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Research Article

INTEGRATED NUTRIENT MANAGEMENT IN BLACKGRAM UNDER RAINFED CONDITION

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AGR (Absolute growth rate), BSH (Bright sunshine hours), GMR (Gross monetary returns), NMR (Net monetary returns), PSB (Phosphate solubilizing bacteria), CRF (Cumulative rainfall).

ABSTRACT

A field experiment entitled "Integrated Nutrient Management in Blackgram under Rainfed Condition" was conducted at the Agriculture Farm, Bhagwant University, and Ajmer during *kharif* season of 2015 on the loamy sand soil. The experiment was laid out in a factorial randomized block design with twenty treatments replicated thrice. Treatment consisted of organic manure viz., FYM @ 3.0 t ha^{-1}, FYM @ 6.0 t ha^{-1}, vermicompost @ 1.5 t ha^{-1}, vermicompost @ 3.0 t ha^{-1} and RDF (25:50 N:P_2O_5 kg ha^{-1}) (F_1, F_2, F_3, F_4 and F_5 respectively) as first factor and seed inoculation of biofertilizer viz., no seed inoculation, *Rhizobium*, PSB and *Rhizobium* + PSB (R_0, R_1, R_2 and R_3 respectively) as second factor. The gross and net plot size were 4.5 x 4.0 m^2 and 3.9 x 3.8 m^2 respectively. The Blackgram was shown on July 2th, 2015. Experimental results revealed that growth characters viz., plant height, number of branches, dry matter leaf area, leaf area index $plant^{-1}$, AGR, RGR, yield contributing characters viz., number of pods $plant^{-1}$, test weight, grain yield, straw yield, biological yield were significantly more with treatment recommended dose of fertilizer (25: 50 N:P_2O_5 kg ha^{-1}).The next best treatments were F_2 (FYM @ 6.0 t ha^{-1}) and F_4 (Vermicompost @ 3.0 t ha^{-1}) . Similarly, treatment F_5 (RDF) recorded significantly higher GMR, NMR and B: C ratio over rest of treatments and significantly lowest NMR and B: C ratio was observed in treatment Vermicompost @ 3.0 t ha^{-1}. The uptake of NPK was recorded significantly higher in treatment RDF over rest of treatments. The available nitrogen, phosphorus, and potassium were recorded significantly higher in treatment F_2 (FYM @ 6.0 t ha^{-1}) over rest of the treatments. Seed inoculation of biofertilizer enhanced the growth attributes viz., plant height, number of branches, dry matter, leaf area, leaf area index $plant^{-1}$, AGR, RGR, yield contributing characters viz., number of pods $plant^{-1}$, test weight, grain yield, straw yield and biological yield were significantly more with treatment R_3 (*Rhizobium*+PSB) than no seed inoculation. Similarly, these treatments also registered significantly higher values of gross monetary returns, net monetary returns and B:C ratio. The uptake of NPK and available nitrogen, phosphorus and potassium per hectare were significantly higher in treatment receiving *Rhizobium* + PSB seed inoculation over rest of treatments.

INTRODUCTION

Blackgram (*Vigna mungo* (L) Heppear) is one to the most important pulse crop in India. Blackgram is an excellent source of high-quality protein. The importance of this crop among other pulse crops is by virtue of its high nutritional value, short duration, adaptability to all season and suitability to various cropping system. It can be used as a rich source of protein & mineral feed for cattle. Black gram is the main source of deity protein (24%) carbohydrate 67%, 3.5% Fiber 1.74% fat and major portion of lysine in a vegetarian diet (Legume Res, 31(1) 57-59, 2008). Blackgram is also used as green manuring crop, being a leguminous crop; it has the capacity to fix atmospheric nitrogen. It also helps in preventing soil erosion Being a short duration crap and adaptability to offseason, it fits well in many intensive crop rotation. Black gram is short duration pulse crop which is grown in India area of 31.9 lakh hector having the production of 19.0 lakh tons with productivity 596 kg ha^{-1} . In Rajasthan, this area occupies an area 1.45 lakh ha with production and productivity is 0.60 lakh tones and 413.79 kg ha^{-1} respectively (Anonymous 2014). Use of fertilizer adversely affected the physical and chemical properties of soil making them acidic or saline Thus it is necessary to add organic matter like FYM compost to maintain soil fertility and productivity where as organic manures are not available in required quantity. Use of organic manures in soil plays vital role in the

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maintenance of native soil fertility. It not only increases the moisture holding capacity of the soil but also plays an important role in soil and water conservation by their binding and aggregation properties Moreover they also help in balancing the nutrient availability to growing as well as succeeding crop plants and boost up the production and quality of crop Organic manures supplies substantial amounts of humus substances. Humus improves the structure, drainage, aeration, of the soil, water holding, buffer and exchange capacity, solubility of soil minerals and serves as a source of energy for the development of microorganisms Slow microbial decomposition of humus, causes gradual release of plant, thereby ensure availability of nutrients on long term basis and hence the residual effect of organic manures is reflected in subsequent seasons of application. Organic manures like FYM, Vermicompost and weed biomass compos arc the important source of plant nutrients. They largely supply organic matter which provides a platform for microbial activities in soil. The release of CO_2 in microbial decomposition and respiration consequently form organic and carbonic acids and enhances the fertility use efficiency and thus reduces the fertilizer requirement. FYM is being used as a major source of organic manures in field crops. Limited availability of this manure is however, an important constraint in its use as a source of nutrients. The pioneering work of Darwin (1881) established the importance of earthworms as a major influence on soil fertility. Vermicompost is nutritionally rich natural organic fertilizer, which release nutrients relatively slow in the soil. It improves the quality of plants along with physical and biological properties of soil i.e. soil aeration, water holding capacity of soil and ecological balance of microbial soil biota. There have been several reports that the use of Vermicompost is a mean to combat the ill effect of chemical fertilizers on soil health. Use of Vermicompost improves soil health, increase the crop yield, soil nutrient status and nutrient uptake. Nitrogen and phosphorus are most important plant nutrient for crop production. These two plant nutrient get more available by seed inoculation with *Rhizobium* and phosphorus solubilizing bacteria (PSB). Inoculation of *Rhizobium* and application of fertilizer improved the yield attributes grain and straw yield (Balchandran and Nagarajan, 2002). The productivity of soil cannot be sustained with the fertilizer alone Application of fertilizers alone has led to a deterioration in health and productivity of our arable soils (Vasanthi and Kumaraswamy, 1999). It has been realized that organic manures must also form part of the manurial schedule to maintain the productivity of the soil. Therefore, to sustain the increase productivity and fertilizer use efficiency application of fertilizers in conjunction with the organic measure is necessary. Integrate nutrient management plays a key role in modern agriculture in increasing the productivity of crops and sustained management of soil fertility. Keeping in this view the present investigation is undertaken to study the "Integrated nutrient management in Blackgram under rainfed condition".

Importance of study:-The present farming totally depends on the use of chemical fertilizers, pesticides and growth regulators for enhancing crop productivity. It is a well-documented fact that increased dependence on agrochemicals including fertilizers has led to several ill effects on the environment. Organic manure greatly reduces leaching of fertilizer, pesticide and herbicides into the ground water. Organic manure improves the activity of earthworm and other soil micro flora and it increases soil infiltration rate and reduces soil evaporation there by it increases soil water storage. Available nitrogen was found to be increased after inoculation of microbes in the soil. The organic manure influences agricultural sustainability by enhancing productivity.

Objectives of study:-It was proposed to undertake the study of entitled "Integrated nutrient management in Blackgram under Rainfed condition" with following objectives. (i) To find out the effect of organic manure on growth and yield of Blackgram. (ii) To find out the effect of bio- fertilizer on growth and yield of Blackgram. (iii) To work out the economics of the treatments. A brief review related to research work conducted in the past on "Integrated nutrient management in blackgram under rainfed condition" is presented in this chapter. The work done on the effect of recommended dose of chemical fertilizers, organic manures (FYM and vermicompost) and Biofertilizers (*Rhizobium* and PSB) on growth, yield attributes, yield, and nutrient uptake of Blackgram are presented under various heads.

Effect of chemical fertilizer:-Although pulses are capable of fixing atmospheric nitrogen yet they need a small basal dose of nitrogenous fertilizer for quick and better start. (Singh *et al.* 2007). The optimum supply of phosphorus to the plant stimulates root development and growth of mungbean (Shukla and Dixit 1996).

Growth Attributes:-Rudreshappa and Halikatti (2002) reported that application of 12.5 kg N + 50 kg P_2O_5 ha^{-1} significantly increased plant height, total dry matter production $plant^{-1}$ and LAI over control in green gram. Singh and Pareek (2003**)** reported that application of phosphorus @ 60 kg ha^{-1} significantly increased the number of nodules and nodules dry weight over control in mung bean. Owla *et al.* (2006) reported that application of 75 kg P_2O_5/ha significantly increased the plant height, LAI, functional leaves/plant, nodules/plant, AGR and RGR over 25 and 50 kg P_2O_5/ha in greengram.

Yield attributes:-Yakadri *et al.* (2002) reported that application of application of 20 kg N + 60 kg P_2O_5 ha^{-1} significantly increased the number of pods $plant^{-1}$ and seed yield of greengram over control. Abraham and Lal (2003) reported that application of recommended dose of fertilizer (20:50:20 NPK kg ha^{-1}) significantly increased the number of pods $plant^{-1}$, seeds pod^{-1}, seed yield and biological yield than the organic manures alone in green gram. Sheoran *et al.* (2008) reported that application of 12.50 kg N + 40 kg P_2O_5/ha significantly increased seed yield by 4.3 percent as compared to 12.50 kg N + 20 Kg P_2O_5 ha^{-1}, which in turn recorded significant yield increase to tune of 15.4 per cent over no fertilizer in mungbean.

Nutrient uptake:- Rudreshappa and Halikatti (2002) studied response of greengram to nitrogen and phosphorus levels and reported that uptake of nitrogen and phosphorus were significantly higher (72.13 and 8.13 kg ha^{-1} respectively) with the application of 12.5 kg N ha^{-1} + 25 kg P_2O_5 ha^{-1} than control. Singh and Pareek (2003) reported that application of 30 kg P_2O_5 ha^{-1} significantly increased the nitrogen and phosphorus content in grain and Stover, N and P uptake kg ha^{-1} over control in greengram.

Effect of organic manure:-Intensive cultivation and growing of exhaustive crops in the sequence has resulted in mining of

nutrients and deficiency of macro and micronutrients in soil. In organic nutrient management development of suitable manure fertilizer schedule depending upon the soil fertility status and crop requirement is necessary. Farmyard manure serves as a potential source of plant nutrients and has an important role in improving soil fertility and productivity and vermicompost rich in NPK, micronutrient and growth regulators which reduce the expenditure on the cost of fertilizer and increase the productivity (Kanase *et al.*2006).

Growth attributes:-Rajkhowa *et al*. (2002**)** observed that significantly increased in plant height and dry matter production due to the application of vermicompost @ 2.5 t ha^{-1} with 100 per cent recommended a dose of fertilizer over control. Singh *et al*. (2008) observed that all the growth parameter *viz.*, plant spread, the number of trifoliate leaves and dry matter accumulation in different plant parts, nodule number and dry weight increased significantly with 5 t FYM ha^{-1} in urdbean. The added organic materials, like vermicompost and enriched compost increased germination growth of shoots, roots and enhanced nodulation of green gram, slightly greater benefits were derived with vermicompost as compared to enriched compost (Shukla and Tyagi, 2009).

Yield attributes:-Reddy and Swamy (2000) conducted a field experiment to study the effect of FYM, PSB and Phosphorus on yield and economics of black gram. Reported that application farmyard manure @ 10t/ha significantly increased pods/plant and seed yield by 9.2 and 6.5 percent respectively over no farmyard manure application. Singh *et al.* (2001) reported that application of FYM @ 5 t/ha significantly increased the yield of mungbean by 9.6 per cent as compared with no use of FYM. **Singh *et al.* (2004)** conducted a field experiment at Haryana and pointed out that application of vermicompost @5 t/ha produced 16.5% higher grain yield compared to FYM in green gram. Singh and Singh (2006) conducted a field experiment to study the effect of farmyard manure on urdbean and results revealed that yield attributes *viz.*, pods per plant, grains per pod, 1000 grain weight and grain yield ha^{-1} in urdbean increased significantly due to direct application of 5 t ha^{-1} farmyard manure over control. Ritu *et al.* (2007) observed that pods $plant^{-1}$ seeds pod^{-1} and 100 seed weight were significantly increased due to the application of FYM @ 5 t ha^{-1} along with 50 per cent recommended a dose of fertilizer in mungbean. **Singh *et al.* (2008)** observed that highest grain yield; protein content and protein yield was recorded with FYM @ 5 t ha^{-1} during both the years in urdbean.

Nutrient uptake:-Rajkhowa *et al.* (2000) reported that nitrogen application through vermicompost significantly increased the plant N, P and K content over RDN through FYM in greengram. Rajkowa *et al.* (2003) conducted field experiment at Jorhat on effect of vermicompost and levels of fertilizer on greengram and observed that significantly increase in N and P uptake due to application of vermicompost with 100 per cent recommended dose of fertilizer over vermicompost with 50 per cent recommended dose of fertilizer.

Effect of biofertilizer:-Nitrogen requirement of pulses is usually met from the fixation of atmospheric nitrogen in association with *Rhizobium* by these crops. *Rhizobium* play a significant role in improving the fertility and productivity of low nitrogen soil (Vijila and Jebaraj 2008) and phosphate solubilizing bacteria dissolve the undissolved forms as a consequence of the release of organic acid and enzymes in soil and make it available to plant.(Singh and Pareek 2003).

