

**Effect of Integrated Nutrient Management on
Growth, Yield, Quality and Economics of
Summer Green Gram [*Vigna radiata* (L.)
Wilczek]**

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

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for the degree of**

MASTER OF SCIENCE

In

AGRICULTURE

(AGRONOMY)

By

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2014

CERTIFICATE - I

*This is to certify that the thesis entitled, “Effect of Integrated Nutrient Management on Growth, Yield, Quality and Economics of Summer Green Gram [Vigna radiata (L.) Wilczek]” submitted in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE in AGRICULTURE (AGRONOMY)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. SANDEEP KUMAR PRAJAPATI** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.*

All the assistance and help received during the course of the investigation has been acknowledged by him.

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Place: Tikamgarh
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List of Abbreviations

Words	Abbreviation/symbol
At the rate	@
Benefit cost ratio	B:C
Centimetre	cm
Co-workers	<i>et al.</i>
Critical difference	CD
Days after sowing	DAS
Degree Celsius	°C
Di-ammonium phosphate	DAP
Evening	Eve.
Farmyard manure	FYM
Figure	Fig.
Gram	g
Gross monetary return	GMR
Harvest Index	HI
Hectare	ha
Indian Council of Agricultural Research	ICAR
Jawaharlal Nehru Krishi Vishwa Vidyalaya	J.N.K.V.V
Kilogram	Kg
Leaf area index	LAI
Maximum	Max.
Meteorological standard week	MSW
Milimetre	mm
Minimum	Min.
Morning	Mor.
Murate of potash	MoP
Net monetary return	NMR
Non significant	NS
Per cent	%
Per hectare	ha ⁻¹
Recommended dose of fertilizer	RDF
Rupee	₹
Standard error of means	S.Em±
Temperature	Temp.

Chapter-1

Introduction

INTRODUCTION

Green gram [*Vigna radiata* (L.) Wilczek] is one of the most ancient and extensively grown leguminous crops of India. It is a native of India and Central Asia and commonly known as mung bean. It is the third important pulse crop after chickpea and pigeon pea, cultivated throughout India for its multipurpose uses as vegetable, pulse, fodder and green manure crop. Its seed is more palatable, nutritive, digestible and non-flatulent than other pulses grown in world. It is a good source of protein (20-24 %), carbohydrates (60-62 %), water (10%), fat (1.0%), fiber (4.0%) and ash (3.0%). Green gram protein is deficient in methionin and cystein but rich in lysine making it an excellent compliment to rice. It is a good source of mineral, pro-vitamin A, B complex and ascorbic acid. Besides being a rich source of protein, it maintains soil fertility through biological nitrogen fixation in soil and thus plays a vital role in furthering sustainable agriculture (Kannaiyan, 1999).

In India, it is cultivated in Maharashtra, Andhra Pradesh, Rajasthan, Orissa and Karnataka. It is grown usually as rainfed crop and can also be grown as pre-monsoon (summer) and late monsoon crop. In India, it is cultivated over an area of 3.0 million hectares with total production of 1.24 million tonnes and productivity of 425 kg ha⁻¹ (Anonymous 2009). In Madhya Pradesh, green gram crop is grown over an area of 80.6,000 hectares with total production of 19.7,000 tonnes and average productivity of 227 kg ha⁻¹ during 2010-11. The area, production and productivity of green gram in Tikamgarh district of Madhya Pradesh is 5.2,000 hectares, 0.9,000 tonnes and 175, respectively during 2010-11 (source: www.mpkrishi.org).

The productivity of this crop is very low because of its cultivation on marginal and sub marginal lands of low soil fertility where little attention is paying to adequate fertilization (Saravanan *et al.*, 2013). However, yield potential of summer green gram is quite high yet at farmers' field, its yield is low. In summer green gram, a high reduction in yield has been reported to occur due to non-use of fertilizers (Singh and Sekhon. 2008). Although, chemical fertilizer are playing a crucial role to meet the nutrients need of the crop, the imbalance and continuous use of chemical fertilizers has adverse effect on soil physical, chemical and biological properties thus affecting the sustainability of crop production, besides causing environmental pollution

(Virmani, 1994). Besides, persistent nutrient depletion is posing a greater threat to the sustainable agriculture. Consumption of chemical fertilizers will also be quite a limiting factor of agricultural production in future. Because of escalating energy cost, chemical fertilizers are not available at affordable price to the farmers. Therefore, there is an urgent need to reduce the usage of chemical fertilizers and inturn increase in the usage of organics is needed to check the yield and quality levels. On the other hand, use of organics alone does not result in spectacular increase in crop yields, due to their low nutrient status (Subba Rao and Tilak, 1977). Therefore, the aforesaid consequences have paved way to grow green gram by integration of organic and inorganic fertilizers along with biofertilizers.

Integration of organic manures and inorganic fertilizer materials has been found to be promising not only in maintaining higher productivity of crops and for providing stability in crop production, besides improving soil physical conditions (Verma *et al.*, 2012). Farmyard manure and vermicompost have been advocated as good organic manure for use in integrated nutrient management programme in field crops. They supply nitrogen, phosphorus, potassium and micronutrients like Fe, S, Mo and Zn *etc.* in available form to the plants through biological decomposition and improves physical-chemical properties of soil, slow release of nutrients, increase in cation exchange capacity and enhances the microbial, crop growth and yield. Biofertilizers are also one of the important components in integrated nutrient management system. They are low cost and eco-friendly inputs, which have tremendous potential of fixing atmospheric nitrogen and can reduce the chemical fertilizer dose by 25–50% (Pattanayak *et al.* 2007).

Keeping in view of the above facts, a field experiment entitled, “**Effect of integrated nutrient management on growth, yield, quality and economics of summer green gram [*Vigna radiata* (L.) Wilczek]**” will be conducted to fulfill the following objectives:

1. To evaluate the effect of integrated nutrient management on crop growth, development and nodulation in green gram.
2. To assess the effect of integrated nutrient management on yield attributes, yield and quality of green gram.
3. To determine the effect of integrated nutrient management on nutrients uptake by the crop.
4. To workout the economics of different treatments.

Chapter-2

Review of Literature

REVIEW OF LITERATURE

In this chapter, the literature collected from different journals and other sources with respect to **effect of integrated nutrient management on growth, yield, quality and economics of summer green gram [*Vigna radiata* (L.) Wilczek]** has been reviewed in details to understand the present position of integrated nutrient management in green gram. The research findings in Madhya Pradesh, India and green gram growing countries in recent years are presented in the following sub-headings. Literature on green gram is not adequate, therefore literature of some other pulse crops have also been included in this chapter to emphasize certain point of view.

2.1 Importance of integrated nutrient management

Reliance on the increased use of chemical fertilizers and associated hazards put back attention on organic sources, which are effective in promoting health and productivity of the soil. Integrated management of chemical fertilizers and organic wastes may be an important strategy for sustainable production of crops. This may not only improve the efficiency of chemical fertilizers along with their minimal use in crop production besides increasing crop yield and improving available major and minor nutrients (Rautaray *et al.*, 2003). The availability of P can be increased if it is mixed with FYM (Hussain *et al.*, 2008) Integrated use of organic and inorganic fertilizers guarantee improved soil health and fertility (Satyanarayana *et al.*, 2002). Bending *et al.*, (2002) concluded that crop residues and soil organic matter both could affect the diversity of soil microbial community and increase the crop growth and yield. Integrated use of nutrient may be one of the solutions to increase mung bean production as well as reducing cost of production and make the best use of locally available resources like animal dung, urine, crop residues etc. The use of organic matter as a low cost supplement to the artificial fertilizers may help decreasing the cost of production.

2.2 Effect of Inorganic fertilizers (N, P and K) on growth, yield attributes, yield, quality, nutrients uptake and economics

N, P, K are considered as the major nutrients in crop production point of view and proper ratio should be maintained among these nutrients to ensure better

growth and improved yield. Application of nitrogen and phosphorus increase the number of pods plant⁻¹ and number of seeds pod⁻¹. A balanced ratio of N and K is also important in plant nutrition. Total N uptake and protein synthesis are reduced in K deficient plants. An excess of N in relation to other nutrients, such as P and K can delay crop maturity.

Sangakkara (1990) conducted a field trial to study the effects of 0-120 kg K₂O ha⁻¹ applied as a basal dressing or split application (60:40 at planting and flowering) on growth, yield parameters and seed quality of mung bean varieties. In the short maturing cv. MI 5, seed yield and quality increased with a basal application of up to 80 kg K ha⁻¹ and a split application of up to 60 kg K ha⁻¹. In the long maturing cv. Type 61, seed yield and quality increased with a basal application of up to 100 kg K ha⁻¹ or a split application of up to 80 kg K ha⁻¹.

Tariq *et al.* (2001) conducted a field experiment to study the effect of P and K application on growth and yield of green gram on a sandy clay loam soil under irrigated condition of Faisalabad (Pakistan). They indicated that plant height, number of branches plant⁻¹, number of pods plant⁻¹, number of seeds pod⁻¹, 1000-seed weight and seed yields were increased significantly by application of P and K along with nitrogen. Application of P₂O₅ and K₂O each @ 70 kg ha⁻¹ along with N application @ 30 kg ha⁻¹ produced highest grain yield of 876.32 kg ha⁻¹.

Malik *et al.* (2003) studied the effect of varying levels of nitrogen (0, 25 and 50 kg ha⁻¹) and phosphorus levels (0, 50, 75 and 100 kg ha⁻¹) on the yield and quality of mung bean (*Vigna radiata* L.) during the year 2001 at Faisalabad (Pakistan). Results indicated that a fertilizer combination of 25:75 kg NP ha⁻¹ resulted in maximum seed yield (1112.96 kg ha⁻¹). However, maximum protein content (25.6%) was obtained from plots fertilized @ 50:75 kg NP ha⁻¹ followed by protein content of 25.1% obtained from plots fertilized @ 25:75 kg NP ha⁻¹. Highest net income (₹ 21374.9 ha⁻¹) was also obtained by applying N and P @ 25 and 75 kg NP ha⁻¹, respectively.

Sadeghipour *et al.* (2010) conducted an experiment on green gram at Tehran (Iran) with five levels of nitrogen (0, 30, 60 and 90 kg N ha⁻¹) and six levels of phosphorus (0, 30, 60, 90, 120 and 150 kg P₂O₅ ha⁻¹). Results showed that application of N and P fertilizers significantly increased the seed yield of green gram. The maximum seed yield (224.2 g m⁻²) was obtained when 90 kg N ha⁻¹ and 120 kg

P_2O_5 ha^{-1} was applied. This increase in seed yield was mainly due to more number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000 seed weight.

Ali *et al.* (2010) in a field experiments to evaluate the influence of three levels of phosphatic fertilizer on mung for two consecutive *kharif* seasons *i.e.*, 2007 and 2008 at Adaptive Research Station, Mianwali. The results revealed that all the levels of phosphatic fertilizer showed significant impact on mung as compared to control plots. However, treatment of phosphatic fertilizer @ 84 kg ha^{-1} out yielded rest of the treatments giving the maximum yield components and grain yield during both years.

Hussain *et. al* (2011) conducted a field experiment at Faisalabad (Pakistan) with five levels of potash (K) fertilizer (0, 30, 60, 90,120 kg ha^{-1}) and reported that maximum plant height (49.93 cm), number of pods $plant^{-1}$ (26.82), number of seeds pod^{-1} (8.32) and seed yield (753 kg ha^{-1}) was obtained with the application of 90 kg K ha^{-1} against minimum in control. However, number of fruiting branches $plant^{-1}$ and 1000-seed weight were recorded maximum with application of 120 kg K ha^{-1} .

Beg (2012) conducted a field experiment to study the effect of potassium and found that the treatment where 1.00 kg K ha^{-1} was applied as foliar spray showed best result. It enhanced almost all the vegetative and yield characteristics of moong bean as compared to both the basal fertilizer doses. In this way a little amount of Potassium used as foliar spray at the time of flowering when the plant required maximum nutrients can enhanced the productivity and save a large amount of fertilizers.

2.3 Effect of FYM, inorganic fertilizers + FYM on growth, yield attributes, yield, quality, nutrients uptake and economics

Farmyard manure (FYM) refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to the cattle. Good quality FYM is more valuable organic manure. The long term manurial studies conducted at many places have revealed the superiority of integrated nutrient supply system in sustaining crop productivity in comparison to chemical fertilizer alone (Gaur, 1991). On an average well decomposed FYM contains 0.5 per cent N, 0.2 per cent P_2O_5 and 0.5 per cent K_2O . It has been estimated that a ton of FYM would supply 3.6 kg nitrogen + 1.9 kg phosphorus + 1.8 kg potassium (Gaur, *et al.*, 1992). FYM promotes seed germination and root growth of the crop plants by improving the water holding capacity and aeration of the soil.

Sharma and Dixit (1987) reported that the application of FYM @ 6 t ha⁻¹ + NPK @ 10:40:0 kg ha⁻¹ recorded significantly higher plant height (73.3 cm), higher number of seeds plant⁻¹ (128), 100 seed weight (111.7 g) and seed yield (20.2 q ha⁻¹) as compared to the application of NPK @ 10:40:0 kg ha⁻¹ (64.6 cm, 104.7, 100.8 g, 16.5 q ha⁻¹,) in soybean. Ramamurthy and Shivashankar (1996) reported that the application of farmyard manure (FYM) @ 10 t ha⁻¹ recorded significantly higher protein content (38.5%), oil content (19.4%), protein yield (1103.6 kg ha⁻¹) and oil yield (522.7 kg ha⁻¹) as compared to control (37.3%, 18.8%, 857.4 kg ha⁻¹ and 433.2 kg ha⁻¹, respectively) in soybean. They also reported that the application of FYM 10 t ha⁻¹ recorded significantly higher seed yield (2694 kg ha⁻¹) as compared to FYM @ 5 t ha⁻¹ (2300 kg ha⁻¹) and control (2070 kg ha⁻¹).

