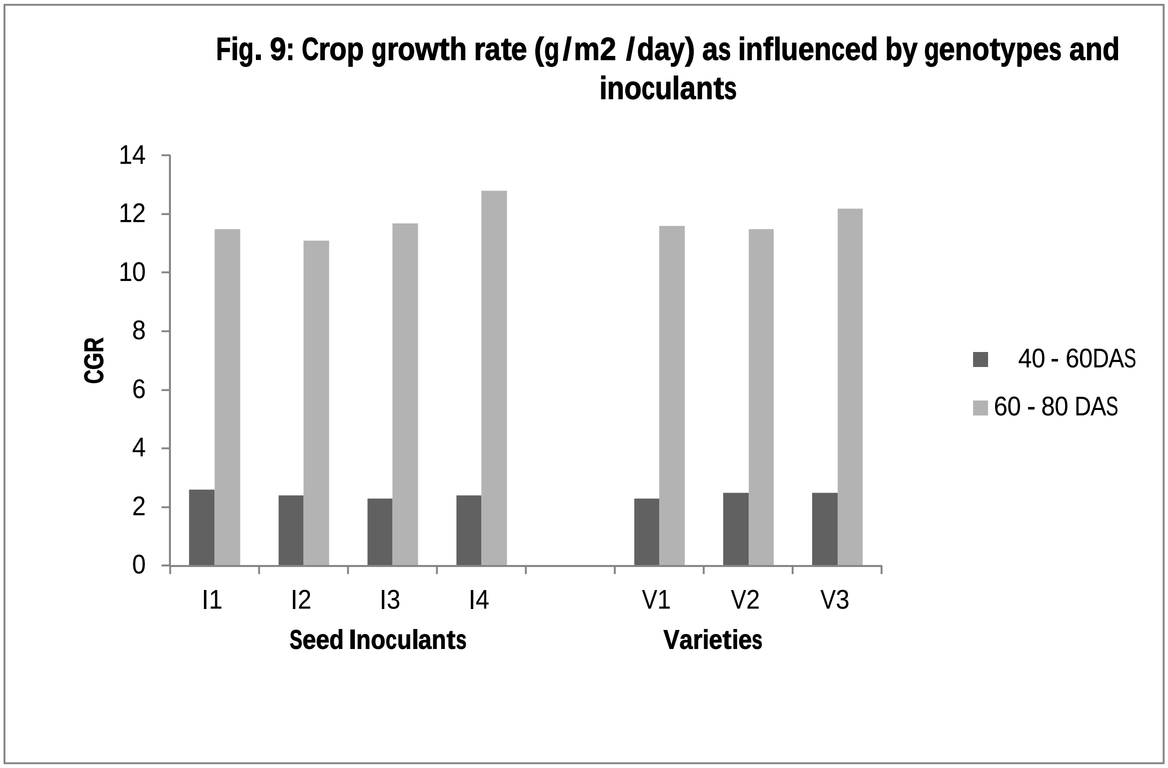


Fig. 9: Crop growth rate (g/m2 /day) as influenced by genotypes and inoculants
14
12
10
8
6
4
2
0
CGR
I1
I2
I3
I4
V1
V2
V3
Seed Inoculants
Varieties
40 - 60DAS
60 - 80 DAS