Growth Attributes"-Choudhury *et al*. (2000) reported that *Rhizobium* inoculation alone significantly increased total dry matter and partitioning in leaf, stem, and root of mungbean. Kharif pointed out that PSB alone was statistically comparable to the uninoculated control but along with *Rhizobium* it gave slightly more nodulation and plant dry matter than *Rhizobium* alone. Ghosh and Joseph (2006) reported that dual inoculation of *Rhizobium* + PSB significantly increased the plant height, number of branches $plant^{-1}$ dry matter of green gram over uninoculated. Khatkar *et al.* (2007) carried out a field experiment at Allahabad to study the effect of biofertilizers and sulphur levels on growth and yield of blackgram and the result revealed that combined inoculation of *Rhizobium* and PSB significantly increased plant height, a higher number of nodules $plant^{-1}$ and plant dry weight of blackgram over control.

***Yield and yield attributes*:-** Ghosh and Joseph (2006) reported that dual inoculation with *Rhizobium* + PSB recorded seed and stove yield over uninoculated and PSB inoculation alone in green gram. Khatkar *et al*. (2007) reported that combined inoculation of *Rhizobium* and PSB recorded significantly highest grain and straw yield of blackgram over control. Yadav *et al*. (2007**)** reported that combined application *Rhizobium* and PSB significantly increase the number of pods $plant^{-1}$, the number of grains pod^{-1}, test weight, grain yield and stover yield over *Rhizobium* inoculation in greengram. Vijila and Jebaraj (2008) observed that application of *Rhizobium* with phosphobacteria improved the yield of greengram over no inoculation.

Nutrient uptake:-Singh and Pareek (2003) reported that combined inoculation of *Rhizobium* + PSB significantly increased the nitrogen and phosphorus content in grain and stover, N and P uptake kg ha^{-1} over control. Singh *et al*. (2004) conducted a field experiment on sandy loam soil at Jobner and revealed that the both *Rhizobium* and PSB inoculation significantly increased the N, P content and its uptake in grain and Stover of greengram over single inoculation. Jain *et al.* (2007) reported that *Rhizobium* along with micronutrients significantly enhanced the P and N uptake as compared to control in mungbean.

Integrated nutrient management:-Suman *et al.* (2006) conducted field experiment on sandy loamy soil at Rajasthan and found that application of NPK + vermicompost enhanced the pods/plant, pod length, number of seeds pod^{-1}, test weight, seed yield and straw yield significantly over NPK alone in greengram. Yadav *et al.* (2007) observed that highest grain yield (12.49 q ha^{-1}) grains pod^{-1} (13), test weight (42 g) and maximum number of nodules (36) were recorded with application of *Rhizobium* and PSB + P_2O_5 @ 75 kg ha^{-1} + poultry manure at 5 t ha^{-1} in green gram.

Economics:-Ghosh and Joseph (2006) reported that dual inoculation with *Rhizobium* + PSB increased the net return and benefit: cost ratio over uninoculated in green gram. Kumar and Elamathi (2007) reported that application of nitrogen 20 kg ha^{-1} + *Rhizobium* increased the total return, net return, and B: C ratio over nitrogen 10 kg ha^{-1} + uninoculated in black gram.

MATERIALS AND METHODS

A field experiment entitled "Integrated nutrient management in Blackgram under Rainfed condition" was conducted during *kharif* season of 2015. The details of material used and methods adopted during the course of investigation are described in this chapter.

Details of experimental material:-Experimental site:- The field experiment was carried out in the plot No.27 at the Agriculture Farm, Bhagwant University, Ajmer during kharif season of 2015.

Soil:-The experimental site was fairly leveled and uniform in depth and topography. In order to know the physical– chemical properties of the experimental site, the soil samples from 30 cm depth were randomly collected from different locations of the experimental field before the start of the experiment and a composite sample was prepared and analyzed for physical and chemical properties of soil. The methods adopted to determine the important initial properties and data pertaining to them are presented in Table 1. The fertility status of the soil of experimental plot presented in Table 1 revealed that the soil was loamy in texture, slightly alkaline in nature, low in organic carbon, low in available nitrogen and phosphorus and moderately in available potassium.

the month of July and August. During summer, the maximum temperature may go as high as 37^0C while in the winter it may fall as low as 5^0C. This region is prone to high wind velocity and soil erosion due to dust stroms in summer. Table 3 shows that maximum temperature ranged between 35.40 ^{0}C and 35.45^0C during the crop growing season were recorded in the 20^{th} and 22^{nd} standard meteorological weeks Likewise, the minimum temperature between 10.3^0C and 10.6^0C was recorded in the 50^{th} and 52^{nd} standard meteorological weeks, respectively. During crop season, total 750.0mm rainfall received. Bright sunshine hours essential for crop growth, flowering, and pod setting. The sunshine hours were low and humidity was high during the rainy season. The maximum relative humidity ranged between 58 and 87.0 per cent during the crop growing season were recorded in the 22^{nd} and 33^{th} standard meteorological weeks.

Experimental details:-Experimental design and treatments:- The present investigation entitled "Integrated nutrient management in Blackgram under rainfed condition" was laid out in Factorial Randomized Block Design with twenty treatments each replicated thrice. The treatments were allotted randomly in each replication. The gross plot size was 4.5 m x 4.0 m.

Table-1 Physical-chemical properties of soil

S. No	Particulars	Results	Methods adopted
		A.	**Mechanical analysis**
1	Coarse Sand %	9.38	
2	Fine sand %	63.72	Bouyoucos hydrometer Method (Piper, 1966)
3	Silt %	10.20	
4	Clay %	16.70	
5	Textural class	Loamy Sand	Textural triangle
		B.	**Chemical analysis**
1	Soil pH	8.4	Beckman's glass electrode, pH meter (Jackson, 1967)
2	Electrical conductivity (dSm^{-1})	1.24	1:2.5 Soil Water Suspension using Electrical Conductivity meter (Jackson,1967)
3	Organic carbon %	0.52	Wet oxidation Walkley and Black method (Jackson, 1967)
4	Available nitrogen (kg ha^{-1})	131.5	Alkaline permanganate method (Subbiah and Asija, 1956)
5	Available phosphorus (kg ha^{-1})	16.8	Olsen's method (Watanabe and Olsen, 1965)
6	Available potassium (kg ha^{-1})	160.76	Neutral N Ammonium Acetate extract using Flame photometer (Hanway and Heidel 1952)

Cropping history of the experimental plot:- a Cropping history of the experimental field for preceding three years of actual commencement of the investigation is given in Table 2.

Table 2 Cropping history of experimental field

Year	Kharif	Rabi
2013-14	Sorghum	-
2014-15	Bajra	wheat
2015	Blackgram (present investigation)	-

Climate and weather conditions:-Ajmer is situated in the sub-tropical zone at the latitude of 24°32' North longitude of 67°02' East. The altitude of the place is 307.41 meters above mean sea level. The climate of Ajmer is semi-Arid and characterized by three distinct seasons' *viz.*, hot and dry summer from March to May, warm and rainy monsoon from June to October and mild cold winter from November to February. Most of the rain received from southwest monsoon during June to October. The black gram crop was shown on July 2^{nd} and harvesting was undertaken September 17^{th}. Ajmer received average annual rainfall of about 750 mm, out of which 80 percent of rainfall is received in *Kharif* season (July-September) by the southwest monsoon. After emergence, there was a good shower during

The net plot size was 3.9 m x 3.8 m. Details of the treatments along with symbols used in the plan of the layout are given in Table 3.

Table 3 Details of treatments

S. No.	Symbol	Treatments
		Factor A: Organic manure
1	F_1	FYM @ 3 t /ha
2	F_2	FYM @ 6 t /ha
3	F_3	Vermicompost @1.5 t /ha
4	F_4	Vermicompost @3.0 t /ha
5	F_5	R.D.F.(25:50 N:P_2O_5 kg ha^{-1})
		Factor B: Biofertilizer
1	R_0	No seed Inoculation
2	R_1	*Rhizobium*
3	R_2	PSB
4	R_3	*Rhizobium* + PSB

Table 5 Details treatment combinations

S. No.	Symbol	Treatment combination
1	F_1R_0	FYM @ 3 t ha^{-1} + No seed Inoculation
2	F_1R_1	FYM @ 3 t ha^{-1} + *Rhizobium*
3	F_1R_2	FYM @ 3 t ha^{-1} + PSB
4	F_1R_3	FYM @ 3 t ha^{-1} + *Rhizobium* + PSB
5	F_2R_0	FYM @ 6 t ha^{-1} + No seed Inoculation
6	F_2R_1	FYM @ 6 t ha^{-1} + *Rhizobium*
7	F_2R_2	FYM @ 6 t ha^{-1} + PSB
8	F_2R_3	FYM @ 6t ha^{-1} + *Rhizobium* + PSB
9	F_3R_0	Vermicompost @1.0 t ha^{-1} + No seed Inoculation
10	F_3R_1	Vermicompost @1.5 t ha^{-1} + *Rhizobium*
11	F_3R_2	Vermicompost @1.5 t ha^{-1} + PSB
12	F_3R_3	Vermicompost @1.5 t ha^{-1} + *Rhizobium* + PSB
13	F_4R_0	Vermicompost @ 3.0 t ha^{-1} + No seed Inoculation
14	F_4R_1	Vermicompost @ 3.0 t ha^{-1} + *Rhizobium*
15	F_4R_2	Vermicompost @ 3.0 t ha^{-1} + PSB
16	F_4R_3	Vermicompost @ 3.0 t ha^{-1} + *Rhizobium* + PSB
17	F_5R_0	R.D.F(25:50 $N:P_2O_5$. kg ha^{-1})+No seed Inoculation
18	F_5R_1	R.D.F(25:50 $N:P_2O_5$. kg ha^{-1}) + *Rhizobium*
19	F_5R_2	R.D.F(25:50 $N:P_2O_5$. kg ha^{-1}) + PSB
20	F_5R_3	R.D.F(25:50 $N:P_2O_5$. kg ha^{-1}) + *Rhizobium* + PSB

Other details

Crop-Blackgram (*Vigna mungo* (L.) Hepper)	Factorial Randomized Block Design	
Variety- Barkha (RBU-38)	Plot size- Gross - 4.5 x 4.0 m^2, Net - 3.9 x 3.8 m^2	
Number of replications-3	Number of treatments-20	Total number of plots-60
Date of sowing-2 July 2015	Spacing-30 x 10 cm	Seed rate-15 kg ha^{-1}
Fertilizer dose- As per treatment	Sowing method- Drilling	Season- Kharif

Cultural operation:-The schedules of various field operations carried out during the period of experimentation are presented in Table 5.

Land preparation: - To obtain fine seed bed, plugging was done up to 30 cm depth using tractor-drawn plough followed by harrowing for clod crushing and removing the stubbles of previous crop and weeds. Stubbles were picked to clean the field. The experiment was laid out as per plan of the layout (Fig.2.).

Seeds and sowing:- the Certified seed of black gram, Barkha was sown @ 15 kg/ ha. The sowing was undertaken after receipt of sufficient rains by drilling method keeping 30 cm distance between two rows while plant to plant distance maintained was 10 cm.

Thinning and gap filling:-After one week of sowing, gaps were filled wherever necessary in the black gram crop. Thinning was done after 12 days of sowing and the single plant was retained per hill at distance of 10 cm to maintained required plant population.

Fertilizer application:-The fertilizers were applied as per treatments. The recommended dose of fertilizer (25 kg N and 50 kg P_2O_5) was applied through urea (46% N) and single superphosphate (16 % P_2O_5).

Organic manures application:-FYM and vermicompost application to the black gram crop was done as per treatments assigned to the respective plots. The application of FYM and vermicompost was done 7 days before sowing and was mixed in soil thoroughly.

Biofertilizers application:-Seed treatment with biofertilizers viz., *Rhizobium* and phosphate-solubilizing bacteria (PSB) were applied as per treatments by inoculating black gram seeds with biofertilizers culture @ 25 g/kg of seed by slurry method. The seed inoculation was done as per the treatment.

Intercultural operations:- The weeds were controlled by giving two hand weeding and one hoeing. The crops were kept free from weeds up to 30 days after sowing.

Harvesting and threshing:-Harvesting was done manually when the crop showed physiological maturity and the grains were completely matured. The harvesting was done by picking of pods. Border rows were harvested and kept separately and then crop from each net plot area was harvested separately. The harvested produce from each net plot was collected in different bags as per treatment. Observation plants were harvested separately and were taken to the laboratory for postharvest studies. After sun drying the produce from each net plot was threshed manually and clean seeds were obtained by winnowing.

Biometric observations:-Five plants were randomly selected from each net plot treatment-wise in all replications. The plants were labeled and various biometric observations were recorded on these plants periodically after 15 days of interval till maturity of the crop. Observations on yield components were recorded after harvest of the crop. Various biometric observations recorded during the period of investigation are given in Table 7.

Table 6 Schedule of cultural operations

S. No.	Field operations	Frequency	Date
	A. Preparatory tillage		
1	Ploughing	1	15.06.2015
2	Harrowing	1	19.06. 2015
3	Leveling with plankar	1	19.06. 2015
4	Layout of experiment	1	21.06. 2015
5	Application of compost as per treatment.	1	24.06. 2015
	B. Sowing		
1	Sowing	1	02.07. 2015
	C. Fertilizer application		
1	Full dose (N + P + K)	1	02.07. 2015
	D. Post sowing operations		
1	Thinning	1	14.07. 2015
2	Hand weeding	2	19.07. 2015
3	Hoeing with blade hoe	2	23.07. 2015 & 31.07. 2015
	E. Harvesting		
1	Harvesting	1	17.09. 2015
	F. Threshing		
1	Threshing	1	20.09. 2015

The techniques followed for recording each observation are also described separately where ever felt necessary.