Aruna and Narsareddy (1999) reported that the application of organic manures @ 15 t ha⁻¹ + 50:0:0 kg NPK ha⁻¹ recorded significantly higher pods plant⁻¹ (56), 100 seed weight (15.7 g), seed yield (1127 kg ha⁻¹), seed protein content (42.1%) and seed protein content (24.4%) over the application of organic manures @ 5 t ha⁻¹ + 50:0:0 kg NPK ha⁻¹ (32.9, 12.8g, 792 kg ha⁻¹, 39.3% and 23.1%, respectively) in soybean. Appavu and Saravanan (1999) observed that the application of FYM had significantly recorded higher seed yield (738 kg ha⁻¹) than control (500 kg ha⁻¹) in soybean. Kathiresan *et al.* (1999) observed in soybean that the application of enriched FYM recorded significantly higher number of pods plant⁻¹ (164), number of seeds pod⁻¹ (2.30) and test weight of 8.40g. The maximum soybean seed yield of 2031 kg ha⁻¹ was obtained by application of enriched FYM, which was 32 % higher over control.

Ghosh *et al.* (2001) reported that the application of FYM @ 10 t ha⁻¹ along with recommended dose of NPK to soybean recorded significantly higher seed yield (2.65 t ha⁻¹) as compared to NPK alone (1.45 ha⁻¹). Patil (2002) noticed higher germination (94.5%), root length (16.6 cm), shoot length (14.0 cm), seedling dry weight (59.8 mg) and protein content (23.2%) in seeds of green gram cv. China mung cultivar treated with RDF + FYM @ 2.5 t ha⁻¹ as compared to RDF and organic manures alone. Reddy *et al.* (2004) reported that the application of FYM @ 10 t ha⁻¹ recorded significantly higher seed yield in sorghum (2623 kg ha⁻¹), pigeon pea (474 kg ha⁻¹), castor (1056 kg ha⁻¹) and sunflower (969 kg ha⁻¹) over application of RDF (1988 kg ha⁻¹, 232 kg ha⁻¹, 653 kg ha⁻¹ and 750 kg ha⁻¹, respectively). Application of

FYM, on an average increased the seed yield of sorghum, sunflower, castor, and pigeon pea by 27, 23, 36 and 30 % respectively, as compared to the recommended dose of chemical fertilizers.

Singh *et al.* (2005) studied residual effect of INM in potato-moong cropping sequence and reported that highest value of all the yield attributes and grain yield of moong was observed with the residual effect of combined application of 100% RDF + FYM @ 15 t ha⁻¹. They also quoted that direct effect of NPK application to moong was more pronounced over residual effect. Yield attributes, grain yield and net return improved significantly with each increment of NPK from 50% RDF to 100% RDF. Integrated nutrient management practices brought about significant variation in organic carbon, phosphorous and nitrogen status of soil and non-significant variation in K status at harvest. Highest improvement in soil fertility was observed with application of FYM @15 t ha⁻¹ + 100% RDF followed by 100% RDF + biofertilizer + crop residue incorporation.

Naeem *et al.* (2006) studied the effect of organic manures and inorganic fertilizers on growth and yield of green gram (*Vigna radiata* L.) and reported that grain yield was recorded highest (1104 kg ha⁻¹) with the application of the inorganic fertilizers @ 25:50:50 kg NPK ha⁻¹. Among organic sources, poultry manure @ 3.5 t ha⁻¹ was found the best followed by FYM @ 5 t ha⁻¹. The economic analysis revealed maximum net benefit from the treatment, where poultry manure was applied. Ali *et al.* (2008) studied the performance of green gram (*Vigna radiata* L.) in wheat-green gram cropping system. Wheat crop received three treatments (T₁) 60-45-0-0, (T₂) 120:90:60:5, and (T₃) 60:90:60:5 kg N:P₂O₅:K₂O:Zn ha⁻¹. The third treatment received 20 t ha⁻¹ FYM one month before sowing of wheat. Wheat crop was followed by green gram which received (T₁) 0:45:0:0, (T₂) 0:90:60:5 and (T₃) 0:90:60:5 kg N:P₂O₅:K₂O:Zn ha⁻¹ in the respective treatments. The data showed that T₃ gave the highest green gram yield of 516 kg ha⁻¹ and significantly different from other treatments with an increase of about 61 % over T₁ and 15 % over T₂.

Ghulam *et al.* (2011) reported that different combinations of organic and inorganic fertilizers significantly affected the grain yield of green gram. Maximum grain yield was obtained from the application of DAP at 124 kg ha⁻¹ along with 10 t ha⁻¹ of poultry litter during both years, while application of DAP at 62 kg ha⁻¹ and 10 t ha⁻¹ FYM ranked second for grain yield. Meena (2013) conducted a field experiment to find out the effects of organic and inorganic sources of nutrient on growth

attributes and dry matter partitioning of green gram in arid western Rajasthan during summer season of 2004. He observed that inorganic source of nutrients as NPK 100% of RDF and organic sources of nutrients like, FYM at 10 t ha⁻¹ and vermicompost at 5 t ha⁻¹ significantly enhanced the growth attributes viz., plant height at harvest, dry matter accumulation and its partitioning (g plant⁻¹) into leaf, stem and pod at 30, 45, 60 DAS and at harvest, dry weight of root nodules (mg plant⁻¹) at flower initiation and peak flowering stages of green gram over control and other treatments. He further quoted that increased levels of inorganic and organic sources of nutrients viz., NPK at 125% recommended dose, FYM at 10, 15 and 20 t ha⁻¹ and vermicompost at 5, 7.5 and 10 t ha⁻¹ remained at par each other. Saravanan *et al.* (2013) observed maximum number of pods and pod length in treatment, which received FYM + 10% RDF of NPK. They also reported that the integrated approach of nutrient management recorded better availability of phosphorus and potassium in fresh and dry seeds of green gram than the individual application.

2.4 Effect of vermicompost and vermicompost + inorganic fertilizers on growth, yield attributes, yield, quality, nutrients uptake and economics

The beneficial effect of vermicompost was first highlighted by Darwin (1881). Vermicompost contains micro site rich in available carbon and nitrogen (Sudhakar *et al.*, 2002). Worm cast incorporated soils are also rich in water soluble P (Gratt, 1970) and contained two to three times more available nutrients than surrounding soils (Sudhakar *et al.*, 2002), which encourages better plant growth. Vermicompost suppress parasitic attacks dramatically and also have shown to increase germination rates, growth etc in wide ranges of crops (Arancon *et al.*, 2004). Similar results were also reported by application of Vermicompost on seed germination in mung bean by Nagavallema *et al.* (2004).

Malligawad *et al.* (2000) in groundnut revealed that application of RDF (25:75:25 kg NPK kg ha⁻¹) + vermicompost @ 1 t ha⁻¹ recorded significantly higher pod yield (3389 kg ha⁻¹) as compared to FYM @ 4 t ha⁻¹ + 50% RDF (3232 kg ha⁻¹), RDF alone (3148 kg ha⁻¹) and no NPK application (2742 kg ha⁻¹). Kumari and Ushakumari (2002) in field experiment studied the effect of enriched vermicompost on the yield and uptake of nutrients by cowpea. The results indicated that enriched vermicompost @ 20 t ha⁻¹ produced 28% yield increment over application of FYM + 30 kg P₂O₅ ha⁻¹ and 21% yield increase over application of vermicompost + 30 kg

P_2O_5 ha^{-1} . The enriched vermicompost treatment also showed its superiority over other treatments for the uptake of N, P and K. Rajkhowa *et al.* (2002) reported that the application of 100 % RDF along with vermicompost @ 2.5 t ha^{-1} recorded significantly higher plant height (52.7 cm), number of pods $plant^{-1}$ (12.7), seeds pod^{-1} (12), 100 seed weight (4.6 g), seed yield (5.35 q ha^{-1}) and it was on par with the application of 75% or 50% RDF + vermicompost (2.5 t ha^{-1}) over control in green gram.

Channaveerswami (2005) reported that combined application of vermicompost @ 2.5 t ha^{-1} + RDF (25:50:50 kg NPK ha^{-1}) + copper ore tailing recorded greater plant height (43.9 cm), number of branches (6.92) and less number of days to 50% flowering (35.2), number of matured pods (17.1), pod yield (3337 kg ha^{-1}) and kernel yield (2362 kg ha^{-1}) and 100 seed weight (35.3 g) in groundnut. This seed obtained with this treatment also recorded higher seed quality parameters like, germination (94.3%), seedling length (23.9), seedling dry weight (4.60 g), seedling vigour index (2249) and lower electrical conductivity (0.186 dSm^{-1}) in groundnut. Govindan and Thirumurugan (2005) observed that the application of vermicompost (75%) had significantly recorded greater plant height (84.7 cm), leaf area index (3.40) over press mud (100% N) (78.2 cm and 2.70, respectively) in soybean.

Shukla and Tyagi (2009) in green gram reported that vermicompost and enriched compost enhanced the soil physical properties and plant nutrients (N, P and K) at the time of crop establishment and early growth. Incorporation of vermicompost and enriched compost before sowing had a greater beneficial impact, especially on physical properties of soil. The added organic materials, like vermicompost and enriched compost increased germination, growth of shoots, roots and enhanced nodulation. The observed slightly greater benefits with vermicompost as compared to enriched compost. The selected microorganisms used were *Rhizobium*, a symbiotic nitrogen fixer and phosphate-solubilizing bacteria, which helped in solubilization of fixed phosphorus. Javed and Panwar (2013) found that the seed germination percentage was high in vermicompost treated soil in *Vigna mungo* and biofertilizer treated in *Glycine max*. *Vigna mungo* protein content was found higher in biofertilizer + chemical fertilizer treated soil, while carbohydrate and phenol content increased in biofertilizer + vermicompost treated soil. High seed germination was observed in vermicompost treated soil.

2.5 Effect of *Rhizobium* inoculation growth, yield attributes, yield, quality, nutrients uptake and economics

Biofertilizers are also one of the important components in integrated nutrient management system. They are low cost and eco-friendly inputs, which have tremendous potential of fixing atmospheric nitrogen and can reduce the chemical fertilizer dose by 25–50% (Pattanayak *et al.* 2007). *Rhizobium* inoculation in green gram increases number of pods and seed yield (Ashraf *et al.*, 2003; Bhuiyan, 2004). Thakur and Panwar (1995) and Solaiman (1999) found an increase in seed yield of green gram with *Rhizobium* seed inoculation.

Daterao *et al.* (1994) conducted an experiment at Akola in Punjabrao Krishi Vidyapeeth and they reported that application of 10 kg N ha⁻¹ with *Rhizobium* inoculation increased the seed yield by 24.5 and 23.6 % over control in green gram and black gram, respectively. Patra and Bhattacharya (1997) observed that higher nodule numbers and seed yield (kg ha⁻¹) were obtained by treating green gram with *Rhizobium* and applied urea (25 kg ha⁻¹). Bhalu *et al.* (1995) quoted that seeds of black gram inoculated with *Rhizobium* gave the highest seed yield (471 kg ha⁻¹) straw yield (742 kg ha⁻¹) and protein content (24.1%) as compared to the un-inoculated seed (434 kg ha⁻¹, 689 kg ha⁻¹, 23.6%, respectively). Takankhar *et al.* (1998) revealed that seed yield and number of pods plant⁻¹ in green gram increased significantly due to *Rhizobium* inoculation as compared to no *Rhizobium* inoculation. Upadhyay *et al.* (1999) reported that significant increase in the plant height, number of branches, number of nodules, pods plant⁻¹, seed pod⁻¹ and seed yield kg ha⁻¹ were observed when green gram seeds inoculated with *Rhizobium* as compared to un-inoculation seeds.

Shivesh *et al.* (2000) observed increased in growth, dry matter accumulation and yield in *Vigna mungo* with N application and *Rhizobium* inoculation as compared to control. Kashem *et al.* (2000) observed that *Rhizobium* inoculation and NPK fertilization increased the grain and straw yields of green gram significantly and obtained higher grain yield with 0:30:20 kg NPK ha⁻¹ + inoculation. Ashraf (2001) concluded that in green gram, number of pods plant⁻¹, number of seeds pod⁻¹, and 1000 seed weight were affected significantly by 50 kg P₂O₅ and with varying levels of N from 20 to 50 kg ha⁻¹ in addition to seed inoculation. He further expressed that higher grain yield (1075 kg ha⁻¹) was recorded in plots fertilized with 50:50 kg NP ha⁻¹

¹ + seed inoculation. In chickpea, Meena *et al.* (2001) noticed that application of 40 kg P₂O₅ ha⁻¹ with *Rhizobium* seed inoculation significantly enhanced pod plant⁻¹ (30.1), seeds pod⁻¹ (1.6), test weight (149.3 g), seed yield (11.1 q ha⁻¹) and protein content (22.5 %) over no inoculation with *Rhizobium*.

Nadeem *et al.* (2004) carried out experiments on *rhizobium* inoculation with and without fertilizers on legume crops and found increased nitrogen contents of seed, number of nodules, yield and yield components over un-inoculated treatments. Rasool *et al.* (2006) reported that seed inoculation + 22:57 kg NP ha⁻¹ produced higher green gram yield (1131.9 kg ha⁻¹) with an increase of 73.98% over control. Bhuiyan *et al.* (2008) conducted a pot experiment during *Kharif* 2005 at the Soil Science Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur with four levels of phosphorus (P) (0, 20, 40, 60 kg ha⁻¹) with common *Rhizobium* inoculants, one control with no *Rhizobium* or fertilization and a *Rhizobium* inoculation only were applied. They reported that performance of *Rhizobium* inoculant alone was superior to control in almost all parameters of the crop studied. *Rhizobium* inoculation along with P significantly increased the height of plants, number of root nodules, dry matter production as well as grain yield of green gram significantly as compared to un-inoculated control. Nodulation (nodule number plant⁻¹) was the highest with 20 kg P ha⁻¹.