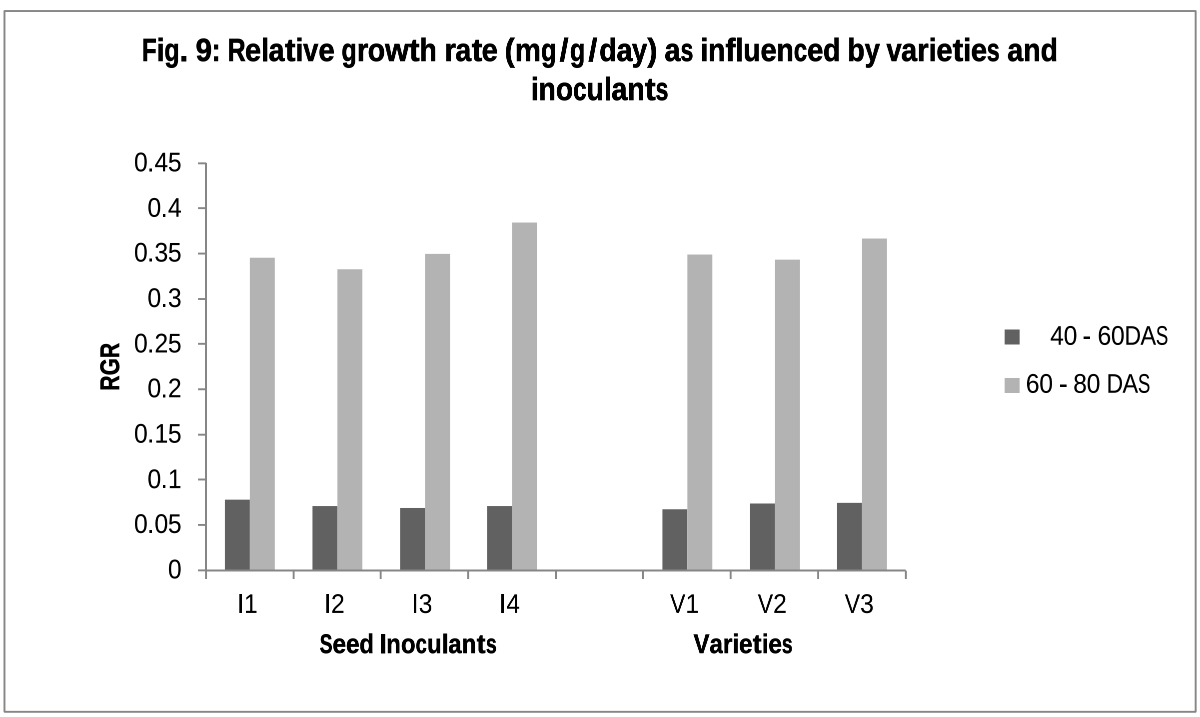


Fig. 9: Relative growth rate (mg/g/day) as influenced by varieties and inoculants
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
RGR
I1
I2
I3
I4
V1
V2
V3
Seed Inoculants
Varieties
40 - 60DAS
60 - 80 DAS