Plant stand:-Emergence count and final plant population:- Number of plants in a row per meter length in each net plot was counted at 15 days after sowing. Final plant stands also taken just before harvest of the crops.

Growth studies:- Plant height:-Height of the plant was measured in cm from the base of the plant to the tip of the main

shoot. The observations were recorded periodically at an interval of 15 days from sowing till harvest of the crop.

Table 7 Schedule of biometric observations

S. No.	Particulars	Frequency	Days after sowing (DAS)
	A. Plant stand		
1	Emergence count	1	15 DAS
2	Final plant stand	1	At harvest
	B. Growth studies		
1	Plant height	4	15, 30, 45, at harvest
2	Number of branches plant^{-1}	4	15, 30, 45, at harvest
3	Dry matter plant^{-1}	4	15, 30, 45, at harvest
4	Leaf area plant^{-1}	4	15, 30, 45, at harvest
5	Leaf area index (LAI)	4	15, 30, 45, at harvest
6	Number of root nodules plant^{-1}	4	30, 45
7	AGR, RGR	4	15, 30, 45, at harvest
	C. Post harvest studies		
1	Number of pods plant^{-1}	1	At harvest
2	Weight of grain plant^{-1} (g)	1	At harvest
3	Test weight (g)	1	After harvest
4	Grain yield (kg) ha^{-1}	1	After harvest
5	Straw yield (kg) ha^{-1}	1	After harvest
6	Biological yield (kg) ha^{-1}	1	After harvest
7	Harvest Index	1	After harvest
8	Protein content	1	After harvest
	D. Chemical studies		
1	Fertility status of soil (N,P,K)	2	Before sowing & after harvest
3	Plant uptake	1	After harvest
	E. Economics studies		
1	Gross monetary return (Rs ha^{-1})	1	After harvest
2	Net monetary return (Rs ha^{-1})	1	After harvest
3	Benefit: Cost ratio	1	After harvest

Number of branches per plant:- The numbers of branches plant^{-1} were recorded from the five selected plants and mean number of branches plant^{-1} was worked out.

Dry matter per plant:- Randomly selected one plant was uprooted from each treatment plot at an interval of 15 days. The root portion of the plant was cut from ground level. The aerial portion of the plant was kept in a brown paper bag and was air dried for 48 hours and then placed into a hot air oven at a regulated temperature of 65^{0}C and final constant dry weight was recorded as dry matter plant^{-1}.

Leaf area per plant:-The leaves from the plant sampled for dry matter study were used for estimating the leaf area. The leaf area (dm^2) was estimated by using the automatic laser area meter, model CI-203, CID Inc USA at the Department of Agronomy.

Leaf area index:-Leaf area index is the measure of crop growth per unit area. Since, the crop yield is to be expressed per unit of ground area, instead of plant^{-1}. The leaf area existing on the unit ground area was proposed by Watson (1952). Leaf area index is the ratio of leaf area to the ground area occupied by crop plant. It is calculated by the following formula.

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Ground area per plant (cm}^2\text{)}}$$

Number of root nodules:- Plant took out carefully with the help of a fork. The roots were then washed by water and the functional root nodules were counted. The mean number of nodules plant^{-1} was reported.

Growth analysis:-Data on growth characters viz., height, dry matter plant^{-1} and leaf area plant^{-1} were further analyzed for the computations of different growth functions viz., absolute growth rate (AGR) for height, dry matter and relative growth rate (RGR) of dry matter. Data on these growth functions were reported and the inferences are drawn on the basis of mean values.

Absolute growth rate (AGR):-The rate of increase in growth variable (w) at the time (t) is called as absolute growth rate (AGR). It is measured as the different coefficient of 'W' with respect to time't'. AGR of two growth variables viz. height of the plant and total dry matter weight was worked out and expressed as cm day^{-1} and g day^{-1}, respectively as under.

$$AGR = dH/dt = \frac{(H_2 - H_1)}{(t_2 - t_1)} \quad (\text{cm day}^{-1}\text{, for plant height})$$

$$AGR = dW/dt = \frac{(W_2 - W_1)}{(t_2 - t_1)} \quad (\text{g day}^{-1}\text{, for dry matter})$$

Where,- dH and dW are increased in variable and dt time interval in days. H_2 and H_1 refer to the height of plant and W_2 and W_1 refer to dry matter plant^{-1} at t_2 and t_1 times, respectively.

Relative growth rate (RGR) (g g^{-1} day^{-1}):- The relative growth rate at which a plant incorporates the new material into its substance by relative growth rate (RGR) of dry matter accumulation and expressed as g of dry matter produced g^{-1} of existing dry weight day^{-1}.

$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1} \quad (\text{g g}^{-1}\text{ day}^{-1})$$

Where, Log_e = Natural logarithm to the base 'e' = 2.3026, W_1 and W_2 = Weight of total dry matter at t_1 and t_2 time, respectively.

Post harvest studies:- Important yield attributing characters were studied after the harvest of the crop.

Number of pods per plant:- The pods from the randomly selected five plants were picked and total numbers of pods were counted. The average number of pods plant^{-1} was estimated.

Weight of grain per plant:- All the pods of the selected observation plants were threshed separately and average grain weight plant^{-1} was worked out.

Test weight:- Thousand grains were counted from representative samples from each net plot and weighted separately. This thousand grains weight was worked out as test weight.

Grain yield per hectare:- The plants harvested from net plot were threshed, cleaned and grain weight plot^{-1} was recorded separately. The grain yield was then converted into hectare yield (kg ha^{-1}).

Straw yield per hectare:- Straw yield was obtained by deducting the weight of grains from the biological yield of respective net plot and transformed into per hectare yield (kg ha^{-1}).

Biological yield per hectare:- The plants from net plot were cut close to the ground, tied into bundles, dried in the sun and their

weight was recorded before threshing as per treatments. From per plot yield per hectare yield was worked out.

Harvest index:-Ratio of grain yield to a biological yield of each net plot was worked out and reported in percentage as harvest index.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Quality study:-Protein content and protein yield:- Nitrogen content (%) in grain of black gram was multiplied by 6.25, to obtain crude protein content in grains. On the basis of crude protein the estimated yields of protein ha^{-1} were calculated by the following a formula.

$$\text{Protein yield (kg ha}^{-1}) = \frac{\text{Grain yield} \times \text{Protein content in grain (\%)}}{100}$$

Chemical studies:- Soil analysis:-Composite soil sample 0-30 cm depth from randomly selected spots in the experimental area was collected before start of the experiment during Kharif 2015. It was air dried in shade, powdered and analyzed for determination of physical and chemical properties of soil. Treatment wise soil sample 0-15 cm and 15-30 cm depth from each plot were collected after harvesting of the crop. The samples were air dried, powdered and analyzed for estimation of available nitrogen, phosphorous and potassium. Balance sheet of N, P_2O_5 and K_2O was worked by considering initial fertility status and final balance of nutrients in the soil after completion of experimentation. The method adopted for these studies are given below.

Soil pH:-Soil pH was determined by pH meter after equilibrating soil with water for 60 minutes in the ratio of 1:2.5 soil water suspensions (Jackson 1967).

Organic carbon (%):-It was determined by Walkley and Blacks method (Jackson, 1967). A ground soil sample of 0.2 mm size were used for estimation of organic carbon. Soil samples were oxidized by potassium dichromate and concentrated sulphuric acid mixture and the volume of untreated dichromate was titrated with a standard ferrous ammonium sulphate solution using diphenylamine as an indicator.

Available nitrogen (kg ha^{-1}):-The available nitrogen from soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956). The easily oxidizable organic nitrogen present in soil was oxidized by potassium permanganate in the presence of NaOH by distillation. During oxidation, the release ammonia was absorbed in boric acid to convert the ammonia to ammonium borate which was titrated with the standard sulphuric acid.

Available phosphorus (kg ha^{-1}):-The Olsen's method (Olsen *et. al*. 1954) was used for determining available phosphorus in soil in which phosphorus was extracted from the soil using 0.5 M sodium bicarbonate ($NaHCO_3$), pH 8.5 as an extract. Phosphorus was estimated calorimetrically by adding ammonium molybdate to aliquot and reducing the molybdenum phosphate complex in acidic medium. The intensity of blue colour on reduction as a measure for concentration of phosphorus in the extract was read on colorimeter using 730 nm red filters.

Available potassium (kg ha^{-1}):-The available potassium i.e. exchangeable and water soluble potassium in soil was determined in neutral normal ammonium acetate (N, NH_4, OAC) extract of soil. Shaking followed by filtration carried out the extraction and the potassium in the extract was estimated by using flame photometer (Jackson, 1967).

Grain and straw analysis:-Plants used for dry matter study at harvest were utilized for estimation of nitrogen, phosphorous and potassium content. These plants were ground and N, P and K in straw and grain were estimated by the method suggested by Jackson (1967) as given below. The total nutrient uptake in Kg ha^{-1} was calculated by using formula.

$$\text{Uptake of nutrient (kg ha}^{-1}) = \frac{\text{Yield (kg ha}^{-1}) \times \text{Nutrient content}}{100}$$

Total nitrogen (%):-Total nitrogen in plant samples was determined by Kjeldahl method in which complex nitrogenous compounds in plant samples were converted into ammonia and then to ammonium sulphate. The ammonia in the ammonium sulphate is released with NaOH during distillation and absorbed in a known volume of standard sulphuric acid. The unutilized excess of standard H_2SO_4 is determined by a back titration with standard sodium hydroxide. The total nitrogen is then calculated from the amount of the standard H_2SO_4 neutralized by absorbed ammonia during distillation (Jackson, 1967).

Digestion of sample:-For the nutrients other than nitrogen, the plant material was digested in a di-acid 9:4 HNO_3: HCLO4. The samples were predigested with 25 ml HNO_3 $gram^{-1}$ sample to avoid explosion. Volume was made up with deionized water and the aliquots of this solution were used for the determination of P and K.

Phosphorus content:-Phosphorous content in the extract was estimated by reacting the extract with vanadomolybdate forming yellow colour complex in HNO_3 medium. The colour was developed in about 30 minute and the transmittance or absorbance of the solution was read at colorimeter using blue filter (Jackson, 1967).

Potassium content:-The extract was diluted to appropriate concentration and was directly atomized to the flame photometer at 548 nm wavelength (Jackson, 1967).

Nutrient uptake:-Nutrient uptake of nitrogen, phosphorous and potassium was calculated by multiplying the percent N, P and K content with corresponding grain and straw yields of each treatment.

Economics of the treatment:-Gross monetary returns (GMR):- The total values of produce i.e. grain yield and straw yield was estimated treatment wise as per prevailing market rate and treated as gross monetary returns. From this gross monetary returns, ha^{-1} were calculated.

Net monetary returns (NMR):-Net monetary returns were calculated by subtracting cost of cultivation from gross returns treatment wise.

Benefit cost ratio:- The benefit cost ratio is the ratio of gross returns to the cost of cultivation. It can also be expressed as returns per rupee invested. This was calculated with the following formula.

$$\text{Benefit cost ratio} = \frac{\text{Gross monetary return}}{\text{Cost of cultivation}}$$

Statistical analysis:- The data collected during the course of the present investigation were statistically analyzed by adopting standard methods known as 'Analysis of Variance' (Panse and Sukhatme, 1967). Where ever results were significant critical differences (CD) were worked out at 5 per cent level of probability for comparison of treatment mean. The treatment effects were presented by making tables of means with appropriate standard error (SE m ±) and CD values.

RESULTS

An experiment entitled "Integrated nutrient management in blackgram under rainfed condition" was conducted during the *kharif* season of 2015 at the Agriculture Farm, Bhagwant University, Ajmer. During the course of field experimentation, the observations recorded on different growth characters, yield attributes and yield of black gram as influenced by different treatments are presented in this chapter under appropriate heads.

Emergence and final plant count at harvest:- Data regarding the emergence and final plant count at harvest as influenced by different treatments are shown in Table 8 Mean emergence and final plant count at harvest were 421.32 and 393.45 respectively.

Effect of organic manure:- The mean emergence and final plant count at harvest did not differ significantly due to organic manure treatments.

Effect of biofertilizers:- The mean emergence and final plant count at harvest did not influence significantly by the different treatments of biofertilizer.

Effect of interaction:-Interaction effects were found non-significant.

Table 8 Emergence count and final plant stand at harvest as influenced by various treatments

Treatment	Emergence Count	Final plant stand
A. Organic Manure		
F_1 - FYM @ 3 t /ha	421.48	393.67
F_2 - FYM @ 6 t /ha	421.55	393.95
F_3 - Vermicompost @1.5 t /ha	421.36	392.84
F_4 - Vermicompost @3.0 t /ha	421.63	393.45
F_5 - R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	421.88	394.10
SE(m)±	0.46	0.72
CD (P=0.05)	NS	NS
B. Seed inoculation of biofertilizer		
R_0 - No seed inoculation	421.55	393.25
R_1 – *Rhizobium*	420.96	392.95
R_2 – PSB	420.15	393.88
R_3 - *Rhizobium* + PSB	421.30	392.96
SE(m)±	0.68	0.43
CD (P=0.05)	NS	NS
Interaction effect		
SE(m)±	1.12	0.81
CD (P=0.05)	NS	NS
General Mean	421.32	393.45

Growth studies:-Plant height (cm):- Data on mean plant height recorded at 15, 30, 45 DAS and at harvest of Blackgram as influenced by different treatments are presented in Table 9 and graphically illustrated in Fig.2. Data presented in Table 9 related that, the mean plant height of Blackgram increased with the advancement of crop age. On an average marked improvement in plant height was observed up to 45 DAS then subsequently declined.