Kumpawat (2010) observed that integrated nutrient management showed significant effect on productivity and nutrient uptake of black gram. Application of 25% RDF + FYM 2.5 t ha⁻¹ along with *Rhizobium* + PSB registered maximum seed yield (1 342 kg ha⁻¹), which was 18.2% higher than 100% RDF. Treatment receiving 75% RDF with vermicompost 0.63 t ha⁻¹ exhibited maximum N and P uptake. Residual effect of integrated nutrient management practices was also equally effective in improving the yield and nutrient uptake of succeeding crop.

Kumawat *et al.* (2010) observed that inoculation of *Rhizobium* + PSB and application of 15 kg N + 20 Kg P₂O₅ ha⁻¹ significantly increased the growth *i.e.*, number of branches plant⁻¹ and root nodules plant⁻¹ and yield attributing characters (pods plant⁻¹, seeds pod⁻¹, test weight and consequently, seed and straw yield in green gram. Dual inoculation of *Rhizobium* + PSB and 15 kg N + 20 kg P₂O₅ ha⁻¹ significantly increased the N and P uptake by seed and straw, protein content of seed, net returns and had higher B: C ratio also. Raiger *et al.* (2011) observed that

application of 100% RDF + phosphate-solubilizing bacteria (PSB) + *Rhizobium* produced highest seed yield of rice bean followed 75% RDF + PSB + *Rhizobium*. They also reported that the inoculants *Rhizobium* and PSB increased and stabilized the yield over locations as compared to control.

Vadgave (2010) at Main Agricultural Research Station, UAS, Dharwad studied the influence of integrated nutrient management on seed yield and quality in green gram. He observed that the application of 100% RDF + vermicompost @ 1.25 t ha^{-1} + *Rhizobium* @ 375 g ha^{-1} gave significantly the higher number of pods plant^{-1} (24.2), number of seeds pod^{-1} (14.2), seed yield ($14.23 \text{ g plant}^{-1}$), seed yield ($1138.89 \text{ kg ha}^{-1}$), test weight (41.95 g) and seed protein content (23.55%) as compared to others treatments.

Chapter-3

Materials and Methods

MATERIALS AND METHODS

The experiment entitled, “**Effect of Integrated Nutrient Management on Growth, Yield, Quality and Economics of Summer Green Gram [*Vigna radiata* (L.) Wilczek]**” was conducted in summer 2013 at Research Farm J.N.K.V.V., College of Agriculture, Tikamgarh (Madhya Pradesh). The materials deployed and the methods followed during the course of this study have been described in this chapter.

3.1 Experimental site

The experimental field was located at Research Farm, J.N.K.V.V., College of Agriculture, Tikamgarh (Madhya Pradesh).

3.2 Climate

Tikamgarh district lies in the Bundelkhand Zone (Agro-climatic Zone-VIII). It is situated in the north-eastern part of Madhya Pradesh at 24° 43' North latitude and 78° 49' East longitude at an altitude of 358 metre mean sea level. It has sub-tropical climate characterized by hot dry summers and cool dry winter. The average maximum temperature during the month of May–June varies between 43.0 to 45.0 °C, while the average minimum temperature varies between 3.0 to 4.5 °C during December-January, which are the coldest months of the year. The average annual rainfall of this region is about 1000 mm, which is mostly received between June to September and a little rainfall (90 mm) is also received during October to May. The average humidity of the tract is about 70 per cent.

The meteorological data prevailed during crop season (summer 2013) was recorded at the Meteorological Observatory located at Research Farm, J.N.K.V.V., College of Agriculture, Tikamgarh (Madhya Pradesh) and presented in Table 1 and depicted as Fig. 1.

Table 1: Weekly meteorological data during crop season (summer 2013) at Tikamgarh

MSW	Temperature (°C)		Relative humidity (%)		Evaporation (mm)	Rainfall (mm)
	Max.	Min.	Mor.	Eve.		
11	32.0	15.0	73.7	33.1	4.7	8.6
12	34.3	16.3	75.3	25.3	4.8	0.0
13	33.0	16.1	74.4	26.7	4.6	1.2
14	35.9	16.3	48.1	17.1	6.4	0.0
15	38.2	19.6	47.9	18.9	7.3	0.0
16	36.2	20.9	49.0	28.0	7.1	0.0
17	36.8	21.7	53.4	25.0	6.6	0.0
18	41.1	21.4	40.3	17.6	8.3	0.0
19	41.1	23.7	39.6	18.1	7.7	0.0
20	42.1	23.9	34.1	14.4	8.9	0.0
21	43.8	27.5	34.1	21.6	10.3	0.0
22	40.5	26.7	55.7	28.6	8.5	0.0
23	41.0	27.6	68.0	38.1	8.8	38.5
24	33.0	25.3	91.0	73.3	6.1	64.9
Total rainfall = 113.2 mm						

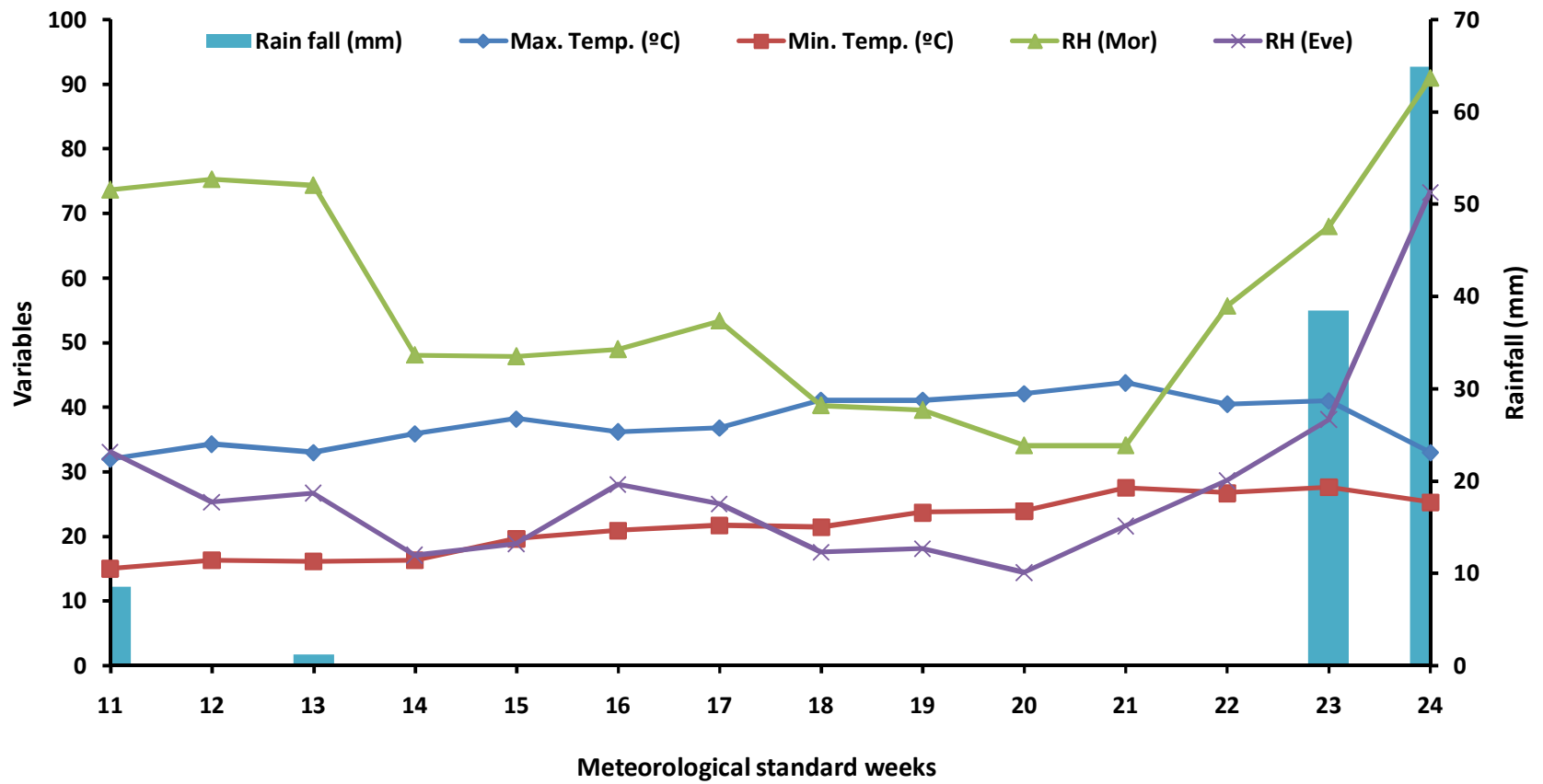


Fig. 1: Mean weekly weather data during summer 2013 at Tikamgarh

3.3 Soil of the experimental field

To study the mechanical composition and chemical properties of the soil, representative soil samples were taken at four randomly selected places in the experimental field from 0-30 cm depth before sowing of green gram crop. These samples were composited and then analyzed to determine mechanical composition and various chemical properties of the experimental field.

3.3.1 Mechanical composition of soil

The composite soil samples were prepared for each soil depth separately and were analyzed by International Pipette Method given by Piper (1966). The results of these analyses are presented in Table 2.

Table 2: Mechanical composition of soil (per cent fraction)

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)
0-30	20.0	30.1	49.9
Textural Class: Clay loam			

3.3.2 Chemical composition of soil

The chemical composition of the soil sample taken from 0-30 cm depth from 4 corners and middle of the field is given in the Table 3. The collected soil samples were mixed thoroughly, dried under shade and ground into fine powdery mass. The values of N, P, K, organic carbon, pH and electrical conductivity were determined or calculated following standard methods/techniques. The data presented in Table 3 indicate that the soil of the experimental site was medium in organic carbon and nitrogen, high in phosphorus, medium in potassium and neutral in reaction.

Table 3: Chemical composition of soil (0-30cm)

Particulars	Value	Method used
pH (1:2)	6.9	Glass Electrode pH Meter (Piper, 1950)
EC (dSm ⁻¹ at 25°C)	19	Conductivity Bridge Meter (Richards, 1954)
Organic Carbon (%)	0.5	Walkley, Black's and Wat's Oxidation Method (Piper 1950)
Available N (kg ha ⁻¹)	266	Alkaline Permanganate Method (Subhiah and Asija, 1956)
Available P (kg ha ⁻¹)	25.9	Olsen's Method (Olsen <i>et al.</i> , 1954)
Available K (kg ha ⁻¹)	255	Flame Photometer Method (Richards, 1954)

3.4 Cropping history of the experimental field

The cropping history of the experimental field is given in Table 4.

3.5 Experimental details

The experiment was laid out in randomized block design with 10 integrated nutrient management treatments and replicated thrice. The layout plan is depicted in Fig. 2 and the details of treatments are given below:

3.5.1 Treatments: 10

T₁: Absolute control

T₂: RDF (20:60:20 kg N, P₂O₅ and K₂O ha⁻¹) + *Rhizobium*

T₃: FYM @ 4 t ha⁻¹ + *Rhizobium*

T₄: 100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*

T₅: 75% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*

T₆: 50% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*

T₇: Vermicompost @ 2 t ha⁻¹ + *Rhizobium*

T₈: 100% RDF + Vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*

T₉: 75% RDF + Vermicompost 1.0 @ t ha⁻¹ + *Rhizobium*

T₁₀: 50% RDF + Vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*

Table 4: Cropping history of the experimental field

Year	Crop season		
	Summer	Kharif	Rabi
2011	Fallow	Fallow	Mustard
2012	Green gram	Fallow	Chickpea
2013	Green gram*	Fallow	Mustard

* *Experimental crop*

3.5.1 Layout

Design	:	Randomized block design
Number of treatments	:	10
Number of replications	:	3
Total number of plots	:	30
Gross plot size	:	5.0 m x 3.6 m
Net plot size	:	4.0 m x 2.4 m
Planting geometry (R x P)	:	30 cm x 10 cm
Seed rate	:	25 kg ha ⁻¹
Fertilizer dose (kg ha ⁻¹)	:	As per treatments
Variety	:	K-851

3.5.2 Varietal characteristics of K-851

This variety was developed by hybridization from a cross 4453-3 and Type -1 at C.S. Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh). Plants are semi-spreading and medium tall. Foliage is dark green with purple pigmentation on stem, branches and petioles. Flowers are yellow in colour. Pods are long (7.5-10.0 cm) with 10-14 seeds pod⁻¹. It matures in 60 - 65 days. Average yield is 10-12 q ha⁻¹. This variety has almost uniform maturity and may be harvested by sickles.