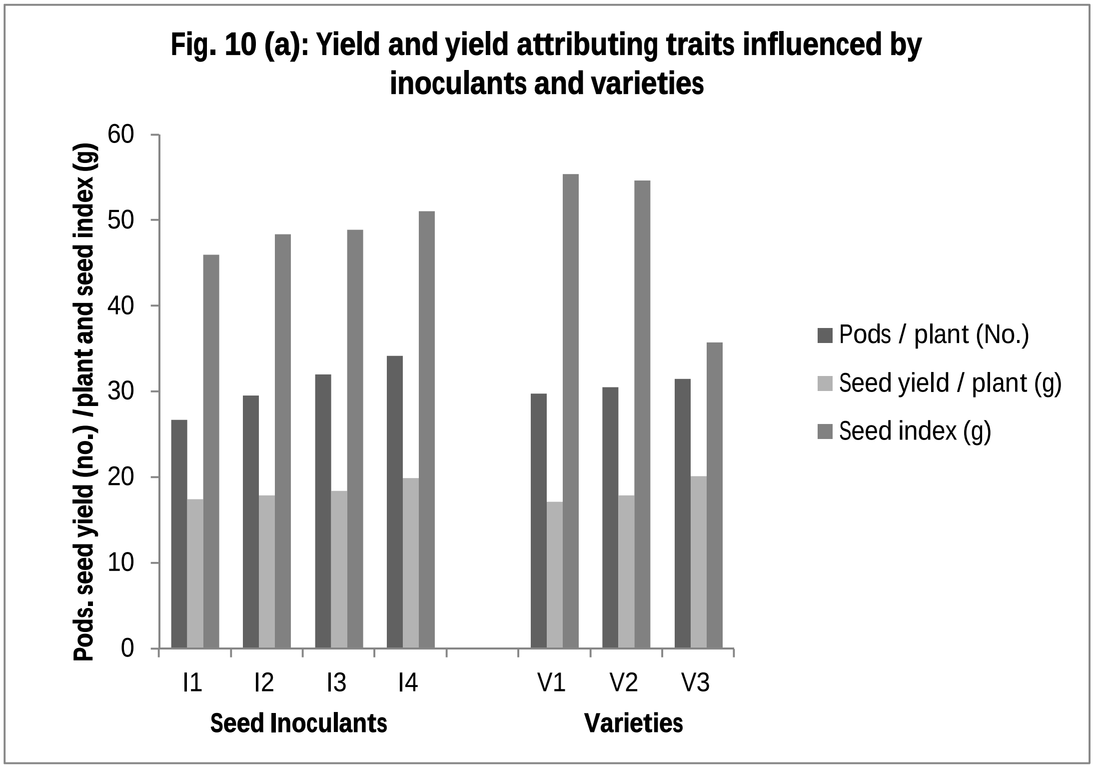


Fig. 10 (a): Yield and yield attributing traits influenced by inoculants and varieties
Pods. seed yield (no.) /plant and seed index (g)
60
50
40
30
20
10
0
I1
I2
I3
I4
V1
V2
V3
Seed Inoculants
Varieties
Pods / plant (No.)
Seed yield / plant (g)
Seed index (g)

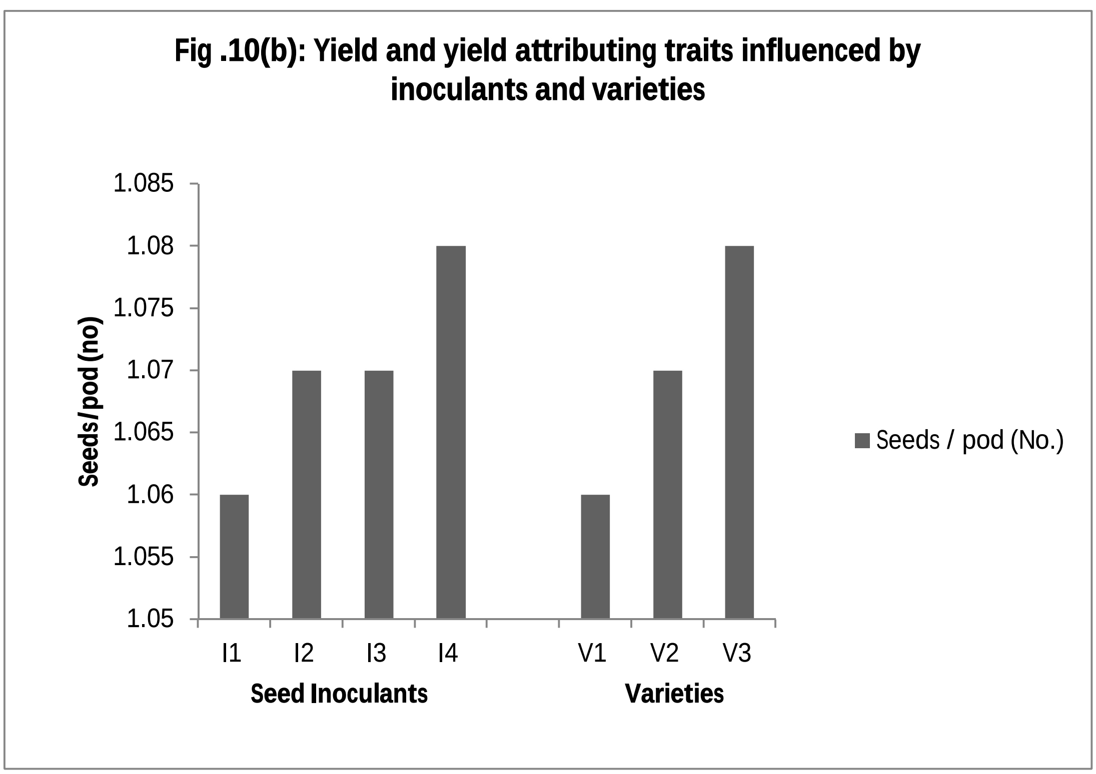


Fig .10(b): Yield and yield attributing traits influenced by inoculants and varieties
Seeds/pod (no)
1.085
1.08
1.075
1.07
1.065
1.06
1.055
1.05
I1
I2
I3
I4
V1
V2
V3
Seed Inoculants
Varieties
Seeds / pod (No.)