Effect of organic manure:- From the data presented in Table 9 showed that organic manure treatments differed significantly in respect of the mean plant height at all the stages of crop growth. The treatment F_5 (RDF) recorded significantly highest plant height over F_1 (FYM @ 3 t ha^{-1}) and F_3 (Vermi compost @ 1.5 t ha^{-1}) all stages of crop growth. Increase in plant height might be due to the nitrogen application increased growth of the plant, since nitrogen as a major component of protoplasm helps in photosynthesis and enhances metabolic rate, cell division and cell elongation which thereby, allow the plant grow faster and phosphorus enhances the root elongation, leaf expansion and helps in cell elongation. Similar results were also obtained by Rajkhowa *et al.* (2002), Rudreshappa and Halikatti (2002), and Sheoron *et al.* (2008).

Effect of biofertilizers:- The plant height of Blackgram was significantly influenced due to seed inoculation of biofertilizer at all the growth stages of crop. Treatment R_3 (*Rhizobium* + PSB) recorded significantly highest plant height at all the growth stages over R_0, and was found at par with R_1 and R_1 at 30 DAS. The increase in crop growth due to combined inoculation of *Rhizobium* + PSB in the present study might be due to nitrogen provided through symbiotic fixation of atmospheric nitrogen and growth regulators produced by *Rhizobium* and also due to solubilization of insoluble phosphates by the production of various organic acids such as lactic acid and acetic acid. Similar results were also obtained by Balachandran and Nagarajan (2002) and Khatkar *et al.* (2007).

Effect of interaction:-Interaction effects were non-significant at all stages of crop growth.

Table 9 Plant height (cm) as influenced by various treatments

Treatments	Days after sowing			
	15	30	45	At harvest
A. Organic Manure				
F_1 - FYM @ 3 t /ha	11.72	24.62	37.26	39.28
F_2 - FYM @ 6 t /ha	13.65	26.10	39.93	43.92
F_3 - Vermicompost @1.5 t /ha	11.10	25.14	38.00	42.54
F_4 - Vermicompost @3.0 t /ha	12.20	26.25	39.63	44.45
F_5 -R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	13.69	26.93	40.38	45.30
SE(m)±	0.22	0.46	0.54	0.73
CD (P=0.05)	0.65	1.29	1.56	2.14
B. Seed inoculation of biofertilizer				
R_0 -No seed treatment	11.04	25.00	37.93	40.31
R_1 –*Rhizobium*	12.03	26.20	38.35	42.40
R_2 –PSB	12.00	26.15	39.83	44.61
R_3 -*Rhizobium* + PSB	13.13	26.65	40.05	45.08
SE(m)±	0.19	0.21	0.44	0.47
CD (P=0.05)	0.57	0.62	1.30	1.39
Interaction effect				
SE(m)±	0.27	0.68	0.82	0.86
CD (P=0.05)	NS	NS	NS	NS
General Mean	12.25	25.89	39.04	43.10

Number of branches per plant:- Data on mean number of branches plant^{-1} recorded at 15, 30, 45 DAS and at harvest as influenced by different treatments are presented in Table 10 and graphically depicted in Fig. 3.

Effect of organic manure:- It could be seen from the data presented in Table 10 that the mean number of branches plant^{-1} of black gram increased from 3.97 at 15 DAS to 8.78 at harvest. The rate of increase was rapid between 15 to 45 DAS and declined thereafter. Treatment F_5 (RDF) recorded a maximum number of branches plant^{-1} which was at par with F_2 and F_4 and significantly higher over F_1 (FYM @ 3 t ha^{-1}) and F_3 treatments at all stages of crop growth. Treatment F_2 and F_4 also produced significantly more number of branches plant^{-1} over F_1 (FYM @ 3 t ha^{-1}) and F_3 at all stages of crop growth. Increase in a number of branches with RDF attributed to a better supply of nutrients resulted in enhanced crop growth by cell enlargement in the meristematic region and thereby more plant height ultimately increased the nodes and internodes and more number of branches plant^{-1} as compared to other treatments. Similar findings were also reported by Ardeshna *et al.* (1993) and Rajender kumar *et al.* (2002).

Effect of biofertilizers:-The mean number of branches plant^{-1} of Blackgram was significantly influenced due to seed inoculation of biofertilizer. Treatment R_3 (*Rhizobium* + PSB) produced a maximum number of branches plant^{-1} over rest of the treatments at all stages of crop growth. Similarly treatment R_1 and R_2 recorded a higher number of branches plant^{-1} over R_0.The combined seed inoculation with *Rhizobium* + PSB improved N and P status of soil and ultimately increased N and P uptake which enhanced growth attributes. Similar results were also obtained by Singh and Pareek (2003) and Ghosh and Joseph (2006).

Interaction effect:-Interaction effects were found non-significant.

Table 10 Number of branches per plant as influenced by various treatments

Treatments	Days after sowing			
	15	30	45	At harvest
A. Organic Manure				
F1 - FYM @ 3 t /ha	3.20	6.40	7.72	7.65
F2 - FYM @ 6 t /ha	4.25	7.73	9.23	9.42
F3 - Vermicompost @1.5 t /ha	3.43	6.87	8.08	7.75
F4 - Vermicompost @3.0 t /ha	4.35	7.69	8.35	9.32
F_5 -R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	4.62	8.06	9.32	9.76
SE(m)±	0.24	0.29	0.36	0.45
CD (P=0.05)	0.72	0.84	1.03	1.34
B. Biofertilizer				
R0 -No seed treatment	3.30	6.23	7.47	7.55
R1 –*Rhizobium*	3.78	7.45	8.75	8.95
R2 –PSB	4.15	7.54	8.86	9.08
R3 - *Rhizobium* + PSB	4.65	8.18	8.98	9.55
SE(m)±	0.13	0.16	0.39	0.42
CD (P=0.05)	0.39	0.46	1.12	1.23
Interaction effect				
SE(m)±	0.27	0.66	1.33	1.29
CD (P=0.05)	NS	NS	NS	NS
General Mean	3.97	7.35	8.56	8.78

Total dry matter per plant:- Data regarding total dry matter accumulation plant^{-1} as influenced by different treatments are presented in Table 11 and graphically depicted in Fig.4. Data on total dry matter accumulation plant^{-1} were influenced by different treatments. The total dry matter accumulation plant^{-1} increased continuously at all stage of crop growth up to maturity. The rate of increase was slow at the initial stage, moderate between 30 – 45 DAS and fast between 45 DAS to harvest. The mean total dry matter accumulation plant^{-1} was highest at harvest (15.01 g).

Effect of organic manure:- Organic manure treatments had a significant influence on total dry matter accumulation plant^{-1} at all stages of crop growth. Treatment F_5 (RDF) recorded significantly higher dry matter accumulation over F_1 (FYM @ 3 t ha^{-1}) and F_3. However, treatment F_5 (RDF) was at par with F_2 and F4 (vermicompost @ 3 t ha^{-1}) at all stages of crop growth. Similarly, treatment F_2 and F_4 recorded significantly higher dry matter over F_1 (FYM @ 3 t ha^{-1}) and F_3 at all dates of observation. Application of recommended dose of fertilizer influenced the vigour of the plant which was probably accelerated the nitrogen fixing power of the plant by increasing the activity of nodule bacteria and resulting in more dry matter accumulation. Similar findings were also reported Rajkhowa *et al.* (2002), Rudreshappa and Halikatti (2002).

Effect of biofertilizers:- Significant differences were noticed due to seed inoculation of biofertilizer over no seed inoculation treatment at all dates of observation. Treatment R_3 (*Rhizobium* + PSB) recorded significantly higher dry matter accumulation over R_0, R_1 and R_2 at all stages of crop growth. The favorable effect of combined inoculation of *Rhizobium* and PSB could be attributed to synergistic interaction among phosphate solubilizing microorganism and *Rhizobium*, which lead to increased availability of nutrient and resulted in better vegetative growth and more dry matter accumulation. These results are in agreement with the findings of Singh and Pareek (2003) Ghosh and Joseph (2006) and Khatkar *et al.* (2007).

Interaction Effect: -Interaction effect effects were absent at all stages of crop growth.

Table 11 Total dry matter (g) per plant as influenced by various treatments

Treatments	Days after sowing			
	15	30	45	At harvest
A. Organic Manure				
F1 - FYM @ 3 t /ha	0.94	4.32	7.73	13.58
F2 - FYM @ 6 t /ha	0.97	4.53	9.07	15.80
F3 - Vermicompost @1.5 t /ha	0.91	4.36	8.11	14.06
F4 - Vermicompost @3.0 t /ha	0.98	4.52	9.02	15.72
F5-R.D.F.(25:50:N:P2O2 kg ha-1).	0.99	4.57	9.27	15.92
SE(m)±	0.01	0.03	0.18	0.17
CD (P=0.05)	0.03	0.08	0.53	0.49
B. Biofertilizers				
R0 -No seed treatment	0.88	4.25	7.96	13.64
R1 –*Rhizobium*	0.97	4.50	8.76	15.05
R2 –PSB	0.96	4.47	8.77	15.12
R3 -*Rhizobium* + PSB	1.03	4.61	9.06	16.25
SE(m)±	0.02	0.04	0.10	0.33
CD (P=0.05)	0.06	0.10	0.29	0.98
Interaction effect				
SE(m)±	0.03	0.04	0.23	0.46
CD (P=0.05)	NS	NS	NS	NS
General Mean	0.96	4.46	8.64	15.01

Leaf area per plant:-Data on mean leaf area plant^{-1} as influenced by different treatments are presented in Table 12. Leaf area plant^{-1} increased progressively with advancement in age up to 45 DAS and declined thereafter. The maximum leaf area was observed at 45 DAS (10.87 dm^2).

Effect of organic manure:- Data on leaf area presented in Table-12 revealed that leaf area plant^{-1} was significantly influenced by different treatments at all stages of crop growth. Highest leaf area was recorded in treat F_5- RDF (25:50 N:P_2O_5 kg ha^{-1}) which was significantly superior over F_1 (FYM @ 3 t ha^{-1}) and F_3 at all stages but it was on par with F_2 (FYM @6 t/ha and F_4 (vermicompost @ 3.0 t ha^{-1}). Similarly, treatment F_2 (FYM @ 6.0 t ha^{-1}) and F_4 were at par and recorded significantly higher leaf area over treatment F_1 (FYM @ 3.0 t ha^{-1}) and F_3 at all stages of observation. The increased leaf area might be due to more number of functional leaves and area available to crop as attempted by nutrient availability that resulted in more cell division and cell increment. These results are in conformity with the work done by Saxena *et al.* (1996).

Effect of biofertilizers:- Seed inoculation of biofertilizers was found significant at all stages of crop growth. Treatment R_3 (*Rhizobium* + PSB) generated significantly highest leaf area over rest of the treatments at all dates of growth stages. However, treatment R_1 and R_2 were on par with each other. Production of amino acids and growth promoting substance by *Rhizobium* and PSB resulted in improvement of plant growth and dry matter production might have increased the leaf area. A similar result was also obtained by Sripriaya Balachandran *et al.* (2005).

Interaction effect:- Interaction effects at every stage of crop growth were found no significant.

Table 12 Leaf area per plant (dm^2) as influenced by various treatments

Treatments	Days after sowing			
	15	30	45	At harvest
A. Organic Manure				
F_1 - FYM @ 3 t /ha	2.15	6.62	9.99	7.95
F_2 - FYM @ 6 t /ha	2.82	8.98	11.28	9.08
F_3 - Vermicompost @1.5 t /ha	2.28	6.86	10.01	7.75
F_4 - Vermicompost @3.0 t /ha	2.40	8.74	11.15	8.84
F_5-R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	2.95	8.90	11.98	9.77
SE(m)±	0.06	0.47	0.66	0.73
CD (P=0.05)	0.16	1.38	1.96	2.19
B. Biofertilizers				
R_0 -No seed treatment	2.11	6.85	10.06	7.93
R_1 –*Rhizobium*	2.49	8.02	10.89	8.75
R_2 –PSB	2.52	8.25	11.01	8.86
R_3 -*Rhizobium* + PSB	2.96	8.96	11.44	9.19
SE(m)±	0.08	0.29	0.26	0.27
CD (P=0.05)	0.22	0.85	0.76	0.72
Interaction effect				
SE(m)±	0.09	0.32	0.42	0.35
CD (P=0.05)	NS	NS	NS	NS
General Mean	2.52	8.02	10.87	8.68

Leaf area index:- The data on leaf area index are presented in table 13 Leaf area index plant^{-1} increased progressively up to 45 days and declined thereafter. The maximum leaf area index (3.61) was recorded at 45 DAS.

Effect of organic manure:- At all the growth stages, treatment F_5 (RDF) recorded maximum leaf area index plant^{-1} which was significantly more over F_1 (FYM @ 3 t ha^{-1}), F_2 and F_3 but at par with F_2 and F_4. Treatment F_2 (FYM @ 6 t ha^{-1}) and F_4 found superior in respect of leaf area index plant^{-1} over F_1 (FYM @ 3 t ha^{-1}) and F_3 at all stages of crop growth. Improvement in vegetative growth and leaf expansion could be ascribed to the beneficial effect of applied recommended dose of fertilizer. Similar results were also reported by Yakadri *et al.* (2002) and Rudreshappa and Halikatti (2002).

Effect of biofertilizers:- Seed inoculation of biofertilizer gave significant differences over no seed inoculation at all dates of observation Treatment R_3 (*Rhizobium* + PSB) produced maximum leaf area index at all stages of observation. The next best treatments were R_1 and R_2 which were significant over R_0 at all growth stages. Improvement in vegetative growth resulted in a more light interception and ultimately leaf area index increased.

Interaction effect:- Non-significant interaction effects were obtained at all stages of crop growth.