3.6 Cultural operations

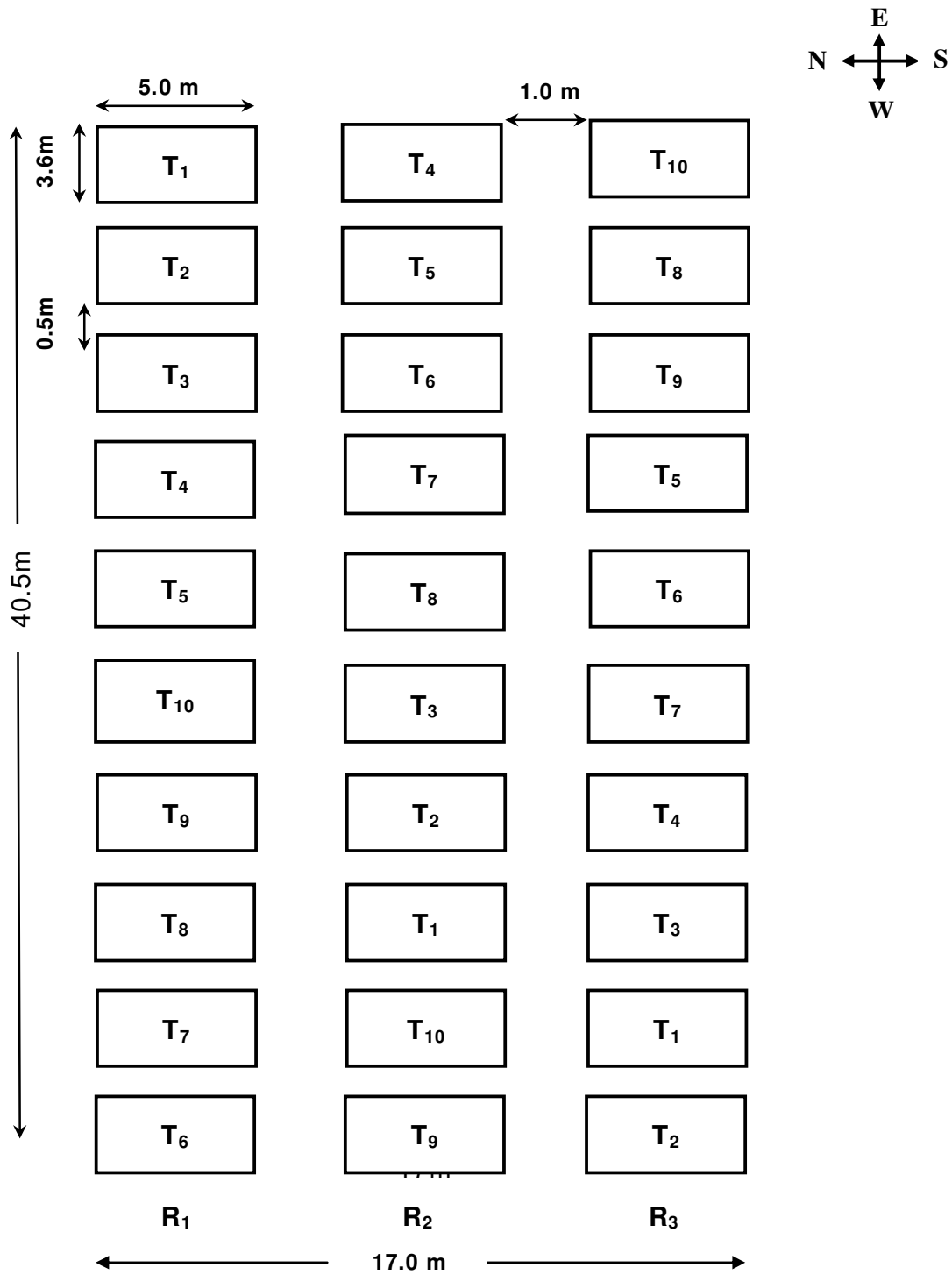
Schedule of cultural operations is given in Table 5.

3.6.1 Field preparation

Experimental field was irrigated 25 days before sowing. Thereafter, at field condition, two cross harrowings each followed by planking were done to prepare a fine and compact seedbed with sufficient amount of moisture at the seeding depth. Trashes, weeds, stubbles and other grasses were removed manually from field to make the clean and leveled plot with fine texture and free from such problem. Then, field was laid out and farmyard manure and vermicompost was incorporated 20 days before sowing in plots as per treatments.

3.6.2 Fertilizer Management

The fertilizer, farmyard manure and vermicompost doses were calculated according to the treatments for each plot. Farmyard manure and vermicompost was



Gross plot size = 5.0 m x 3.6 m = 18.0 m²
 Net plot size = 4.0 m x 2.4 m = 9.6 m²

Fig. 2: Layout of the experiment

incorporated 20 days before sowing in the respective plots as per the treatment specifications. Full dose of nitrogen, phosphorus and potassium was applied as basal. The diammonium phosphate (DAP) and murate of potash (MoP) was the sources of nitrogen, phosphorous and potassium, respectively.

3.6.3 Seed treatment

To protect the crop from soil and seed borne fungal diseases, seeds of green gram were treated before sowing with fungicide Thiram @ 2.5 g kg⁻¹ seed. Thereafter, seeds of green gram were inoculated with *Rhizobium* culture (except control).

3.6.4 Sowing

The green gram crop was sown in lines 30 cm apart drawn by *kudali* using a seed rate of 25 Kg ha⁻¹. The seeds were hand sown on uniformly in the furrows and was covered with soil immediately after sowing.

3.6.5 Thinning and weeding

Irrespective of treatments, thinning of extra plants was done 15 days after sowing by hand pulling to obtain the recommended intra-row spacing of 10 cm. To eliminate weeds in all the plots of experimental area, two hoeing was done at 20 and 40 days after sowing.

3.6.6 Irrigation

The experiment was conducted under irrigated condition. Therefore, irrigation was applied as per requirement (Table 5).

3.6.7 Plant protection

Two sprays of insecticide Dimethoate 30% EC @ 2 ml L⁻¹ of water was given, first at 20 DAS and second was repeated 20 days after first spray for the control of white fly.

3.6.8 Harvesting and threshing

The crop was harvested manually with *hasiya*. Before harvesting, five plants already tagged was pulled out from every plot to record post harvest observations. The crop in net plots was harvested separately and left in the respective plots for sundry. The crop was threshed by manual laborers and was weighed to get seed

yield, stover yield and biological yield kg plot⁻¹. Thereafter, these yields were converted into kg ha⁻¹.

3.7 Observations recorded

3.7.1 Pre-harvest observations

3.7.1.1 Growth parameters

Five plants were selected at random in net plot area and tagged for recording observations.

3.7.1.1.1 Plant population (m⁻²)

The population of plants was randomly selected in three sites of each plot and counted the plants for one square meter area at 15 DAS and harvest of crop.

3.7.1.1.2 Plant height (cm)

The height of plants was measured of five tagged green gram plants at different stages *viz.*, 15, 30, 45 DAS and at harvest. Height was measured from the base of the plant (point of root-shoot interaction) to the tip of the top most leaf with the help of measuring scale. Then the average of plant height was worked out.

3.7.1.1.3 Number of primary branches (plant⁻¹)

The number of primary branches was counted separately from already tagged five green gram plants at 15, 30, 45 DAS and at harvest and their average was worked out.

3.7.1.1.4 Leaf area index (LAI)

The leaf area of leaves from five plants drawn for biomass observation at 15, 30, 45 DAS and at harvest were used for measuring leaf area with the help of graph paper. Then, the leaf area index (LAI) was calculated by using following formula:

$$\text{LAI} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Ground area covered (cm}^2\text{)}}$$

3.7.1.1.5 Biomass and its partitioning

Five plants sample from each plot were uprooted at 15, 30, 45 DAS and at harvest avoiding border effects. The plants were divided into different parts *viz.*,

Table 5: Schedule of cultural operations

Nature of operation	
Pre - sowing	Date of operation
1. Pre-sowing irrigation	06-42013
2. Field preparation	12-04-2013
3. Field lay out	14-04-2013
4. Incorporation of FYM and vermicompost	26-03-2013
5. Basal application of N, P and K	15-04-2013
6. Sowing	15-04-2013
7. Final layout of field	16-04-2013
Post - sowing	
1. First irrigation	22-04-2013
2. Thinning	30-04-2013
3. First weeding <i>i.e</i> , first hoeing	05-05-2013
4. Plant protection	06-05-2013
5. Second irrigation	08-05-2013
6. Third irrigation	15-05-2013
7. Fourth irrigation	23-05-2013
8. Plant protection	24-05-2013
9. Second hoeing	26-05-2013
10. Fifth irrigation	30-05-2013
11. Sixth irrigation	06-06-2013
12. Harvesting	18-06-2013
13. Threshing	22-06-2013

leaves, stem and pods (if present). The samples were then allowed to sundry for 2-3 days. Thereafter, the samples were oven dried at 60°C for 72 hours and weighed by electronic balance. The biomass partitioning among different plant parts was then converted to gram per plant (g plant^{-1}). Based on biomass of different plant parts, the total biomass accumulation and its allocation to various plant parts were obtained.

3.7.1.1.6 Number of root nodules (plant^{-1})

From each plot, five plants were randomly selected for counting of nodules. A block of soil containing the plants was dug out at the distance of 15 cm either side of

row to a depth of 22.5 cm. The soil adhering on the root system was removed by washing with water and the average number of nodules plant⁻¹ was counted at 30, 45 and 60 DAS.

3.7.1.1.7 Dry biomass of root nodules (g plant⁻¹)

Root nodules collected were oven dried at 65°C for 72 hrs. and the dry weight of nodules (mg plant⁻¹) was recorded at 30, 45 and 60 DAS, respectively.

3.7.2 Post-harvest observations

3.7.2.1 Yield attributing characters

The yield attributes listed below were studied from the sample of five plants collected for biomass observation at the time of harvest.

3.7.2.1.1 Number of pods (plant⁻¹)

Total number of pods were counted on five randomly selected plants for biomass observation and then converted into number of pods plant⁻¹.

3.7.2.1.2 Number of seeds (pods⁻¹)

Ten pods were drawn randomly from five selected plants and were threshed and cleaned. The number of seeds was counted by numegral seed counter and then the average number of seeds pod⁻¹ was calculated.

3.7.2.1.3 1000-seeds weight (g)

Thousand seeds (randomly drawn seed sample out of net plot produce) were counted on numegral seed counter and then weighed by electronic balance to record 1000-seeds weight (test weight) in grams.

3.7.2.2 Final yield and harvest index

3.7.2.2.1 Biological yield (kg ha⁻¹)

Crop was harvested manually from net plot area of 4.0 m x 2.4 m (9.6 m²) and bundles were made plot wise. The whole plant samples (biological yield) were allowed to sundry in the plot for 3-4 days. After sun drying, samples were weighted and then converted into kg ha⁻¹.

3.7.2.2.2 Seed yield (kg ha⁻¹)

After sun drying, harvested crop from net plot area was threshed manually. The seed yield of net plot was then converted into kg ha⁻¹.

3.7.2.2.3 Stover yield (kg ha⁻¹)

Stover yield was calculated by subtracting seed yield (kg ha⁻¹) from biological yield (kg ha⁻¹).

3.7.2.2.4 Harvest index (%)

The harvest index (HI) was calculated as per formula given below:

$$\text{HI (\%)} = \frac{\text{Seed yield/economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.8 Quality parameters

The seed and stover samples of pods were taken after harvest the crop, processed and subjected to analysis for quality parameters such N, P, K and protein contents as well as their uptake as affected by different treatments.

3.8.1 Preparation of plant samples

Collected seed and stover samples of green gram were further dried in hot air oven at 60 ± 2° C for eight to ten hours for 2-3 day to take all constant weight and processed chemical analysis.

3.8.1.1 Digestion of samples

The plants samples were subjected to wet digestion for estimating various nutrients in the seed and stover. For nutrients other than N, the plant samples were digested in a diacid mixture. Mixture of HNO₃ and HClO₄ was added 10 ml for estimate major and micronutrient. One gram processed sample was taken in digestion tubes and were placed in a low heat digestion chamber (160 °C). Then, the tubes were heated at higher temperature (210 °C) until the production of red NO₂ fumes ceased. The contents were further evaporated until the volume was reduced to about 3 to 5 ml but not to dryness, indicating completion of digestion. After cooling the tubes, the solution was diluted with glass-distilled water and volume was made up to 100 ml volumetric flask. Aliquots of this solution were used for the determination of P, K and other nutrients.

3.8.1.1.1 Nutrient content

Nutrient content *i.e.*, nitrogen, phosphorus and potassium of green gram in seed and stover were analyzed on dry weight basis as per standard procedures given in Table 6.

3.8.1.2 Nutrient uptake (kg ha⁻¹)

Nutrient uptake (N, P and K) by green gram crop was calculated in kg ha⁻¹ in relation to seed and stover yields (kg ha⁻¹) by using the following formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{) in seed} = \frac{\text{Nutrient content in seed (\%)} \times \text{seed yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Nutrient uptake (kg ha}^{-1}\text{) in stover} = \frac{\text{Nutrient content in stover (\%)} \times \text{stover yield (kg ha}^{-1}\text{)}}{100}$$

3.8.2 Protein content

The total nitrogen was estimated by micro-Kjeldahl method as per procedure suggested by Jackson (1976) and the protein was calculated by formula given under (AOAC, 1975).

$$\text{Protein content (\%)} = \text{Kjeldahl nitrogen content (\%)} \times 6.25^*$$

(*based on the assumptions that nitrogen constitutes 16 % of a protein).

Table 6: Methods of plant chemical analysis

Particulars Nutrients	Analytical method	Method employed
Nitrogen	Micro – Kjeldahl method	Jackson ,1976
Phosphorus	Vanado molybdate yellow colour method	Chapman and Pratt, 1978
Potassium	Flame-photometric method	Page <i>et al.</i> , 1982

3.9 Economics of the treatments

3.9.1 Cost of cultivation (₹ ha⁻¹)

Total cost of production incurred to economic produced of the crop is called cost of cultivation. The price of inputs that were prevailing at the time of their use were taken into consideration to work out the cost of cultivation. The cost of cultivation of different treatments was converted to per hectare (₹ ha⁻¹) and given in Appendix - LVII .

3.9.2 Gross monetary return (₹ ha⁻¹)

The market price of economic produce such as grain and stover were taken into consideration to work out the total return *i.e.*, gross monetary return (GMR, ₹ ha⁻¹).