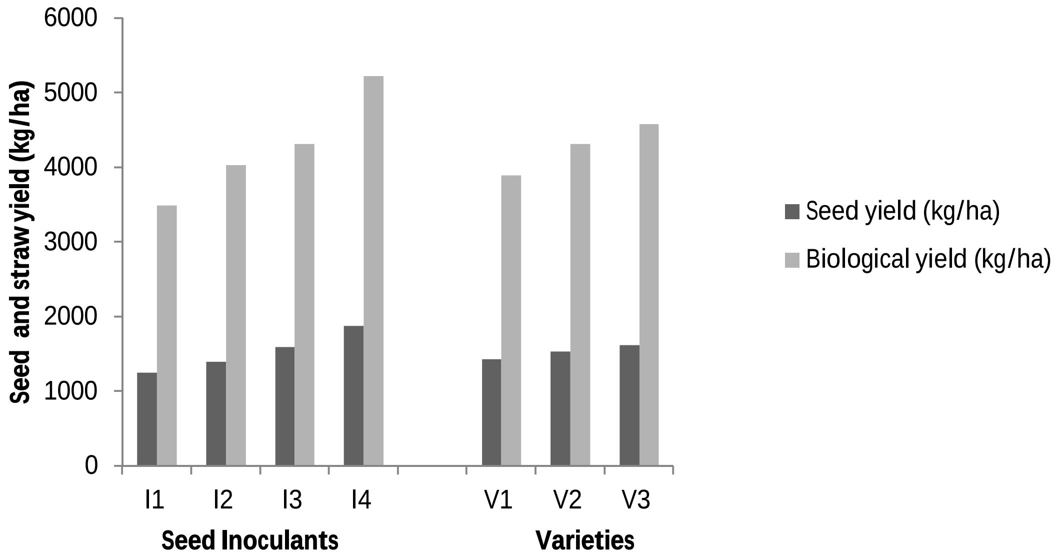


Fig. 11(a): Response of seed inoculant and variety on seed yield kg/ha and straw yield kg/ha

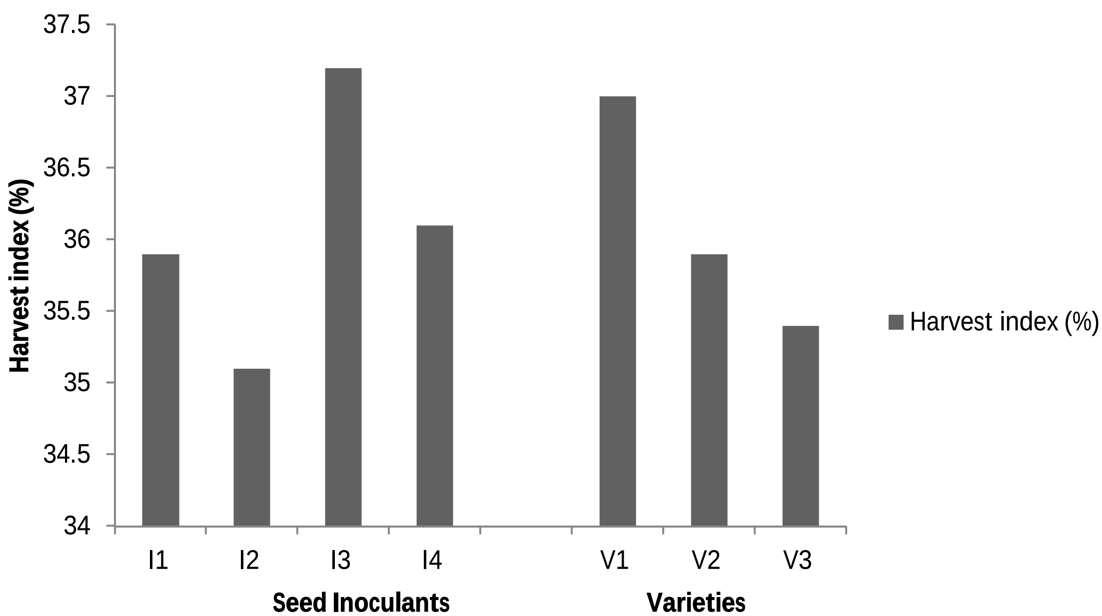


Fig. 11(b): Response of seed inoculant and variety on seed yield kg/ha and straw yield kg/ha