Table 13 Leaf area index as influenced by various treatments

Treatments	Days after sowing			
	15	30	45	At harvest
A. Organic Manure				
F_1 - FYM @ 3 t /ha	0.71	2.20	3.32	2.64
F_2 - FYM @ 6 t /ha	0.93	2.99	3.75	3.01
F_3 - Vermicompost @1.5 t /ha	0.76	2.28	3.32	2.57
F_4 - Vermicompost @3.0 t /ha	0.80	2.91	3.70	2.94
F_5-R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	0.98	2.96	3.98	3.24
SE(m)±	0.02	0.15	0.21	0.24
CD (P=0.05)	0.05	0.46	0.63	0.71
B. Biofertilizers				
R_0 -No seed treatment	0.70	2.28	3.35	2.63
R_1 –*Rhizobium*	0.83	2.67	3.63	2.90
R_2 –PSB	0.84	2.75	3.67	2.94
R_3 -*Rhizobium* + PSB	0.98	2.98	3.81	3.05
SE(m)±	0.02	0.09	0.08	0.08
CD (P=0.05)	0.07	0.28	0.25	0.27
Interaction effect				
SE(m)±	0.03	0.08	0.10	0.12
CD (P=0.05)	NS	NS	NS	NS
General Mean	0.83	2.66	3.61	2.8

Number of root nodules per plant:-Data on the mean number of root nodules plant^{-1} recorded at 30 DAS and 45 DAS of the crop as influenced by various treatments are presented in Table 14. It is obvious from the data that, the mean number of nodules plant^{-1} increased from 30 to (29.56) to 45 DAS (36.15).

Effect of organic manure:- It is seen from the data that the treatment F_5 (RDF) recorded significantly a maximum number of nodules plant^{-1} over rest of treatments under study. Treatment F_2 and F_4 were next best and also significant over F_1 (FYM @ 3 t ha^{-1}) and F_3 at all dates of observation. Application of recommended dose of fertilizer influenced the better root development and plant vigor which has enhanced the nitrogen fixing power of the plant by increasing the activity of nodulating bacteria and resulting in more number of nodules plant^{-1}. The results are in conformity with the findings of Shukla and Dixit (1996), Singh and Pareek (2003) and Owla *et al.* (2006).

Effect of biofertilizers:- The significant differences due to seed inoculation with biofertilizer was noticed at 30 and 45 DAS and seed inoculation with *Rhizobium* + PSB (R_3) treatment produced a significantly higher number of nodules plant^{-1} over rest of treatments at both the stages. However, R_1 and R_2 treatments were significant over R_0. Combined inoculation *Rhizobium* + PSB increased a number of root nodules plant^{-1} might be due to solubilization of insoluble phosphates by PSB and nitrogen provided through symbiotic fixation of atmospheric nitrogen and growth regulators produced by *Rhizobium*. Similar observations were also reported by

Balachandran and Nagarajan (2002), Khatkar *et al.* (2007) and Poonam *et al.* (2007).

Interaction effect:- Interaction effects were non-significant at all stages of crop growth.

Table 14 Number of root nodules per plant as influenced by various treatments.

Treatment	Days after sowing	
	30	45
A. Organic Manure		
F_1 - FYM @ 3 t /ha	27.15	32.81
F_2 - FYM @ 6 t /ha	29.79	37.46
F_3 - Vermicompost @1.5 t /ha	28.87	34.65
F_4 - Vermicompost @3.0 t /ha	30.97	36.89
F_5 -R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	31.02	38.94
SE(m)±	0.02	0.33
CD (P=0.05)	0.06	0.96
B. Biofertilizers		
R_0 -No seed treatment	27.80	31.23
R_1 –*Rhizobium*	29.56	36.16
R_2 –PSB	29.64	36.08
R_3 -*Rhizobium* + PSB	31.24	41.13
SE(m)±	0.09	1.23
CD (P=0.05)	0.26	3.67
Interaction effect		
SE(m)±	0.10	1.35
CD (P=0.05)	NS	NS
General Mean	29.56	36.15

Absolute growth rate for height (AGR):- Data on absolute growth rate for height as influenced by various treatments are presented in Table-15. Data were not statically analyzed. Inferences are drawn from mean values. The mean absolute growth rate for height was increased from 15 to 30 DAS (0.93) and 30 to 45 DAS (0.87) cm plant $^{-1}$ day $^{-1}$) and declined thereafter.

Effect of organic manure:- Treatment F_5 (RDF) recorded highest AGR for height (0.989 cm $plant^{-1}$ day^{-1}) followed by F_4 at all the stages except at 30-45 DAS, where F_2 gave highest AGR.

Effect of biofertilizers:- Treatment F3 gave highest AGR at 30-45 and 45- at harvest stage.

Table 15 Absolute growth rate for height (cm $plant^{-1}$ day^{-1}) as influenced by various treatments

Treatments	Days after sowing		
	15 – 30	30 – 45	45 – At harvest
A. Organic manure			
F_1 - FYM @ 3 t /ha	0.927	0.849	0.139
F_2 - FYM @ 6 t /ha	0.870	0.909	0.271
F_3 - Vermicompost @1.5 t /ha	0.943	0.857	0.303
F_4 - Vermicompost @3.0 t /ha	0.975	0.872	0.307
F_5 -R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	0.989	0.879	0.333
B. Biofertilizers			
R_0 -No seed treatment	0.931	0.862	0.158
R_1 –*Rhizobium*	0.944	0.812	0.270
R_2 –PSB	0.943	0.912	0.318
R_3 -*Rhizobium* + PSB	0.901	0.893	0.335
General Mean	0.936	0.871	0.270

Absolute growth rate for dry matter (g $plant^{-1}$ day^{-1}):- Data on absolute growth rate for dry matter as influenced by various treatments are presented in Table 16. Data were not statistically analyzed. Inferences are drawn on the basis of mean values. AGR values were highest at 45 harvests competed to other stages.

Effect of organic manure:- In general AGR values were higher in F5 (RDF) followed by F4 and F3. Application of recommended dose of fertilizer increased the plant height, leaf area $plant^{-1}$ and dry matter accumulation which might have resulted in increased absolute growth rate. Similar findings were also reported by Tomar *et al.* (1995) and Owla *et al.* (2006).

Effect of biofertilizers:-In general treatment R_3 (*Rhizobium* + PSB) recorded highest AGR followed by R_2 and R_1. Lowest values were observed in R_0 treatment. Combined inoculation of seed with *Rhizobium* and PSB improved the nitrogen and phosphorus status of soil, which enhanced the plant height and dry matter production ultimately absolute growth rate might have increased.

Table 16 Absolute growth rate for dry matter (g $plant^{-1}$ day^{-1}) as influenced by various treatments

Treatments	Days after sowing		
	15 – 30	30 – 45	45 – At harvest
A. Organic manure			
F_1 - FYM @ 3 t /ha	0.225	0.227	0.390
F_2 - FYM @ 6 t /ha	0.237	0.303	0.448
F_3 - Vermicompost @1.5 t /ha	0.229	0.250	0.396
F_4 - Vermicompost @3.0 t /ha	0.235	0.300	0.447
F_5 -R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	0.237	0.313	0.443
B. Biofertilizers			
R_0 -No seed treatment	0.224	0.247	0.379
R_1 –*Rhizobium*	0.235	0.283	0.419
R_2 –PSB	0.233	0.287	0.422
R_3 -*Rhizobium* + PSB	0.238	0.297	0.479
General Mean	0.233	0.279	0.425

Relative growth rate (RGR):- Data regarding the value of relative growth rate as influenced by various treatments periodically are shown in Table 17. Data were not statistically analyzed. Inferences are drawn on the basis of mean values.

Effect of organic manure:- No definite trend was noticed in respect of RGR values at all the stages. Application of RDF increased RGR values might be due to increasing in leaf area and dry matter. These results resemble the findings reported earlier by Owla *et al.* (2006).

Effect of biofertilizers:- In general treatments R_3, R_2, and R_1 produced higher RGR values compared to R_0 especially during 30-45 and 45 at harvester *Rhizobium* inoculation fixes nitrogen through nodules of the plant whereas PSB solubilizes native P rendering more phosphorus to soil, which enhanced the plant height and more dry matter accumulation ultimately RGR might have increased.

Table 17 Relative growth rate (g g^{-1} day^{-1}) as influenced by various treatments

Treatments	Days after sowing		
	15 – 30	30 – 45	45 – At harvest
A. Organic manure			
F_1 - FYM @ 3 t /ha	0.103	0.039	0.038
F_2 - FYM @ 6 t /ha	0.104	0.047	0.037
F_3 - Vermicompost @1.5 t /ha	0.105	0.042	0.037
F_4 - Vermicompost @3.0 t /ha	0.103	0.046	0.037
F_5 -R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	0.102	0.047	0.036
B. Biofertilizers			
R_0 -No seed treatment	0.106	0.042	0.036
R_1 –*Rhizobium*	0.103	0.044	0.036
R_2 –PSB	0.104	0.045	0.036
R_3 -*Rhizobium* + PSB	0.101	0.045	0.039
General Mean	0.103	0.044	0.037

Yield attributes:- Data in respect of postharvest studies viz number of pods plant^{-1}, the weight of gram plant^{-1} and test weight as affected by various treatments are shown in table No.18. Mean value of a number of pods plant^{-1}, weight of grain plant-1 and test weight were 21.78, 7.34 and 38.42 respectively.

Number of pods per plant:- Data in table 18 revealed that number of pods plant^{-1} was affected significantly due to different treatments and the mean number of pods plant^{-1} was 21.78.

Effect of organic manure:- Organic manure treatments significantly influenced the number of pods plant^{-1}. Treatment F_5 (RDF) produced significantly the highest number of pods plant^{-1} and was significantly superior over F_1 (FYM @ 3 t ha^{-1}) and F_3, but at par with F_2 and F_4. Similarly, treatment F_2 and F_4 recorded significantly higher number of pods plant^{-1} over F_1 (FYM @ 3t ha^{-1}) and F_3. Application of RDF recorded significantly more number of pods plant^{-1} over rest of the treatments. Phosphorus plays vital role productive phase of the crop. It enhances carbohydrate synthesis and rate of metabolic activities through increased leaf area and its efficient utilization in protein synthesis resulting in more number of developed pods plant^{-1}.These results are in conformity with the findings of Rajkhowa (2002), Rudreshappa and Halikatti (2002), Yakadri *et al.* (2002) and Singh and Pareek (2003).

Effect of biofertilizers:- The seed inoculation of biofertilizer treatment R_3 (Rhizobium + PSB) produced significantly highest number of pods plant^{-1} over R_0 and R_1. Treatment R_2 and R_1 were next best and significantly superior to R_0. The combined inoculation of *Rhizobium* + PSB has enhanced the root growth and root nodulation which in turn housed a maximum number of developed pods plant^{-1}. These results are in conformity with the findings of Shukla and Dixit (1996), Saraf *et al.* (1997) and Sripriaya Balachandran *et al.* (2005).

Interaction effect:- Interaction effect at every stage of crop growth was found no significant.

Weight of grains per plant:- Data pertaining to the weight of grains plant^{-1} was given in Table 18 It was observed that, the weight of grains plant^{-1} significantly influenced due to various treatments. The mean weight of grains plant^{-1} was 7.34 gm.

Effect of organic manure:- Treatments of organic manure significantly differed in respect of weight of grain plant^{-1}. Treatment F_5 (RDF) produced a significantly higher weight of grains plant^{-1} over treatment F_1 (FYM @ 3 t ha^{-1}), and F_3, but at par with F_2 and F_4 (vermicompost @ 3 t ha^{-1}). Treatment F_2 and F_4 was also significantly superior over treatment F_1 (FYM @ 3 t ha^{-1}) and F_3. Weight of grains plant^{-1} increased might be due to application of recommended dose of fertilizer influenced the yield attributes through the production of photosynthesis and their increased translocation to reproductive parts. Similar result have also been reported by Saxena *et al.* (1996) and Rudreshappa and Halikatti (2002)

Effect of biofertilizers:- Seed inoculation of biofertilizer had significantly influence on the weight of grains plant^{-1}. Treatment R_3 (*Rhizobium* + PSB) recorded the highest weight of grain plant^{-1} and found significantly superior to R_0 and R_2. However, treatment R_0 and R_2 was also at par. Combined inoculation of *Rhizobium* and PSB increased the grain yield plant^{-1} might be due to plant synthesizes more photosynthates and the storage organ (seed) was better developed.

Interaction effect:-Interaction effect at every stage of crop growth was found no significant.

Test weight (gm):- Data regarding the test weight as influenced by organic manure and seed inoculation of biofertilizer are given in Table 18

Effect of organic manure:- Organic manure treatment significantly influenced the test weight. Treatment F_5 (RDF) recorded maximum test weight which was on par with R_2 and R_4 and significantly superior over F_1 (FYM @ 3 t ha^{-1}) and F3. It might be due to efficient grain filling by better translocation of photosynthates by application of recommended dose of fertilizer resulted in improved test weight of grains. Saxena (1996) and Suman *et al.* (2006) reported similar findings.

Effect of biofertilizers:- Seed inoculation of biofertilizer treatment significantly influenced the test weight. Treatment R_3 (*Rhizobium* + PSB) produced highest test weight over R_0, but at par with R_1 and R_2. Under inoculated treatments, plant synthesizes more photosynthates and the storage organ was better developed which might have increased the test weight. Similar results were also obtained by Shukla and Dixit (1996), Singh and Pareek (2003).

Interaction effect:-Interaction effect at every stage of crop growth was found no significant.