3.9.3 Net monetary return (₹ ha⁻¹)

The net monetary return (NMR) was calculated by deducting the cost of cultivation (₹ ha⁻¹) from gross monetary return (₹ ha⁻¹).

$$\text{NMR (₹ ha}^{-1}\text{)} = \text{Gross monetary return (₹ ha}^{-1}\text{)} - \text{cost of cultivation (₹ ha}^{-1}\text{)}$$

3.9.4 B: C ratio

Benefit cost ratio was worked out as follows:

$$\text{B:C ratio} = \frac{\text{Net monetary returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.10 Meteorological observations

Daily observations on maximum and minimum temperatures, bright sunshine hour's, open pan evaporation, wind speed and rainfall were recorded from the Meteorological Observatory situated at Research Farm, J.N.K.V.V., College of Agriculture, Tikamgarh.

3.11 Statistical analysis

The statistical methods given by Panse and Sukhatme (1961) were used for analysis and interpretation of experimental results. In order to evaluate comparative performance of various treatments, the data was analysed by the technique of

analysis of variance given by Fischer (1950). To judge the significance of the differences between two treatments, critical difference (CD) was worked out by following formula:

$$CD = \sqrt{\frac{\text{Error variance}}{n}} \times \sqrt{2} \times \text{'t' value at 5\%}$$

Where, CD = Critical difference.

n = number of replication of that factor for which CD is to be calculated.

t = the value from Fischer's (1950) table for error degree of freedom at 5 per cent level of significance.

Chapter-4

Results

RESULTS

The results of field study entitled, “**Effect of Integrated Nutrient Management on Growth, Yield, Quality and Economics of Summer Green Gram [*Vigna radiata* (L.) Wilczek]**” conducted during summer 2013 are described in this chapter along with appropriate Tables and Figures.

4.1 General weather condition

Data pertaining to weather conditions prevailed during crop season (summer 2013) are presented in Table 1 and depicted as Fig. 1. The mean weekly maximum temperatures during crop season varied from 32.0 °C to 43.8 °C, while the corresponding values of mean weekly minimum temperature varied from 15.0 °C to 27.6 °C. The mean weekly morning relative humidity (RH) and evening relative humidity varied from 34.1 to 91.0 per cent and 14.4 to 73.3 per cent, respectively. The total amount of rainfall received during crop season was 113.2 mm.

4.2 Pre-harvest observations

4.2.1 Plant population

The data pertaining to plant population (m^{-2}) at 15 DAS and at harvest as influenced by different integrated nutrient management treatments were statistically analysed and presented in Table 7. The analysis of variance of plant population (m^{-2}) at 15 DAS at harvest are given in Appendices I – II. The perusal of data indicated that plant populations observed similar trend both at 15 DAS and at harvest and found statistically non-significant among all the integrated nutrient management treatments.

4.2.2 Plant height (cm)

The data pertaining to plant height at 15, 30, 45 DAS and at harvest as influenced by different integrated nutrient management treatments were statistically analysed and presented in Table 8 and depicted in Fig. 3. The analysis of variance of plant height at 15, 30, 45 DAS and at harvest are given in Appendices III – VI.

Table 7: Effect of different integrated nutrient management treatments on plant population (m^{-2})

Treatments	Plant population (m^{-2})	
	15 DAS	Final
T ₁ : Absolutely control	30.3	29.0
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	32.0	31.0
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	30.7	29.7
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	32.0	30.7
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	32.0	30.7
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	31.0	29.7
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	32.0	30.7
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	30.7	29.3
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	30.3	29.0
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	31.0	29.7
S.Em±	0.56	0.59
CD (P=0.05)	NS	NS

Irrespective of different treatments, it is evident from the data (Table 8) that plant height increased with the advancement in the age of the plant and reached the maximum at harvest. Plant height at 30, 45 DAS and at harvest was significantly affected by different integrated nutrient management treatments. However, all the treatments were failed to affect plant height significantly at 15 DAS. Plant height at 30 DAS (16.7 cm), 45 DAS (39.4 cm) and at harvest (54.8 cm) was recorded significantly greater under T₈ (100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*) as compared to other treatments and found statistically at par with T₄ (16.5 cm, 38.1

cm and 52.5 cm, respectively), T₉ (15.9 cm, 38.0 cm and 53.9 cm, respectively) and T₅ (15.4 cm, 36.9 cm and 51.3 cm, respectively). Similarly, plant height among T₅, T₆ and T₁₀, treatments was also found non-significant at harvest. The significantly lowest plant height of 13.3 cm, 30.4 cm and 41.5 cm at 30, 45 and at harvest, respectively was recorded under T₁ (control).

4.2.3 Number of primary branches (plant⁻¹)

The data pertaining to number of primary branches (plant⁻¹) at 30, 45 DAS and at harvest as influenced by different integrated nutrient management treatments were statistically analysed and given in Table 9. The analysis of variance number of primary branches (plant⁻¹) at 30, 45 DAS and at harvest are given in Appendices VII – IX.

The number of primary branches (plant⁻¹) recorded at 30, 45 DAS and at harvest was significantly affected by different integrated nutrient management treatments. The number of primary branches (plant⁻¹) at 30 DAS (3.73), 45 DAS (5.73) and at harvest (5.80) was registered significantly higher under T₈ (100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*), which was found statistically non-significant with T₄ (3.67, 5.67 and 5.70, respectively), T₉ (3.46, 5.53 and 5.57, respectively) and T₅ (3.43, 5.47 and 5.57, respectively). Similarly, number of primary branches (plant⁻¹) among T₅, T₆ and T₇ treatments did not differ significantly 30, 45 DAS and at harvest. The significantly lowest number of primary branches (plant⁻¹) of 2.93, 4.13 and 4.20 at 30, 45 and at harvest, respectively was recorded under T₁ (control).

4.2.4 Leaf area index (LAI)

The data pertaining to leaf area index (LAI) at 15, 30, 45 DAS and at harvest as influenced by different integrated nutrient management treatments were statistically analysed and summarized in Table 10 and depicted in Fig. 4. The analysis of variance of LAI at 15, 30, 45 DAS and at harvest are given in Appendices X - XIII.

Irrespective of treatments, leaf area index increased steadily up to 45 DAS and declined thereafter towards maturity among all the treatments. The perusal of data indicated that different integrated nutrient management treatments were significantly influenced the LAI at 15, 30, 45 DAS at harvest.

Table 8: Effect of different integrated nutrient management treatments on plant height (cm)

Treatments	Plant height (cm)			
	15 DAS	30 DAS	45 DAS	At harvest
T ₁ : Absolutely control	6.60	13.3	30.4	41.5
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	7.23	14.8	35.9	50.3
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	6.83	14.3	35.7	45.9
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	7.27	16.5	38.1	52.5
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	6.93	15.4	36.9	51.3
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	6.87	14.7	36.6	47.4
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	6.73	14.3	36.8	46.3
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	7.40	16.7	39.4	54.8
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	7.20	15.9	38.0	53.9
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	6.90	15.0	36.7	47.6
S.Em±	0.26	0.32	0.45	0.29
CD (P=0.05)	NS	0.95	1.41	0.87

Leaf area index of 0.20, 0.90, 3.01 and 2.74 at 15, 30, 45 and at harvest was recorded significantly higher under T₈ (100% RDF + vermicompost @ 1.0 t ha⁻¹ + *rhizobium*) as compared to other treatments and found non-significant with T₄ (0.19, 0.87, 2.96 and 2.62, respectively). The significantly lowest LAI of 0.12, 0.64, 2.16 and 1.79 at 15, 30, 45 and at harvest, respectively was recorded under T₁ (control).

4.2.5 Total biomass and its partitioning (g plant⁻¹)

The data related to total biomass (dry matter) and its partitioning to different parts viz., leaves, stem and pods (if any) at 15, 30, 45 DAS and at harvest as influenced by different integrated nutrient management treatments were statistically analysed and presented in the Tables 11-12 and depicted in Figs. 5 - 8.

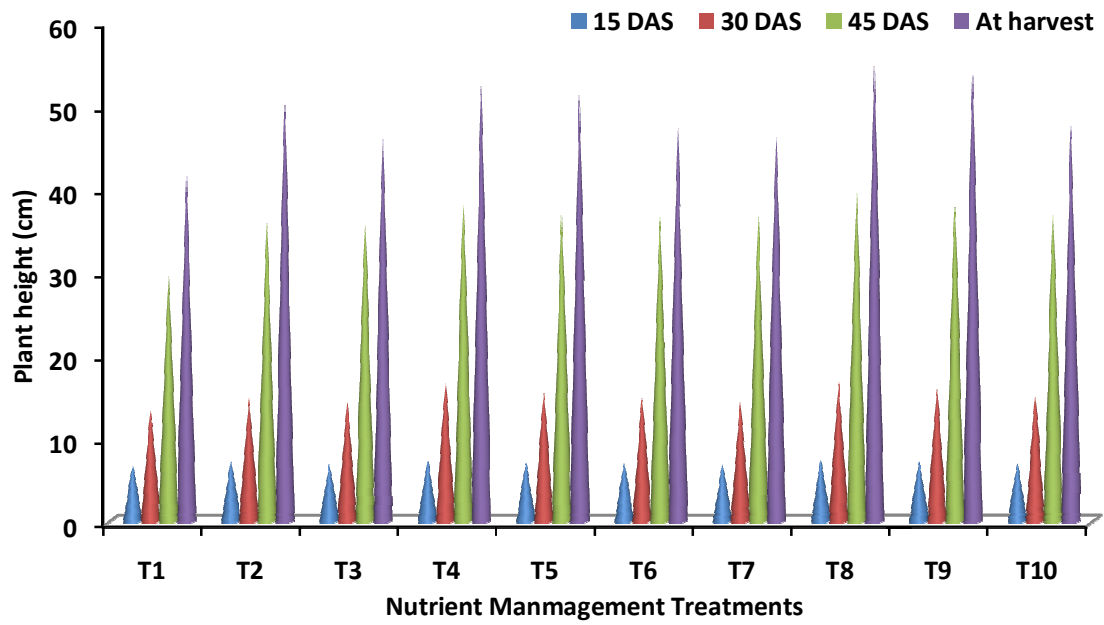


Fig. 3. Effect of different integrated nutrient management treatments on plant height (cm)

Table 9: Effect of different integrated nutrient management treatments on number of primary branches (plant⁻¹)

Treatments	Number of primary branches (cm)		
	30 DAS	45 DAS	At harvest
T ₁ : Absolutely control	2.93	4.13	4.20
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	3.33	5.40	5.42
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	3.13	5.20	5.27
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	3.67	5.67	5.70
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	3.43	5.47	5.57
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	3.27	5.33	5.40
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	3.20	5.27	5.30
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	3.73	5.73	5.80
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	3.46	5.53	5.57
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	3.30	5.37	5.41
S.Em±	0.14	0.20	0.14
CD (P=0.05)	0.40	0.58	0.42

The analysis of variance of total biomass and its partitioning into different plant parts at 15, 30, 45 DAS and at harvest are given in Appendices XIV – XXVII.

Irrespective of treatments, the biomass allocation towards leaves was higher as compared to stem and pods up to harvest. The allocation of biomass to reproductive part (pod) continued to increase from 45 DAS to maturity. The perusal of data in Tables 11-12 indicates that all the integrated nutrient management treatments significantly affected the total dry biomass as well as its partitioning into different parts (leaves, stem and pods) at 15, 30, 45 DAS and at harvest.

At 15 DAS (Table 11), application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) produced significantly higher total dry biomass (0.41 g plant⁻¹)

Table 10: Effect of different integrated nutrient management treatments on leaf area index

Treatments	Leaf area index			
	15 DAS	30 DAS	45 7DAS	At harvest
T ₁ : Absolutely control	0.12	0.64	2.16	1.79
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	0.15	0.80	2.78	2.45
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	0.12	0.72	2.45	2.31
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	0.19	0.87	2.96	2.62
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	0.17	0.82	2.83	2.54
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	0.14	0.78	2.96	2.40
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	0.13	0.78	2.71	2.41
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	0.20	0.90	3.01	2.74
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	0.18	0.83	2.84	2.54
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	0.14	0.79	2.72	2.41
S.Em±	0.01	0.03	0.06	0.07
CD (P=0.05)	0.03	0.09	0.18	0.20

and its partitioning into leaves (0.35 g plant⁻¹) and stem (0.05 g plant⁻¹), which found statistically at par with T₄ (0.38, 0.34 and 0.05 g plant⁻¹, respectively), T₉ (0.34, 0.30 and 0.04, g plant⁻¹, respectively) and T₅ (0.32, 0.27 and 0.04, g plant⁻¹, respectively). T₂ (0.34, 0.29 and 0.05 g plant⁻¹, respectively), However, stem dry biomass did not differ among all treatments. Similarly, total dry biomass and its partitioning into different plant parts did not differ among treatments T₃, T₅, T₆ and T₇ at 15 DAS. The significantly lowest total dry biomass of 0.22 g plant⁻¹ and its partitioning into stem (0.04 g plant⁻¹) was recorded in control (T₁).