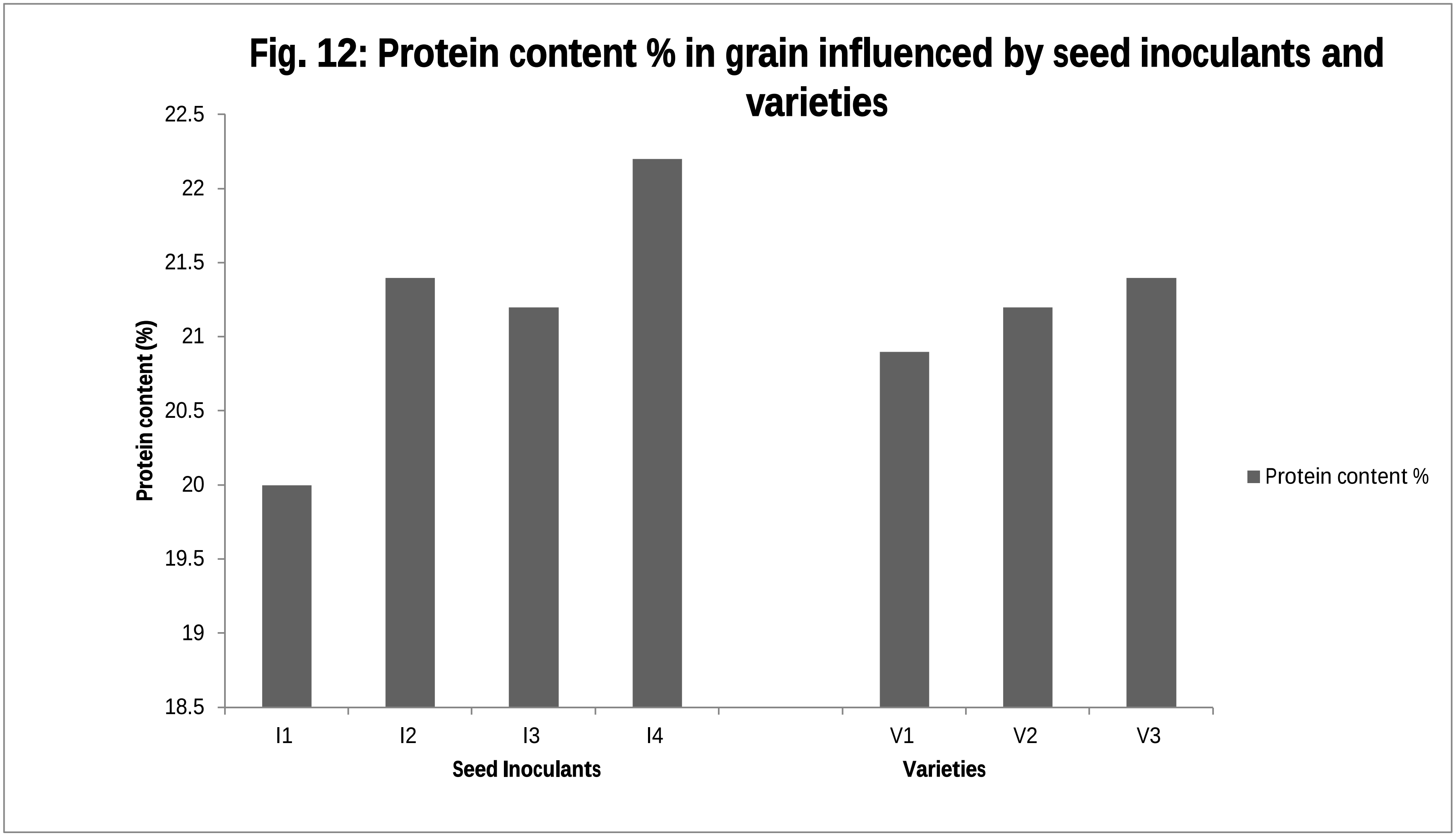


Fig. 12: Protein content % in grain influenced by seed inoculants and varieties
Protein content (%)
22.5
22
21.5
21
20.5
20
19.5
19
18.5
I1
I2
I3
I4
V1
V2
V3
Seed Inoculants
Varieties
Protein content %