Table18 Yield attributes as influenced by various treatments

Treatments	No. of pods plant^{-1}	Grain wt. plant^{-1} (gm)	Test wt. (1000) grains
A. Organic Manure			
F_1 - FYM @ 3 t /ha	20.72	6.46	38.32
F_2 - FYM @ 6 t /ha	23.90	7.41	38.52
F_3 - Vermicompost @1.5 t /ha	18.68	7.18	37.94
F_4 - Vermicompost @3.0 t /ha	21.49	7.52	38.22
F_5-R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	24.15	8.13	39.10
SE(m)±	0.88	0.29	0.34
CD (P=0.05)	2.62	0.84	1.00
B. Biofertilizers			
R_0 -No seed treatment	20.13	6.42	37.83
R_1 –*Rhizobium*	21.14	7.62	38.42
R_2 –PSB	21.52	7.19	38.41
R_4 -*Rhizobium* + PSB	23.83	8.12	39.02
SE(m)±	0.74	0.33	0.21
CD (P=0.05)	2.20	0.98	0.60
Interaction effect			
SE(m)±	1.04	0.66	0.36
CD (P=0.05)	NS	NS	NS
General Mean	21.78	7.34	38.42

Yield studies:- Data on grain yield, straw yield, biological yield (kg ha^{-1}) and harvest index (%) as influenced by various treatments are shown in Table 19 and graphically illustrated in Fig.5. The mean grain and straw yield of black gram was 1258 and 2163 kg ha^{-1}, respectively. Similarly the mean biological yield and harvest index was3421 kg /ha and 36.71 kg /ha.

Grain yield:- Data on grain yield, straw yield and biological yield (kg ha^{-1}) and harvest index (%) as influenced by various treatments and are presented in table 19 and graphically illustrated in fig 10. The mean grain and straw yield of a black gram was 1245 kg ha^{-1} and 2163 kg ha^{-1} respectively. Similarly, the average biological yield and harvest index was 3405 kg ha^{-1} and 36.56 respectively.

Effect of organic manure:- The differences in grain yield due to various organic manure treatments were significant. The data on grain yield presented in table 19 revealed that highest grain yield 1368 kg ha^{-1} was obtained in treatment F_5 (RDF) which was at par with treatment F_2 (FYM @ 6 t kg ha^{-1}) and significantly superior to rest of the treatments under study. The percentage increase in grain yield in treatment F_5 (RDF) was 21.60, 6.21, 14.67 and 9.44 % over F1, F2, F3 and F4 treatments respectively. Similarly, treatment F2 and F4 were next best and was at par with each other. Treatment F1 and F3 recorded lower yields and gave at par yields. Similar results were also reported by many workers viz., Yakadri *et al.* (2002), Rajkhowa *et al.* (2002) and Satish kumar *et al.* (2003) and reported that the application of RDF significantly increased the grain and stover yield of green gram over vermicompost @ 2.5 t ha^{-1} and FYM @ 2.5 t ha^{-1}.

Effect of biofertilizers:- Seed inoculation treatments were significant over no inoculation. Among the seed inoculation treatments, treatment R_3 (*Rhizobium* + PSB) recorded highest grain yield (1321 kg ha^{-1}) which was at par with treatment R_1 and R_2. *Rhizobium* inoculation fixes nitrogen through nodules of the plant whereas PSB solubilizes native P rendering more phosphorus to the soil solution. Thus combined inoculation of seeds with *Rhizobium* and PSB improved N and P status of soil and ultimately increased N and P uptake which enhanced the yield of the crop. These results are in conformity with the findings of Balachandran and Nagarajan (2002) and Singh and Pareek (2003).

Interaction effect:-Interaction effects at various treatment combinations were found not significant.

Straw yield:- Straw yield (kg ha^{-1}) of black gram was significantly affected by organic manure and biofertilizer treatments. Mean straw yield was 2163 kg ha^{-1}.

Effect of organic manure:- Maximum straw yield (2330 kg ha^{-1}) was recorded in treatment F_5 (RDF) which was at par with treatment F2 and F_4, and gave significantly higher yield over F_1 and F3 treatments. Similarly, F2 and F4 gave at par straw yield and found significantly superior over F_1 and F3. The increase in straw yield with application RDF might have attributed to the higher photosynthetic activity in black gram plant leading to a better supply of carbohydrates resulted in more number of branches and dry matter. Similar results were also obtained by Rajender Kumar *et al.* (2002).

Effect of biofertilizer:- Treatment R_3 (*Rhizobium* + PSB) gave highest straw yield which was at par with R_1 and R_2. All the three treatments of seed inoculation recorded significantly higher straw yield over no seed treatment R_0. Increase in straw yield might be due to the cumulative influence of improvement in vegetative growth of the crop through the atmospherically nitrogen fixed in the root nodules. Ghosh and Joseph (2006), Khatkar *et al.* (2007) and Yadav *et al.* (2007**)** also obtained similar results.

Interaction effect:- Interaction effects were not significant

Biological yield:- Table 19 indicated that biological yield of black gram differed significantly due to different treatments and mean biological yield was 3405 kg ha^{-1}

Effect of organic manure:- Maximum biological yield (3698 kg ha^{-1}) was observed in treatment F_5 (RDF) which was significantly superior over rest of the treatments except F2. Treatment F_2 and F_4 was at par and produced significantly higher biological yield than F1 and F3, the latter two were being at par. Nitrogen being a constituent of protein, enzymes chlorophyll, which helps in developing better infrastructure through increased branching and vegetative growth to have more reproductive site due to delayed senescence of leaves. Thus photosynthesis takes for a longer period resulting in greater availability of assimilates for improving dry matter accumulation, yield components, and yield. Similar results were also obtained by Abraham and Lal (2003).

Effect of biofertilizer:- Seed inoculation with *Rhizobium* + PSB (R_3) gave highest biological yield and which at par with treatment R_1 and significantly superior over R_0 and R_2. Similarly, R_1 and R_2 gave significantly more biological yield than R_0.This might be due increased dry matter production, yield components, and yield.

Interaction effect:- None of the interaction was found significant.

Harvest index:-Data on harvest index (%) presented in Table 19. Data were not analyzed statistically and hence inferences are drawn on the basis of mean values. The mean harvest index was 36.56 per cent.

Effect of organic manure:- The highest harvest index value was found in F3 followed by F_5 (RDF). In rest of the treatments (F1, F2 and F4), the harvest index values were more or less equal.

Effect of biofertilizer:- *In* general the harvest index values in seed inoculation treatment (R_1, R_2 and R3) were comparatively higher than no seed inoculation treatment (R_0)

Table 19 Grain yield, straw yield, biological yield and harvest index as influenced by various treatments

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
A. Organic Manure				
F_1 - FYM @ 3 t /ha	1125	1960	3085	36.46
F_2 - FYM @ 6 t /ha	1288	2270	3558	36.20
F_3 - Vermicompost @1.5 t /ha	1193	1970	3163	37.71
F_4 - Vermicompost @3.0 t /ha	1250	2285	3535	35.36
F_5-R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	1368	2330	3698	36.99
SE(m)±	33	48	52	--
CD (P=0.05)	93	149	160	--
B. Biofertilizers				
R_0 -No seed treatment	1121	1998	3119	35.94
R_1 –*Rhizobium*	1252	2217	3469	36.09
R_2 –PSB	1285	2156	3414	37.63
R_3 -*Rhizobium* + PSB	1321	2281	3602	36.67
SE(m)±	29	53	58	--
CD (P=0.05)	83	154	168	--
Interaction effect				
SE(m)±	67	88	102	--
CD (P=0.05)	NS	NS	NS	--
General Mean	1245	2163	3405	36.56

Quality studies:- Protein content and protein yield:- Data pertaining to the protein content and protein yield of a black gram as influenced by various treatments are presented in table 20.

Effect of organic manure:-- Data presented in table 20 revealed that the highest protein content (22.62) was recorded in treatment (RDF) and found significantly superior over F1 and F_3, but at par with treatment, F_2 and F_4. Treatment F_1 and F3 recorded the lowest protein content in black gram. Treatment F_5 (RDF) recorded maximum protein yield as compared to the rest of treatments. Lowest protein yield was recorded with treatment F_3 (vermicompost @ 1 t ha^{-1}). Application RDF increases the protein content and protein yield might be the due greater availability of nitrogen and phosphorus. The phosphorus influences photosynthesis, biosynthesis of protein and phospholipids, nucleic acid synthesis, membrane transport and cytoplasmic streaming. These results are in conformity with the findings of Shukla and Dixit (1996), Rudreshappa and Hallikatti (2002) and Singh and Pareek (2003).

Effect of biofertilizer:-The protein content and protein yield of blackgram was significantly influenced by seed inoculation of biofertilizer. Treatment R_3 (*Rhizobium* + PSB) recorded maximum protein content and protein yield over rest of the treatment. It might be due to higher grain yield and nitrogenase activity under *Rhizobium* + PSB inoculation which ultimately increased the N uptake in the grain which resulted in higher protein content. Similar results were also obtained by Shukla and Dixit (1996) and Singh and Pareek (2003).

Interaction effect:-Interaction effect at every stage of crop growth was found no significant

Table 20 Protein content (%) and protein yield (kg ha^{-1}) as influenced by various treatments

Treatments	Protein Content (%)	Protein yield (kg ha^{-1})
A. Organic Manure		
F_1 - FYM @ 3 t /ha	19.78	233.66
F_2 - FYM @ 6 t /ha	21.97	285.40
F_3 - Vermicompost @1.5 t /ha	19.55	220.10
F_4 - Vermicompost @3.0 t /ha	21.98	281.27
F_5 -R.D.F.(25:50:N:P_2O_2 kg ha^{-1}).	22.62	316.87
SE(m)±	0.30	13.92
CD (P=0.05)	0.89	41.14
B. Seed inoculation of biofertilizer		
R_0 -No seed treatment	18.18	214.16
R_1 –*Rhizobium*	22.53	280.79
R_2 –PSB	21.76	273.65
R_3 -*Rhizobium* + PSB	23.10	305.83
SE(m)±	0.49	5.77
CD (P=0.05)	1.55	17.32
Interaction effect		
SE(m)±	0.68	7.18
CD (P=0.05)	NS	NS
General Mean	21.27	267.97

Nutrient uptake by Blackgram:- Nitrogen content in grain and straw:-Effect of organic manure:-The data presented in table 21 showed that organic manure treatment significantly influenced nitrogen content in grain and straw by blackgram. Treatment F_5 (RDF) recorded significantly higher nitrogen content in grain (3.52 %) and straw (0.6 %) over F_1 and F_3, but at par with F_2 and F_4 (vermicompost @ 3 t ha^{-1}). However, treatment F_2 (FYM @ 6.0 t ha^{-1}) F_2 and F_4 were at par and significant over F_1 and F_3. Recommended dose of fertilizer might have improved the nutrient availability status resulting in greater uptake of nitrogen and similar result also obtained by Singh and Pareek (2003) and Rudeshappa and Hallikatti (2002).

Effect of biofertilizer:-Nitrogen content in grain and straw was significantly influenced by seed inoculation of biofertilizer. Treatment R_3 (*Rhizobium* + PSB) recorded significantly higher nitrogen content in grain and straw over R_0 and R_2. However, treatment R_1 was also found significant over R_0 but, at par with R_2. Dual inoculation of *Rhizobium* + PSB recorded the maximum nitrogen content in grain and straw and found superior to control, PSB and *Rhizobium* alone. Nitrogen and phosphorus are major plant nutrient and combined inoculation of nitrogen fixer and PSM benefit the plant than either group of organism alone. This might be due to the fact *Rhizobium* inoculation increased the root nodulation through better root development and more nutrient availability, resulting in better absorption and utilization of all plant nutrients, thus resulting in more nitrogen and phosphorus content in seed and straw. Similar results were also obtained by Singh and Pareek (2003).

Interaction effect: -Interaction effect was found no significant.

Nitrogen uptake (kg ha^{-1}):- Data in respect of uptake of N by grain, straw and total uptake by the plant are presented in table 21.

Effect of organic manure:- Data presented in table 21 revealed that total uptake of N by the grain, straw and plant as a whole was significantly influenced by organic manure treatments. Treatments F_5 (RDF) recorded significantly higher N uptake by grain, straw and total uptake by the crop over rest of the treatments. Similarly, treatment F_2 and F_4 were next best and found significantly superior over treatment F_1 and F_4. Higher dry matter production due to increased availability of nutrients from the application of recommended dose of fertilizer might have increased the nitrogen uptake. Similar results were also obtained by Rajkhowa *et al.* (2002) Rudreshappa and Hallikatti (2002) and Rajender kumar *et al.* (2002).

Effect of biofertilizer:-Seed inoculation of bio-fertilizer treatments differed significantly in respect of uptake of N by Blackgram maximum uptake of N by grain, straw, and total uptake was found in treatment R_3 (Rhizobium + PSB) which was significantly superior over rest of the treatments. Treatment R_1 and R_2 was found comparable to each other and gave significantly higher uptake than treatment R_0. It was due to higher grain yield and nitrogenase activity under combined inoculation of *Rhizobium* + PSB which ultimately increased the N uptake in grain and straw. These results confirm the findings as obtained by Shukla and Dixit (1996) and Balyan *et al.* (2002).

Effect of interaction:-Interaction effect at every stage of crop growth was found not significant.

Phosphorus content in grain and straw of black gram:- The data regarding phosphorus content in grain and straw of black gram is presented in Table 22.

Effect of organic manure:- Organic manure treatments had a significant effect on phosphorus content in grain and straw of black gram.