At 30 DAS (Table 11), the trend of total dry biomass and its partitioning into leaves and stem was similar as at 15 DAS. Application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) produced significantly higher total dry

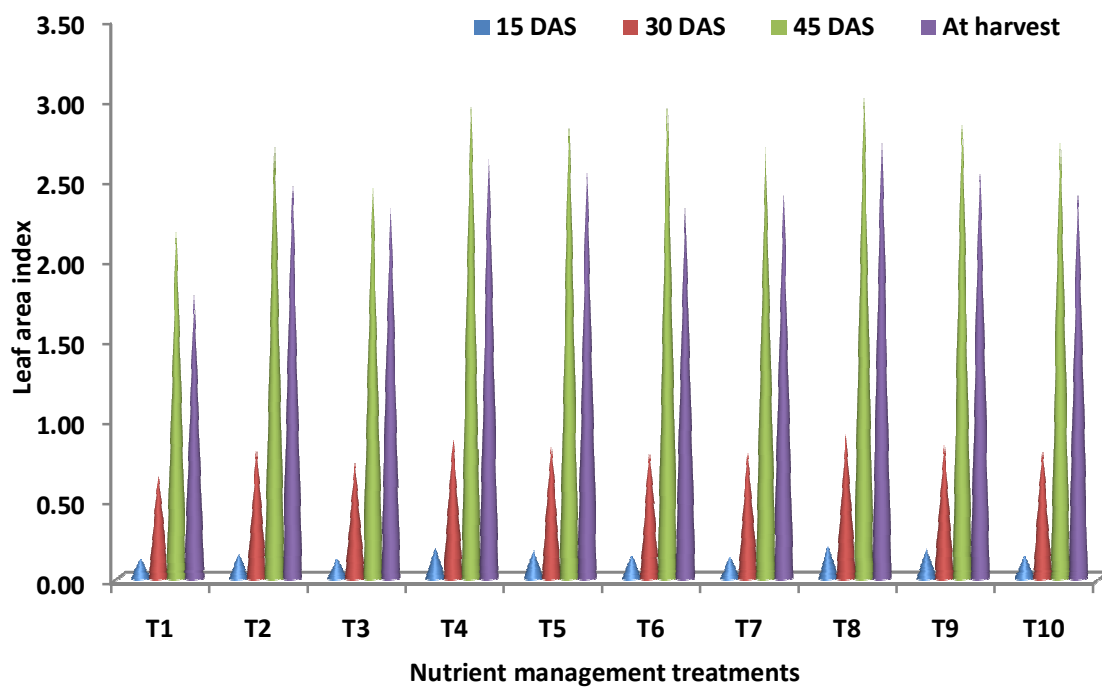


Fig. 4. Effect of different integrated nutrient management treatments on leaf area index

biomass ($1.98 \text{ g plant}^{-1}$) and its partitioning into leaves ($1.57 \text{ g plant}^{-1}$) and stem ($0.41 \text{ g plant}^{-1}$) as compared to other treatments and found statistically at par with T_4 ($1.94, 1.55$ and $0.39 \text{ g plant}^{-1}$, respectively), T_9 ($1.89, 1.51$ and $0.38, \text{ g plant}^{-1}$, respectively) and T_5 ($1.86, 1.50$ and $0.36, \text{ g plant}^{-1}$, respectively). Total dry biomass and its partitioning into leaves and stem among treatments T_3 ($1.65, 1.32$ and $0.33, \text{ g plant}^{-1}$, respectively) T_6 ($1.69, 1.35$ and $0.34, \text{ g plant}^{-1}$, respectively), T_7 ($1.68, 1.35$ and $0.33, \text{ g plant}^{-1}$, respectively) and T_{10} ($1.70, 1.37$ and $0.33, \text{ respectively}$) was also found non-significant. The significantly lowest total dry biomass ($1.39 \text{ g plant}^{-1}$) and its partitioning into leaves ($1.19 \text{ g plant}^{-1}$) and stem ($0.20 \text{ g plant}^{-1}$) was recorded in control (T_1).

At 45 DAS and at harvest, trend of total dry biomass and its partitioning into leaves, stem and pods was similar as observed at 15 and 30 DAS (Table 12). At 45 DAS and at harvest, application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) recorded significantly higher total dry biomass (12.4 and $19.9 \text{ g plant}^{-1}$) and its partitioning into leaves (9.56 and $9.88 \text{ g plant}^{-1}$), stem (2.08 and $3.75 \text{ g plant}^{-1}$) and pods (0.80 and $6.31 \text{ g plant}^{-1}$) as compared to other treatments and found statistically at par with T_4, T_9 and T_5 . The significantly lowest total dry biomass (9.35 and $13.5 \text{ g plant}^{-1}$) and its partitioning into leaves (7.31 and $8.29 \text{ g plant}^{-1}$), stem (1.77 and $2.08 \text{ g plant}^{-1}$) and pods (0.27 and $3.14 \text{ g plant}^{-1}$) at 45 DAS and at harvest, respectively was recorded in control (T_1).

4.2.6 Number of root nodules (plant^{-1})

The data related to number of nodules (plant^{-1}) at 30, 45 and 60 DAS as influenced by different integrated nutrient management treatments were statistically analysed and presented in Table 13. The analysis of variances of number of nodules (plant^{-1}) at 30, 45 and 60 DAS are given in Appendices XXVIII – XXX.

Irrespective of treatments, number of nodules (plant^{-1}) increased up to 45 DAS and declined thereafter at 60 DAS among all the treatments. The perusal of data in Table 15 indicates that number of nodules (plant^{-1}) was differed significantly among all the integrated nutrient management treatments and followed the same trend at 30, 45 and 60 DAS and. The application of FYM @ 4.0 t ha^{-1} (T_3) registered significantly more number of root nodules plant^{-1} ($10.5, 18.5$ and 16.3) followed by T_7 ($9.8, 17.9$ and 15.8), T_6 ($8.8, 17.1$ and 15.3), T_{10} ($8.5, 16.8$ and 14.3), T_5 ($8.3, 15.6$

Table 11: Effect of different integrated nutrient management treatments on total biomass and its partitioning (g plant⁻¹) at 15 and 30 DAS

Treatments	15 DAS			30 DAS		
	Leaves	Stem	Total	Leaves	Stem	Total
T₁ : Absolutely control	0.18	0.04	0.22	1.19	0.20	1.39
T₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	0.26	0.05	0.31	1.45	0.34	1.79
T₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	0.24	0.04	0.27	1.32	0.33	1.65
T₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	0.34	0.05	0.38	1.55	0.39	1.94
T₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	0.27	0.04	0.32	1.50	0.36	1.86
T₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	0.26	0.04	0.30	1.35	0.34	1.69
T₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	0.24	0.04	0.28	1.35	0.33	1.68
T₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	0.35	0.05	0.41	1.57	0.41	1.98
T₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	0.30	0.04	0.34	1.51	0.38	1.89
T₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	0.27	0.04	0.31	1.37	0.36	1.73
S Em±	0.02	0.01	0.02	0.03	0.01	0.4
CD (P=0.05)	0.06	NS	0.70	0.09	0.02	0.11

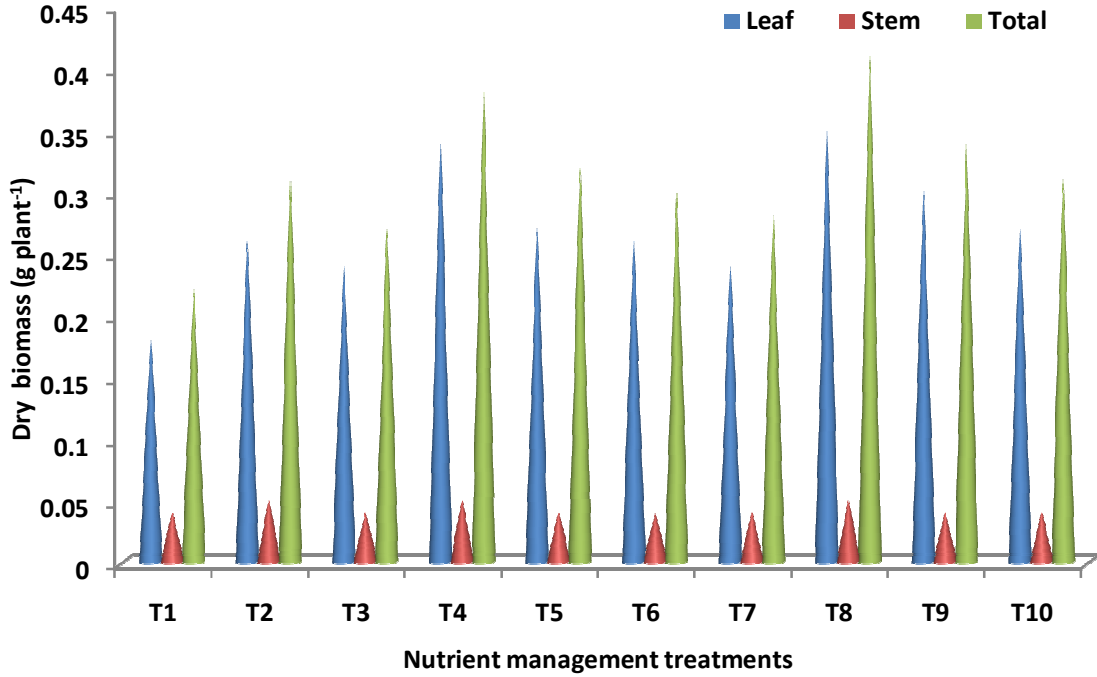


Fig. 5: Effect of different integrated nutrient management treatments on total dry biomass and its partitioning (g plant⁻¹) at 15 DAS

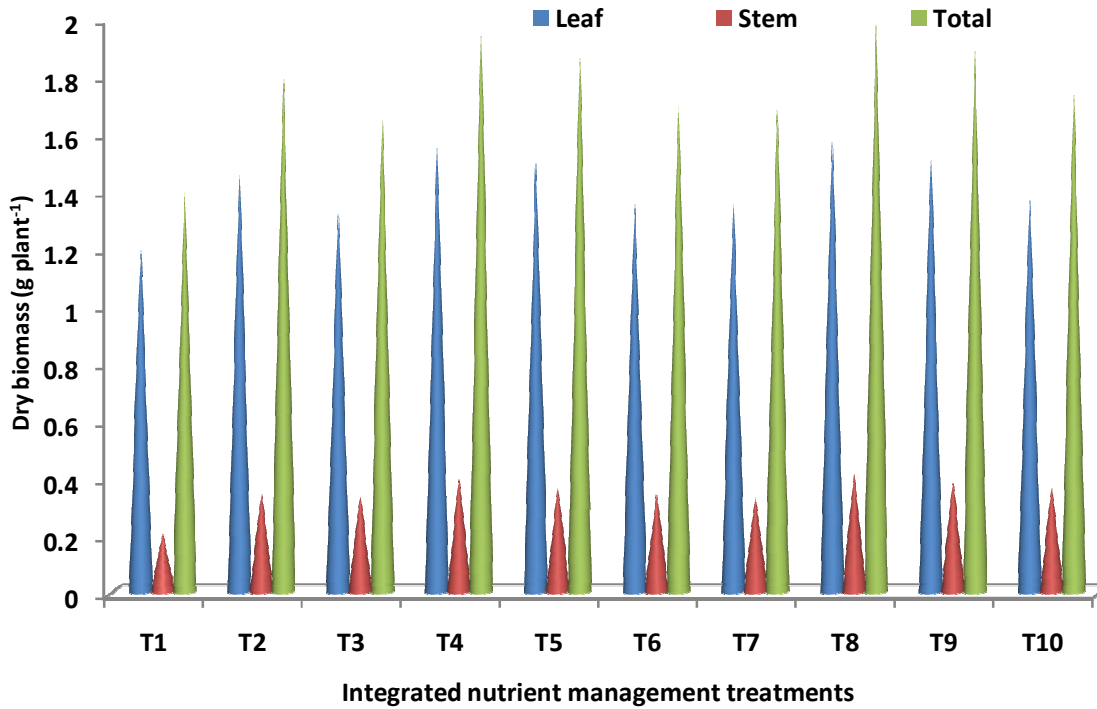


Fig. 6: Effect of different integrated nutrient management treatments on total dry biomass and its partitioning (g plant⁻¹) at 30 DAS

Table 12: Effect of different integrated nutrient management treatments on total biomass and its partitioning (g plant⁻¹) at 45 DAS and harvest

Treatments	45 DAS				At harvest			
	Leaves	Stem	Pod	Total	Leaves	Stem	Pod	Total
T₁ : Absolutely control	7.31	1.77	0.27	9.35	8.29	2.08	3.14	13.5
T₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	9.31	1.95	0.56	11.8	9.36	3.11	5.43	17.9
T₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	7.94	1.81	0.28	10.0	8.94	2.67	4.26	15.9
T₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	9.51	2.07	0.78	12.4	9.84	3.70	6.17	19.7
T₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	9.46	2.03	0.77	12.3	9.48	3.58	6.01	19.1
T₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	8.23	1.90	0.44	10.6	9.30	2.80	4.31	16.4
T₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	8.22	1.86	0.40	10.5	9.28	2.79	4.27	16.3
T₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	9.56	2.08	0.80	12.4	9.88	3.75	6.31	19.9
T₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	9.49	2.05	0.78	12.3	9.56	3.61	6.10	19.3
T₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	8.27	1.98	0.47	10.7	9.37	2.85	4.39	16.6
S Em±	0.17	0.06	0.01	0.18	0.19	0.07	0.13	0.24
CD (P=0.05)	0.52	0.14	0.03	0.54	0.58	0.21	0.38	0.71

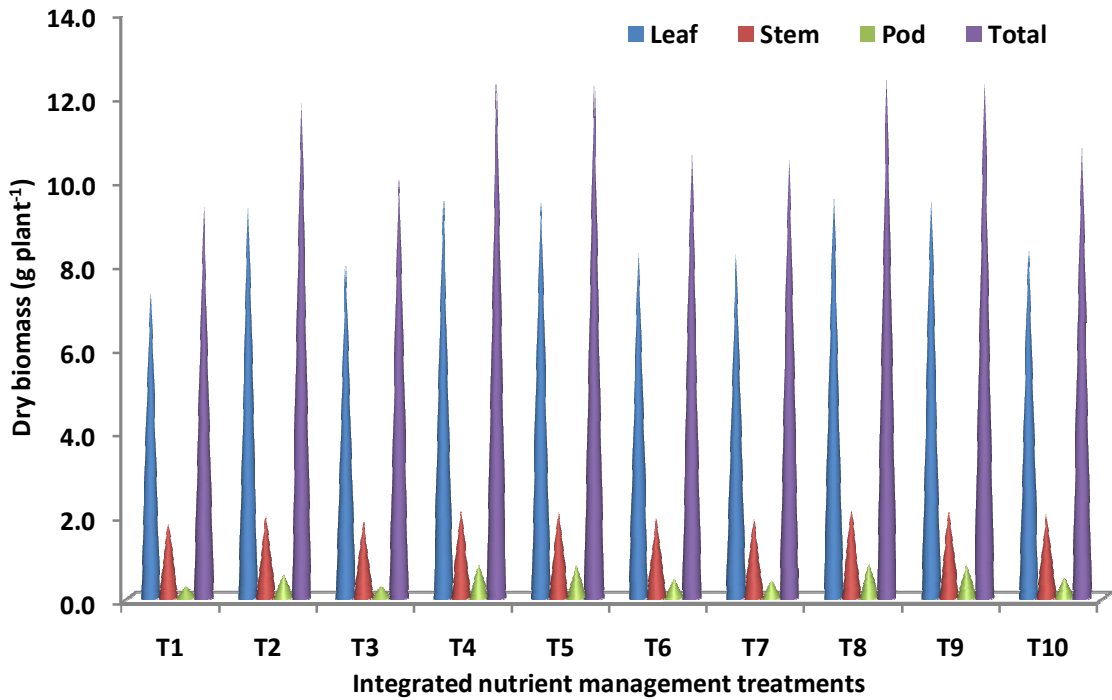


Fig. 7: Effect of different integrated nutrient management treatments on total dry biomass and its partitioning (g plant⁻¹) at 45 DAS

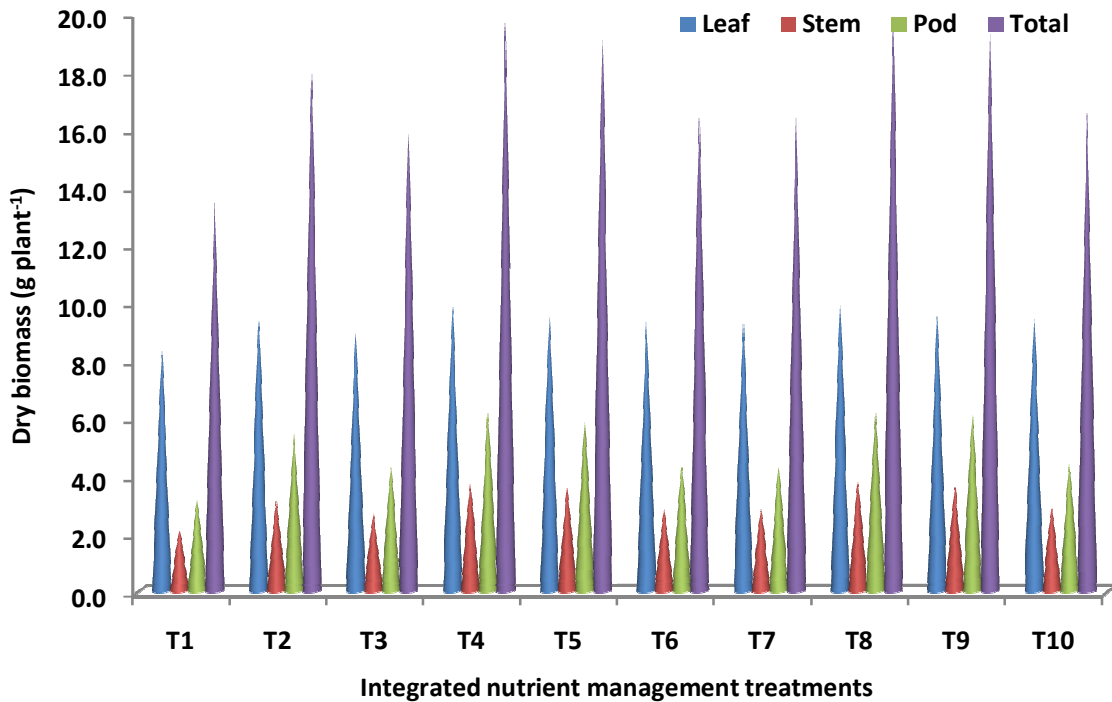


Fig. 8: Effect of different integrated nutrient management treatments on total dry biomass and its partitioning (g plant⁻¹) at harvest

and 13.9), T₉ (7.8, 15.1 and 13.4), T₁ (7.3, 14.5 and 13.1), T₄ (6.9, 14.2 and 12.4), T₈ (6.7, 13.8 and 11.6) and the lowest number of root nodules plant⁻¹ of 6.3, 13.2 and 11.4 was recorded with the application of RDF (20:60:20 kg N, P₂O₅ and K₂O ha⁻¹ + *Rhizobium* (T₂) at 30, 45 and 60 DAS, respectively. However, number of root nodules (plant⁻¹) between treatments T₃ and T₇ and between T₇ and T₆ did not differ significantly. Similarly, number of root nodules (plant⁻¹) among treatments T₅, T₆ and T₁₀ was also found non-significant.

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

The data pertaining to dry weight of nodules (mg plant⁻¹) at 30, 45 and 60 DAS as influenced by different integrated nutrient management treatments were statistically analysed and presented in the Table 13. The analysis of variance of dry weight of nodules (mg plant⁻¹) at 30, 45 and 60 DAS are given in Appendices XXXI – XXXIII.

Irrespective of treatments, dry weight of nodules (mg plant⁻¹) increased up to 45 DAS and declined thereafter at 60 DAS among all the treatments. The perusal of data in Table 13 reveals that all the integrated nutrient management treatments significantly affected the dry weight of nodules (mg plant⁻¹) at 30, 45 and 60 DAS and followed the same trend as for number of nodules (plant⁻¹).

The application of FYM @ 4.0 t ha⁻¹ (T₃) recorded significantly higher dry weight of root nodules (19.1, 37.0 and 32.1 mg plant⁻¹) followed by T₇ (14.6, 35.6 and 30.6 mg plant⁻¹), T₆ (14.1, 34.2 and 29.5 mg plant⁻¹), T₁₀ (13.5, 33.9 and 29.2 mg plant⁻¹), T₅ (13.3, 33.8 and 27.9 mg plant⁻¹), T₉ (13.2, 33.5 and 27.8 mg plant⁻¹), T₁ (12.9, 33.4 and 27.8 mg plant⁻¹), T₄ (12.5, 32.5 and 25.0 mg plant⁻¹), T₈ (11.3, 30.8 and 24.1 mg plant⁻¹) and significantly the lowest (10.4, 30.7 and 23.7 mg plant⁻¹) was recorded in treatment T₂ (RDF (20:60:20 kg N, P₂O₅ and K₂O ha⁻¹ + *Rhizobium*) at 30, 45 and 60 DAS, respectively. However, dry weight of root nodules (mg plant⁻¹) between treatments T₁ and T₄, between T₄ and T₅, between T₆ and T₇ and between T₉ and T₁₀ did not differ significantly at 30 and 45 DAS. Similarly, dry weight of root nodules (mg plant⁻¹) between treatments T₆ and T₇ was also found non-significant at 60 DAS.

Table 13: Effect of different integrated nutrient management treatments on number of root nodules (plant⁻¹) and dry weight of root nodules (mg plant⁻¹)

Treatments	Number of root nodules (plant ⁻¹)			Dry weight of root nodules (mg plant ⁻¹)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T ₁ : Absolutely control	7.3	14.5	13.1	12.9	33.4	27.8
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	6.3	13.2	11.4	10.4	30.7	23.7
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	10.5	18.5	16.3	19.1	37.0	32.1
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	6.9	14.2	12.1	12.5	32.5	25.0
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	8.3	15.6	13.9	13.3	33.8	27.9
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	8.8	17.1	15.3	14.1	34.2	29.5
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	9.8	17.9	15.8	14.6	35.6	30.6
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	6.7	13.8	11.6	11.3	30.8	24.1
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	7.8	15.1	13.4	13.2	33.5	27.8
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	8.5	16.8	14.3	13.5	33.	29.2
S Em±	0.38	0.32	0.45	0.26	0.38	0.31
CD (P=0.05)	1.15	0.96	1.33	0.76	1.15	0.94

4.3 Post-harvest observations

4.3.1 Yield attributes and yield

In the final analysis at the time of harvest, the yield attributes viz., number of pods (plant^{-1}), number of seeds (pod^{-1}) and 1000-seeds weight (g) were recorded.

4.3.1.1 Number of pods (plant^{-1})

The data pertaining to number of pods (plant^{-1}) as influenced by different integrated nutrient management treatments was statistically analysed and given in Table 14. The analysis of variance of number of pods (plant^{-1}) are given in Appendix – XXXIV.

The perusal of data in Table 14 clearly reveals that the number of pods (plant^{-1}) was significantly affected by different integrated nutrient management treatments. The application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) produced significantly higher number of pods (13.5 plant^{-1}) as compared to other treatments and found statistically at par with T_4 (13.3 plant^{-1}), T_9 (12.9 plant^{-1}) and T_5 (12.9 plant^{-1}). The significantly lowest ($10.6 \text{ pods plant}^{-1}$) was recorded in control (T_1). The number of pods (plant^{-1}) among treatments T_3 ($11.0 \text{ pods plant}^{-1}$), T_6 ($11.3 \text{ pods plant}^{-1}$), T_7 ($11.1 \text{ pods plant}^{-1}$) and T_{10} ($11.4 \text{ pods plant}^{-1}$) did not differ significantly.

4.3.1.2 Number of seeds (pod^{-1})

The data recorded on number of seeds (pod^{-1}) as influenced by different integrated nutrient management treatments was statistically analysed and summarized in Table 14. The analysis of variance of number of seeds (pod^{-1}) is given in Appendix – XXXV.

The perusal of data in Table 14 clearly indicates that the number of seeds (pod^{-1}) was significantly affected by different integrated nutrient management treatments and followed the same trend as in number of pods (plant^{-1}). The application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) recorded significantly higher number of seeds (10.6 pod^{-1}), which was found statistically at par with T_4 (10.4 pod^{-1}), T_2 (10.2 pod^{-1}), T_9 (10.2 pod^{-1}), T_5 (10.1 pod^{-1}), T_{10} (9.9 pod^{-1}), T_6 (9.8 pod^{-1}), T_7 (9.8 pod^{-1}) and T_3 (9.6 pod^{-1}). The significantly lowest seeds (8.9 pods^{-1}) was recorded in control (T_1).

4.3.1.3 1000-seeds weight (g)

The data pertaining to 1000-seeds weight (g) as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 14. The analysis of variance of 1000-seeds weight is given in Appendix – XXXVI.

The perusal of data in Table 14 clearly reveals that all the integrated nutrient management treatments was significantly affected by different integrated nutrient management treatments and followed the same trend as in number of pods (plant^{-1}). The application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) exhibited significantly higher 1000-seeds weight (36.6 g), which was found statistically at par with T_4 (36.4), T_9 (36.3 g), T_5 (36.1 g), T_2 (36.1 g), T_6 (35.7 g plant^{-1}), T_7 (35.3 g plant^{-1}) and T_{10} (36.1 g plant^{-1}). The significantly lowest 1000-seeds weight (34.4 g) was recorded in control (T_1) and found statistically at par with T_3 (34.5 g).

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

The data pertaining to seed yield (kg ha^{-1}) as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 14 and depicted in Fig. 9. The analysis of variance of seed yield (kg ha^{-1}) is given in Appendix – XXXVII.

The perusal of data in Table 14 reveals that the seed yield (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments. The seed yield of $1187.6 \text{ kg ha}^{-1}$ was recorded significantly higher with application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8), which found statistically at par with T_4 ($1151.3 \text{ kg ha}^{-1}$), T_9 ($1134.7 \text{ kg ha}^{-1}$) and T_5 ($1107.2 \text{ kg ha}^{-1}$). Similarly, the seed yield among treatments T_3 ($1023.9 \text{ kg ha}^{-1}$), T_5 ($1107.2 \text{ kg ha}^{-1}$), T_6 ($1061.3 \text{ kg ha}^{-1}$), T_7 ($1038.4 \text{ kg ha}^{-1}$) and T_{10} ($1074.5 \text{ kg ha}^{-1}$) did not differ significantly. The significantly lowest seed yield of 767.5 kg ha^{-1} was recorded in control (T_1).

4.3.2.7 Stover yield (kg ha^{-1})

The data pertaining to stover yield (kg ha^{-1}) as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 14 and depicted in Fig. 9. The analysis of variance of stover yield (kg ha^{-1}) is given in Appendix – XXXVIII.

It is evident from the data in Table 14 that all the integrated nutrient management treatments were failed to show significant affect on stover yield (kg ha^{-1}). However, numerically, the value of stover yield (kg ha^{-1}) was registered higher in T_8 ($3099.4 \text{ kg ha}^{-1}$) and the lowest value of stover yield ($2681.8 \text{ kg ha}^{-1}$) was recorded under control (T_1).

4.3.2.8 Biological yield (kg ha^{-1})

The data pertaining to biological yield (kg ha^{-1}) as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 14 and depicted in Fig. 9. The analysis of variance of biological yield (kg ha^{-1}) is given in Appendix – XXXIX.

The perusal of data in Table 14 reveals that the biological yield (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments. The biological yield of $4426.9 \text{ kg ha}^{-1}$ was recorded significantly higher with application of 100% RDF + FYM @ 2.0 t ha^{-1} + *Rhizobium* (T_4), which found statistically at par with T_8 ($4390.7 \text{ kg ha}^{-1}$), T_9 ($4266.4 \text{ kg ha}^{-1}$), T_2 ($4198.0 \text{ kg ha}^{-1}$), T_5 ($4149.7 \text{ kg ha}^{-1}$) and T_{10} ($4130.6 \text{ kg ha}^{-1}$). The significantly lowest biological yield of $3444.1 \text{ kg ha}^{-1}$ was recorded in control (T_1).