Table 21 Nitrogen content and its uptake as influenced by various treatments

Treatments	N content (%)		N uptake (kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
A. Organic Manure					
F1 - FYM @ 3 t /ha	3.22	0.44	38.06	8.62	46.68
F2 - FYM @ 6 t /ha	3.48	0.56	45.34	12.71	58.05
F3 - Vermicompost @1.5 t /ha	3.20	0.46	35.90	9.46	45.36
F4 - Vermicompost @3.0 t /ha	3.48	0.52	43.43	11.74	56.17
F5-R.D.F.(25:50:N:P2O2 kgha-1).	3.52	0.60	50.39	12.98	63.37
SE(m)±	0.08	0.04	1.65	0.62	1.86
CD (P=0.05)	0.23	0.11	4.82	1.81	5.57
B. Seed inoculation of biofertilizer					
R0 -No seed treatment	2.93	0.42	34.96	8.61	43.51
R1 –*Rhizobium*	3.56	0.53	44.60	11.75	56.35
R2 –PSB	3.45	0.51	43.47	10.73	45.20
R3 -*Rhizobium* + PSB	3.68	0.62	48.61	14.14	62.75
SE(m)±	0.06	0.03	1.22	1.02	1.65
CD (P=0.05)	0.17	0.03	3.64	3.00	4.93
Interaction effect					
SE(m)±	0.09	0.05	1.34	1.25	1.68
CD (P=0.05)	NS	NS	NS	NS	NS
General Mean	3.38	0.52	42.72	11.30	53.04

Treatment F_5 (RDF) recorded significantly highest phosphorus content in grain (1.33 %) and straw (0.59 %) over F_1 and F_3, but found at par with F_2 and F_4. However, treatment F_2 and F_4 were also recorded significantly highest phosphorus content in grain and straw over F_1 and F_3. It might be due improvement in nutrient content in soil solution in available forms which resulted in more uptake of phosphorus. Similar results were also obtained by Singh and Pareek (2003).

Effect of biofertilizer:-Seed inoculation with biofertilizers had a significant effect on phosphorus content in grain and straw of blackgram. Treatment R_1, R_2 and R_3 were at par and recorded significantly higher phosphorus content in grain and straw over R_0. The favorable effect of combined inoculation of *Rhizobium* and PSB could be attributed to synergistic interaction among the phosphate solubilizing microorganism and *Rhizobium* which leads to increased availability of nutrients. The results are in close conformity as reported by Singh and Parrek (2003) and singh *et al.* (2004).

Interaction effect:- Interaction effect at every stage of crop growth was found not significant.

Phosphorus uptake (kg ha^{-1}):- Data in respect of uptake of phosphorus by grains, straw and total uptake by the plant is presented in table 22.

Effect of organic manure:-The data presented in Table 22 showed that organic manure treatments significantly influenced P uptake by the grain, straw and total uptake by the crop. Treatment F_5 (RDF) recorded significantly higher P uptake by grain (18.63 kg ha^{-1}), straw (13.74 kg ha^{-1}) and its total uptake (32.37 kg ha^{-1}) by the crop over rest of the treatments. Treatment F_2 (FYM @ 6 t ha^{-1}) and F_4 were also recorded significantly higher P uptake by grain, straw and total uptake over F_1 and F_3. The P uptake increased with RDF application it was due to higher dry matter accumulation, N fixation and accumulation of phosphorus by better development of root nodules. Similar results were obtained **by** Shukla and Dixit (1996). Rudreshappa and Halikati (2002) and Sheoran *et al.* (2008).

Effect of biofertilizer:-Seed inoculation of biofertilizer treatments had a significant effect on uptake of P by crop. Treatment R_3 (*Rhizobium* + PSB) recorded significantly higher phosphorus uptake by grain (17.17 kg ha^{-1}), straw (13.45 kg ha^{-1}) and its total uptake (30.62 kg ha^{-1}) over rest of the treatments. Combined seed inoculation of *Rhizobium* + PSB increased P uptake. It was due to higher dry matter accumulation and greater availability of phosphorus which ultimately resulted in an increase in P uptake. Similar findings were also reported by Singh *et al.* (2004) and Jain *et al.* (2007).

Interaction effect:-Interaction effect at every stage of crop growth was found not significant.

Table 22 Phosphorus content and its uptake as influenced by various treatments

Treatments	P content (%)		P uptake (Kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
A. Organic Manure					
F1 - FYM @ 3 t /ha	0.99	0.50	11.94	9.80	21.74
F2 - FYM @ 6 t /ha	1.22	0.52	15.90	11.80	27.77
F3 - Vermicompost @1.5 t /ha	1.08	0.47	12.16	9.25	21.41
F4 - Vermicompost @3.0 t /ha	1.32	0.57	16.65	13.02	29.67
F5-R.D.F.(25:50:N:P2O2 kgha-1)	1.33	0.59	18.63	13.74	32.37
SE(m)±	0.05	0.03	0.82	0.54	0.95
CD (P=0.05)	0.14	0.08	2.52	1.60	2.82
B. Biofertilizers					
R0 -No seed treatment	1.03	0.48	12.90	9.84	22.74
R1 –*Rhizobium*	1.27	0.53	15.91	11.30	27.21
R2 –PSB	1.25	0.54	15.75	11.36	27.11
R3 -*Rhizobium* + PSB	1.30	0.59	17.17	13.45	30.62
SE(m)±	0.02	0.02	1.95	0.94	0.96
CD (P=0.05)	0.06	0.06	5.58	2.80	2.88
Interaction effect					
SE(m)±	0.03	0.04	2.03	1.14	1.12
CD (P=0.05)	NS	NS	NS	NS	NS
General Mean	1.20	0.53	15.22	11.50	26.74

Potassium content in grain and straw of blackgram:-Data in respect of potassium content in grain and straw is presented in table 23

Effect of organic manure:- Data presented in Table 23 showed that organic manure treatments significantly influenced potassium content in grain and straw by blackgram. Treatment F_5 (RDF) recorded significantly higher potassium content in grain (0.52 %) and straw (1.32 %) over rest of the treatments. However, F_2 (FYM @ 6 t ha^{-1}) and F_4 recorded significantly higher potassium content in grain and straw over F_1 and F_3.

Effect of biofertilizer:-Potassium content in grain and straw was significantly influenced by seed inoculation of biofertilizer. Treatment R_1, R_2 and R_3 was at par and recorded higher potassium content in grain and straw over R_0. However, treatment R_1 and R_2 were found at par with each other.

Potassium uptake (kg ha^{-1}):- Data in respect of K uptake by grain, straw and total uptake by the plant is presented in table 23.

Effect of Organic manure:- Organic manure treatments had a significant effect on uptake of K by grain straw and total uptake. Treatment F_5 (RDF) recorded higher K uptake by grain (7.17 kg ha^{-1}), straw (30.76 kg ha^{-1}) and total uptake (37.93 kg ha^{-1}) over rest of the treatments. However, treatment F_2 (FYM @ 6 t ha^{-1}) and F_4 recorded significantly higher K uptake by grain, straw and total uptake over F_1 and F_2.. Higher dry matter production due to increased availability of nutrients from the

RDF might have enhanced the K uptake. These results are in conformity with the findings of Mathan *et al.* (1996).

Effect of biofertilizer:-Seed inoculation of biofertilizer treatments had a significant effect on uptake of K by crop. Treatment R_3 (*Rhizobium* +PSB) recorded significantly higher K uptake (33.84 kg ha^{-1}) over rest of the treatments. However, treatment R_1 and R_2 were at par with each other and significantly superior to R_0.

Interaction effect:-Interaction effects were no significant at all stages of crop growth.

Table 23 Potassium content and its uptake as influenced by various treatments

Treatments	K content (%)		K uptake (Kg ha^{-1})		
	Grain	Straw	Grain	Straw	Total
A. Organic Manure					
F1 - FYM @ 3 t /ha	0.41	1.05	4.92	20.58	25.20
F2 - FYM @ 6 t /ha	0.49	1.21	6.38	27.46	33.84
F3 - Vermicompost @1.5 t /ha	0.40	1.04	4.50	20.48	24.98
F4 - Vermicompost @3.0 t /ha	0.47	1.09	6.03	26.87	32.90
F5 -R.D.F.(25:50:N:P2O2 kg ha-1)	0.52	1.32	7.17	30.76	37.93
SE(m)±	0.03	0.02	0.37	1.08	1.33
CD (P=0.05)	0.08	0.07	1.10	3.06	3.82
B. Biofertilizers					
R0 -No seed treatment	0.43	1.12	5.16	22.96	28.12
R1 –*Rhizobium*	0.46	1.16	5.76	25.72	31.48
R2 –PSB	0.46	1.16	5.80	24.41	30.21
R3 -*Rhizobium* + PSB	0.49	1.20	6.47	27.37	33.84
SE(m)±	0.01	0.018	0.18	0.82	1.02
CD (P=0.05)	0.03	0.053	0.52	2.42	3.01
Interaction effect					
SE(m)±	0.04	0.03	0.23	0.92	1.25
CD (P=0.05)	NS	NS	NS	NS	NS
General Mean	0.46	1.16	5.81	25.17	38.9

Available nitrogen, phosphorus and potassium in the soil after harvest:- The data respect of available nitrogen, phosphorus and potassium in the soil after harvest of the crop as influenced by various treatments are presented in table 24 and graphically depicted in Fig.6.

Available nitrogen (kg ha^{-1}):-Effect of organic manure:- Available nitrogen in the soil was significantly improved by the organic manure treatments. Highest available nitrogen (156.1 kg ha^{-1}) was observed in F_2 (FYM@ 6 t ha^{-1}) and built up of 24.3 kg ha^{-1} was observed which was significantly superior to rest of the treatments. Lowest available nitrogen (205.4 kg ha^{-1}) was recorded by treatment F_3 (Vermicompost @ 1.5 t ha^{-1}) than the remaining treatment.

Effect of biofertilizer:-Available nitrogen in the soil was significantly improved due to seed inoculation of biofertilizer. Treatment R_3 (*Rhizobium* + PSB) gave significantly superior soil built up N over rest of the treatments. Similarly, treatment R_1 and R_2 recorded significantly higher available nitrogen over R_0.

Interaction effect:-Interaction effect at every stage of crop growth was found not significant.

Available phosphorus (kg ha^{-1}):-Effect of organic manure:- Available phosphorus in soil was significantly improved by organic manure treatments. The highest phosphorus (25.4kg ha^{-1}) was observed in treatment F_2 (FYM @ 6 t ha^{-1}) and built up to 8.6 kg ha^{-1} was observed which was significantly superior over rest of the treatments. Lowest available phosphorus (17.2 kg ha^{-1}) was recorded by F_1 (FYM @ 3 t ha^{-1}).

Effect of biofertilizer:-Available phosphorus in the soil was significantly improved due to seed inoculation of biofertilizer. Treatment R_3 (*Rhizobium* + PSB) recorded significantly superior over R_0, R_1 and R_2.

Interaction effect:-Interaction effect at every stage of crop growth was found no significant.

Available Potassium (kg ha^{-1}):-Effect of organic manure:- Available potassium in soil was significantly influenced by organic manure treatments. The highest available potassium (168.0 kg ha^{-1}) was observed in treatment F_2 (FYM @ 6 t ha^{-1}) built up to 7.3 kg was observed which was significantly superior to rest of the treatments. Lowest available potassium (161.4 kg ha^{-1}) was recorded by F_1 (FYM @ 3 t ha^{-1}).

Effect of biofertilizer:-Available potassium in soil was significantly influenced due to seed inoculation of biofertilizer. The highest available potassium (324.9 kg ha^{-1}) was observed in R_3 (*Rhizobium* + PSB) which were significantly superior over rest of the treatments.

Interaction effect:-Interaction effects were absent.

Table 24 Available N, P_2O_5, K_2O status in soil after harvest as influenced by various treatments at harvest of crop

Treatments	Available nutrients (kg ha-1)		
	N	P2O5	K2O
A. Organic manure			
F1 - FYM @ 3 t /ha	147.9	17.2	161.4
F2 - FYM @ 6 t /ha	156.1	25.4	168.0
F3 - Vermicompost @1.5 t /ha	147.4	18.4	163.5
F4 - Vermicompost @3.0 t /ha	153.9	22.7	167.8
F5 -R.D.F.(25:50:N:P2O2 kg ha-1)	152.7	22.4	166.5
SE(m)±	0.55	0.54	0.23
CD (P=0.05)	1.62	1.60	0.68
B. Biofertilizers			
R0 -No seed treatment	148.5	17.5	163.0
R1 –*Rhizobium*	151.6	20.2	165.2
R2 –PSB	150.9	20.0	165.1
R3 -*Rhizobium* + PSB	154.5	22.6	165.7
SE(m)±	0.48	0.42	0.21
CD (P=0.05)	1.45	1.47	0.62
Interaction effect			
SE(m)±	0.48	0.88	0.36
CD (P=0.05)	NS	NS	NS
General Mean	151.5	20.7	165.1
Initial value	131.8	16.8	160.7

Economics of the treatments:- Data in regarding gross monetary return, net monetary return and B:C ratio are presented in Table 25 and graphically depicted in Fig.7. The mean grass monetary return, net monetary return and B: C ratio were 59770, 33111 Rs ha $^{-1}$ and 2.26 respectively.

Gross monetary return:-Effect of organic manure:-The highest gross monetary returns of Rs.65190 were received in treatment F_5 (RDF) which was significantly more than rest of the treatment. Treatment F2 and F4 were at par and found significantly superior to F1. Treatment F1 and F3 recorded lower gross monetary return were comparable to each other.

Effect of biofertilizer:-Seed inoculation treatment (R_1, R_2 and R_3) recorded significantly higher gross return over no seed treatment (R0). Treatment R_3 (*Rhizobium* + PSB) gave maximum gross monetary returns; however, it was at par with R_1 and R_2.

Net monetary returns:- Data on net monetary returns presented in table 25 revealed that net monetary returns were

significantly influenced by organic manure and seed inoculation treatments. The mean net monetary returns were Rs.33111 ha^{-1}.

Effect of organic manure:- Organic manure treatments add significant effect found net monetary returns. Treatment F_5 (RDF) generated highest net monetary returns (Rs.42490 $^{ha-1}$) which were significantly higher than the rest of the treatments. Application of FYM @ 6 t (F2) was found next best and was significantly superior to F1, F3 and F4 treatments. Treatment F4 (vermicompost @ 3.0 t ha^{-1}) despite its better effect on growth and yield characters also recorded better yields, gave lowest net monetary returns due to more cost of cultivation attributed through higher prices of vermicompost in the market.

Effect of biofertilizer:-Treatment R_1, R_2 and R_3 (*Rhizobium* + PSB) found significantly superior to R_0 in respect of net monetary returns. Among the seed inoculation treatments, R_3 gave highest net monetary returns but it was at par with R_1 and R_2.

Interaction effect:-Interaction effect at every stage of crop growth was found not significant.

Benefit to cost ratio: - Data on benefit-cost ratio are presented in Table 25. The mean benefit-cost ratio was 2.26. Data were not statistically analyzed. Inferences are drawn from the mean value.

Effect of organic manure:- Highest B:C ratio of 2.87 was obtained in treatment F_5 (RDF) followed by treatment F_1 and F2. Lowest B: C ratio was recorded in treatment F_4 (vermicompost @ 3.0 t ha^{-1}).

Effect of biofertilizer:-All seed inoculation treatment (R_1, R_2 and R_3) recorded higher values of benefit to cost ratio over no seed treatment (R_0). Treatment R_3 (*Rhizobium* + PSB) was best among the inoculation treatment.

Table 25 Gross monetary returns, net monetary returns and benefit cost ratio as influenced by various treatments

Treatments	Gross monetary returns (Rs.ha-1)	Net monetary returns (Rs.ha-1)	Benefit cost ratio
A. Organic Manure			
F1 - FYM @ 3 t /ha	54500	30600	2.28
F2 - FYM @ 6 t /ha	61672	34770	2.29
F3 - Vermicompost @1.5 t /ha	57492	30603	2.14
F4 - Vermicompost @3.0 t /ha	60000	27100	1.82
F5 -R.D.F.(25:50:N:P2O2 kg ha-1)	65190	42490	2.87
SE(m)±	948	823	-
CD (P=0.05)	2838	2453	-
B. Biofertilizers			
R0 -No seed treatment	54324	30028	2.24
R1 –*Rhizobium*	60088	33328	2.25
R2 –PSB	61540	33780	2.22
R3 -*Rhizobium* + PSB	63124	35304	2.27
SE(m)±	951	860	-
CD (P=0.05)	2840	2542	-
Interaction effect			
SE(m)±	1012	867	-
CD (P=0.05)	NS	NS	NS
General Mean	59770	33111	2.26

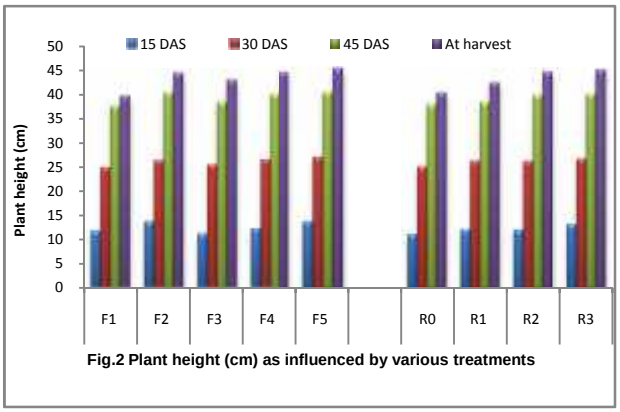

Fig.2 Plant height (cm) as influenced by various treatments

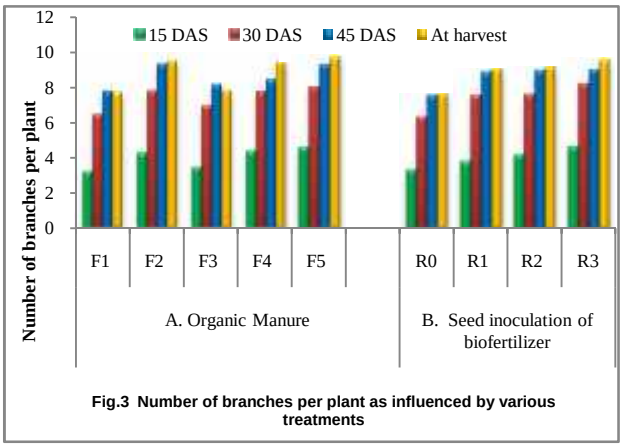

Fig.3 Number of branches per plant as influenced by various treatments

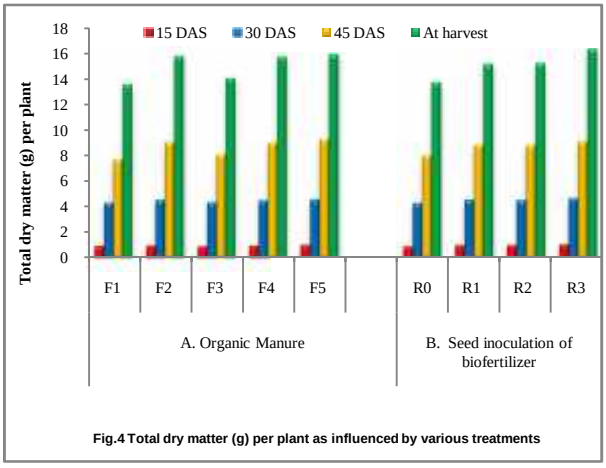

Fig.4 Total dry matter (g) per plant as influenced by various treatments

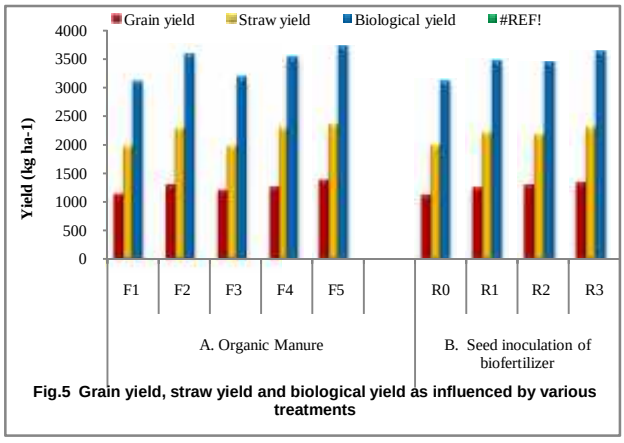

Fig.5 Grain yield, straw yield and biological yield as influenced by various treatments

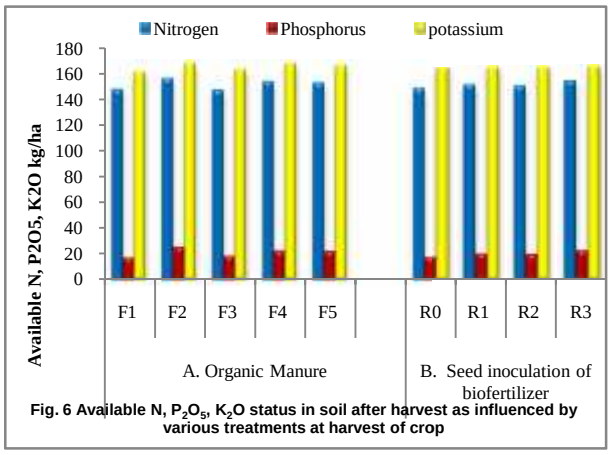

Fig. 6 Available N, P_2O_5, K_2O status in soil after harvest as influenced by various treatments at harvest of crop

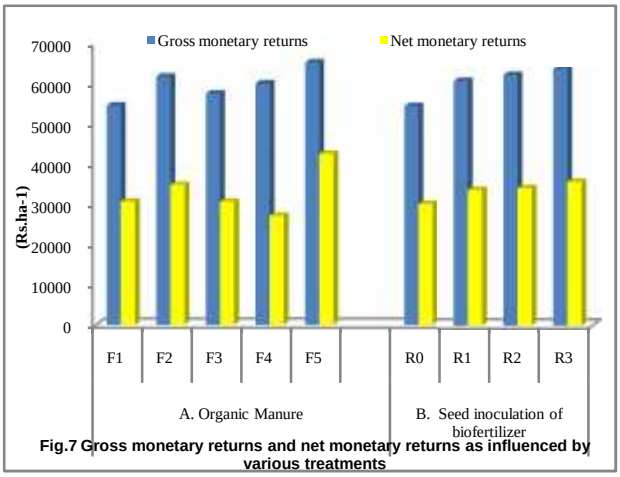

Fig.7 Gross monetary returns and net monetary returns as influenced by various treatments

CONCLUSION

A field experiment entitled "Integrated nutrient management in black gram under rainfed condition" was conducted at Agriculture Farm, Bhagwant University, and Ajmer during *Kharif* season of 2015. The soil of experimental plot was clayey in texture, medium in organic carbon, low in available nitrogen and phosphorus and rich in potassium. The Blackgram crop was shown on 2 July 2015 and harvested by 17th September 2015. Total rainfall of 574.2 mm was recorded during the crop growing season. Overall the weather during crop growing season was quite satisfactory. The experiment was laid out in Factorial Randomized Block Design (FRBD) with twenty treatments replicated thrice. Treatments consisted of organic manure viz., FYM @ 3.0 t ha^{-1}, FYM @ 6.0 t ha^{-1}, vermicompost @ 1.5 t ha^{-1}, vermicompost @ 3.0 t ha^{-1}, and RDF (25:50 N:P_2O_5 kg ha^{-1}) (F_1 F_2, F_3, F_4 and F_5 respectively) as first factor and biofertilizer viz., no seed inoculation, Rhizobium, PSB and Rhizobium + PSB (R_0, R_1, R_2 and R_3 respectively) as second factor. The findings recorded during the course of investigation are summarized below.

Effect of organic manure: - Plant stand: - The treatments of organic manure and biofertilizer had no significant influence on emergence count and final plant stand.

Growth characters:- Growth characters viz., plant height, the number of branches, dry matter, leaf area, leaf area index, the number of nodules $plant^{-1}$, AGR for dry matter and RGR were significantly greater with treatment F_5 (RDF 25:50 N:P_2O_5 kg ha^{-1}). Treatments F_2 and F_4 were next best.

Yield attributes and yield:- Yield attributes and yield viz., the number of pods $plant^{-1}$, the weight of grains $plant^{-1}$ test weight and grain weight and grain yield, straw yield and biological yield were significantly higher with F_5 (RDF 25:50 N:P_2O_5 kg ha^{-1}) followed by F_2 and F_4.

Protein content and yield:- The protein content and protein yield were significantly higher with the treatment F_5 (RDF 25:50 N:P_2O_5 kg ha^{-1}).

Nutrient uptake by Blackgram:-Mean nitrogen, phosphorus, and potassium content in grain and straw of Blackgram were significantly higher with the treatment of recommended dose of fertilizer (F_5). Total uptake of nitrogen, phosphorus, and potassium by black gram plant were significantly higher with treatment of F_5 (RDF 25:50 N: P2O5 kg ha^{-1}). Similarly, available nitrogen, phosphorus and potassium were found higher in treatment F_2 (FYM @ 6 t ha^{-1}) which was significantly superior over rest of treatments.

Economics:- Gross monetary returns, net monetary returns, and B:C ratio were significantly highest in recommended dose of fertilizer treatment.

Effect of biofertilizer: - Plant stand:-Differences among the treatments of seed inoculation of biofertilizer on emergence count and final plant stand was found to be non-significant.

Growth characters:- Growth characters viz., plant height, number of branches, dry matter, leaf area, leaf area index, number of nodules $plant^{-1}$, AGR for dry matter and RGR were significantly more with treatment R_3 (Rhizobium + PSB).

Yield attributes and yield:-Yield attributes and yield viz., the number of pods $plant^{-1}$, the weight of grains $plant^{-1}$, test weight and grain weight and grain yield, straw yield and biological yield were significantly higher with treatments R_3 (Rhizobium + PSB).

Nutrient uptake by Blackgram:-The average nitrogen, phosphorus and potassium content in grain and straw of blackgram were significantly higher with the treatment of R_3 (Rhizobium + PSB). Total uptake of nitrogen, phosphorus and potassium by blackgram plant were significantly higher with the treatment of R_3 (Rhizobium + PSB). Similarly, available nitrogen, phosphorus and potassium were found higher in treatment R_3 which was significantly superior over rest of treatments.

Economics:- Gross monetary returns, net monetary returns and B:C ratio were significantly higher in combined inoculation of Rhizobium and PSB treatment. The following conclusions could be drawn from the present investigations.

- Application of recommended dose of fertilizer (25:50 N:P_2O_5 kg ha^{-1}) significantly enhanced the growth contributing characters plant height, the number of branches, the number of root nodules $plant^{-1}$ and dry matter. Yield attributes viz., the number of pods $plant^{-1}$ number of grains pod^{-1}, test weight and gain weight $plant^{-1}$ and yield viz., grain, straw, and biological yield of black gram than the application of vermicompost @ 3.0 t ha^{-1}.
- Seed inoculation of biofertilizer with Rhizobium + PSB significantly increased the growth contributing characters, yield attributes and yield of Blackgram.

- Gross, net monetary returns and B:C ratio were found significantly higher in treatment receiving recommended dose of fertilizer (25:50 N:P_2O_5 kg ha^{-1})
- Seed inoculation with Rhizobium + PSB significantly increased the GMR, NMR and B: C ratio.
- Seed treatment with Rhizobium + PSB along with RDF (25:50 N:P_2O_5 kg ha^{-1}) was found beneficial for harvesting economic yields of black gram. The next best treatment was FYM @ 6 t ha^{-1}.

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