4.3.2.9 Harvest index (%)

The data pertaining to harvest index (%) as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 14. The analysis of variance of harvest index (%) is given in Appendix – XL.

The perusal of data in Table 14 reveals that the harvest index (%) was significantly affected by different integrated nutrient management treatments. The harvest index of 27.2% was recorded significantly higher with application of 100% vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8), which was found statistically at par with all other treatments except T_1 , which had the significantly lowest harvest index of 22.2%.

4.4 Quality

4.4.1 Protein content (%) in seed and straw

The data pertaining to protein content (%) in seed and straw as influenced by different integrated nutrient management treatments was statistically analysed and

Table 14: Effect of different integrated nutrient management treatments on yield attributes and yields

Treatments	Number of pods (plant ⁻¹)	Number of seeds (pod ⁻¹)	1000 seed weight (g)	Seed yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest Index (%)
T ₁ : Absolutely control	10.6	8.9	34.4	767.6	2676.5	3444.1	22.2
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	11.4	10.2	36.1	1086.9	3111.1	4198.0	26.1
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	11.0	9.6	34.5	1023.9	2878.9	3902.8	26.2
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	13.3	10.4	36.4	1151.3	3275.6	4426.9	27.0
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	12.9	10.1	36.1	1107.2	3042.5	4149.7	26.8
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	11.3	9.8	35.7	1061.3	2944.7	4006.0	26.5
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	11.1	9.8	35.3	1038.4	2949.8	3988.2	26.3
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	13.5	10.6	36.6	1187.6	3203.1	4390.7	27.2
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	12.9	10.2	36.3	1134.7	3131.7	4266.4	26.7
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	11.4	9.9	36.1	1074.5	3056.0	4130.6	26.0
S Em±	0.33	0.35	0.49	23.9	91.1	90.6	0.47
CD (P=0.05)	0.97	1.06	1.47	71.4	NS	271.0	1.36

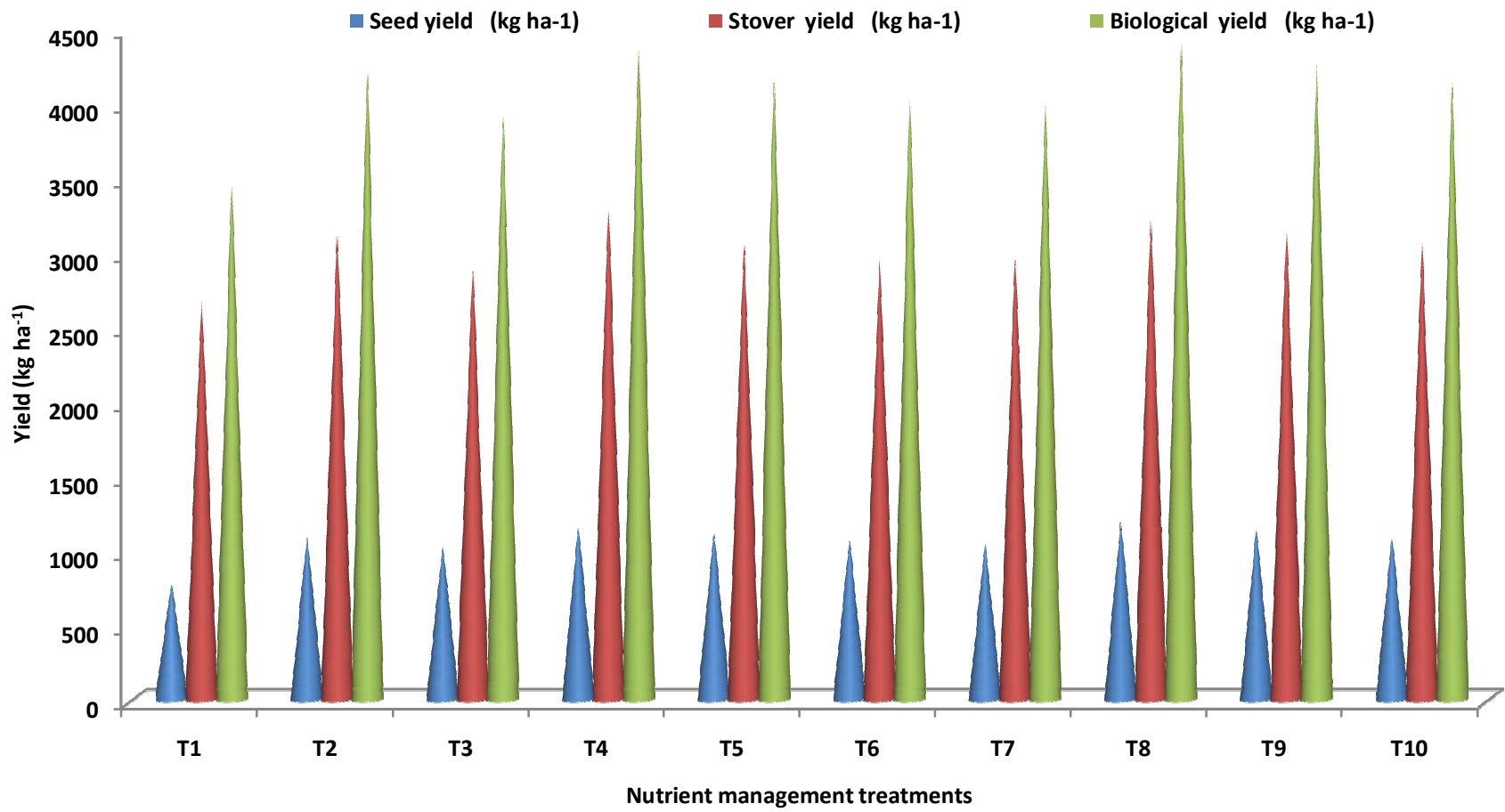


Fig. 9: Effect of different integrated nutrient management treatments on final yields (kg ha⁻¹)

presented in Table 15. The analysis of variance of protein content is given in Appendices XLI – XLII.

It is evident from the data in Table 15 that all the integrated nutrient management treatments were failed to show significant affect on protein content (%) in seed. However, protein content (%) in straw was significantly affected by different integrated nutrient management treatments.

The perusal of data in Table 15 clearly reveals that the application of 50% RDF + vermicompost @ 1.0 t ha⁻¹ (T₁₀) recorded significantly higher protein content in straw (6.77%), which found statistically at par with T₆ (6.73%), T₇ (6.63%), T₅ (6.60%), T₃ (6.56%), T₄ (6.48%), T₉ (6.48%) and T₈ (6.46%). The significantly lowest value of protein content (6.29%) was recorded under control (T₁) followed by T₂ (6.42%).

4.4.2. Protein yield (kg ha⁻¹) in seed and straw

The data related to protein yield (kg ha⁻¹) in seed and straw as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 15. The analysis of variance of protein yield (kg ha⁻¹) in seed and straw is given in Appendices XLIII-XLIV.

The perusal of data in Table 15 reveals that protein yield (kg ha⁻¹) in seed and straw was significantly affected by different nutrient management treatments.

The protein yield of 262.1 kg ha⁻¹ in seed was recorded significantly higher with the application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) followed by T₄ (249.7 kg ha⁻¹), T₉ (245.9 kg ha⁻¹), T₅ (237.6 kg ha⁻¹), T₂ (235.7 kg ha⁻¹), T₁₀ (229.5 kg ha⁻¹), T₆ (225.3 kg ha⁻¹), T₇ (217.6 kg ha⁻¹), T₃ (214.1 kg ha⁻¹) and significantly lowest protein yield of 164.4 kg ha⁻¹ in control (T₁).

The protein yield of 211.2 kg ha⁻¹ in straw was recorded significantly higher with application of 100% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium* (T₄) followed by T₁₀ (206.8 kg ha⁻¹), T₈ (206.5 kg ha⁻¹), T₉ (203.0 kg ha⁻¹), T₅ (201.1 kg ha⁻¹), T₂ (200.1 kg ha⁻¹), T₆ (198.0 kg ha⁻¹), T₇ (195.9 kg ha⁻¹), T₃ (189.0 kg ha⁻¹) and significantly the lowest protein yield of 168.2 kg ha⁻¹ in control (T₁). The protein yield (kg ha⁻¹) in straw between treatments T₆ and T₇, between T₈ and T₁₀ and between T₅ and T₉ did not differ significantly.

Table 15: Effect of different integrated nutrient management treatments on protein content and protein yield

Treatments	Quality parameters			
	Protein content (%)		Protein yield (kg ha ⁻¹)	
	Seed	Straw	Seed	Straw
T ₁ : Absolutely control	21.4	6.31	164.4	168.2
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	21.6	6.42	235.7	200.1
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	20.9	6.56	214.1	189.0
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	21.7	6.48	249.7	211.2
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	21.5	6.60	237.6	201.1
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	21.3	6.73	225.3	198.0
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	21.0	6.63	217.6	195.9
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	22.0	6.46	262.1	206.5
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	21.7	6.48	245.9	203.0
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	21.4	6.77	229.5	206.8
S.Em±	0.45	0.10	1.01	1.00
CD (P=0.05)	NS	0.31	3.03	3.00

4.5 Nutrients uptakes (kg ha⁻¹)

4.5.1 Nitrogen uptake

The data pertaining to nitrogen uptakes in seed, straw and total nitrogen uptake (seed + straw) as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 16. The analysis of variance of nitrogen uptake in seed, straw and total nitrogen uptake (seed + straw) is given in Appendices XLV-XLVII.

4.5.1.1 Nitrogen uptake in seed

The perusal of data in Table 16 reveals that nitrogen uptake in seed (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments. The nitrogen uptake of 41.9 kg ha^{-1} in seed was recorded significantly higher with application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) followed by T_4 (40.0 kg ha^{-1}), T_9 (39.3 kg ha^{-1}), T_5 (38.0 kg ha^{-1}), T_2 (37.7 kg ha^{-1}), T_{10} (36.7 kg ha^{-1}), T_6 (36.0 kg ha^{-1}), T_7 (34.8 kg ha^{-1}), T_3 (34.2 kg ha^{-1}) and significantly the lowest nitrogen uptake of 26.3 kg ha^{-1} in control (T_1).

4.5.1.2 Nitrogen uptake in straw

The perusal of data in Table 16 reveals that nitrogen uptake in straw (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments. The nitrogen uptake of 33.8 kg ha^{-1} in straw was recorded significantly higher with application of 100% RDF + FYM @ 2.0 t ha^{-1} + *Rhizobium* (T_8) followed by T_{10} (33.1 kg ha^{-1}), T_8 (33.0 kg ha^{-1}), T_9 (32.5 kg ha^{-1}), T_5 (32.2 kg ha^{-1}), T_2 (32.0 kg ha^{-1}), T_6 (31.7 kg ha^{-1}), T_7 (31.4 kg ha^{-1}), T_3 (30.2 kg ha^{-1}) and significantly the lowest nitrogen uptake of 26.9 kg ha^{-1} in control (T_1). However, nitrogen uptake in straw among treatments T_2 , T_5 , T_6 and T_9 did not differ significantly. Similarly, nitrogen uptake in straw among treatments T_8 , T_9 and T_{10} was also found non-significant.

4.5.1.3 Total nitrogen uptake (seed + straw)

The perusal of data in Table 16 reveals that total nitrogen uptake (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments. The application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) registered significantly higher total nitrogen uptake (74.9 kg ha^{-1}) followed by T_4 (73.7 kg ha^{-1}), T_9 (71.8 kg ha^{-1}), T_5 (70.2 kg ha^{-1}), T_{10} (69.8 kg ha^{-1}), T_2 (69.7 kg ha^{-1}), T_6 (67.7 kg ha^{-1}), T_7 (66.2 kg ha^{-1}), T_3 (64.5 kg ha^{-1}) and significantly the lowest total nitrogen uptake of 53.2 kg ha^{-1} in control (T_1).

4.5.2 Phosphorus uptake

The data pertaining to phosphorus uptake in seed, straw and total phosphorus uptake (seed + straw) as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 16. The analysis of variance of phosphorus uptake in seed, straw and total phosphorus uptake (seed + straw) is given in Appendices XLVIII - L.

4.5.2.1 Phosphorus uptake in seed

The perusal of data in Table 16 reveals that phosphorus uptake in seed (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments. The application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) exhibited significantly higher phosphorus uptake (4.12 kg ha^{-1}) in seed followed by T_4 (3.86 kg ha^{-1}), T_9 (3.77 kg ha^{-1}), T_5 (3.66 kg ha^{-1}), T_2 (3.61 kg ha^{-1}), T_{10} (3.50 kg ha^{-1}), T_6 (3.44 kg ha^{-1}), T_7 (3.34 kg ha^{-1}), T_3 (3.29 kg ha^{-1}) and significantly the lowest phosphorus uptake of 2.54 kg ha^{-1} in control (T_1).

4.5.2.2 Phosphorus uptake in straw

The perusal of data in Table 16 reveals that phosphorus uptake in straw (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments and followed the same trend as in phosphorus uptake in seed. The phosphorus uptake of 4.38 kg ha^{-1} in straw was recorded significantly higher with application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) followed by T_4 (4.33 kg ha^{-1}), T_2 (4.00 kg ha^{-1}), T_9 (3.89 kg ha^{-1}), T_5 (3.73 kg ha^{-1}), T_{10} (3.73 kg ha^{-1}), T_6 (3.54 kg ha^{-1}), T_7 (3.44 kg ha^{-1}), T_3 (3.23 kg ha^{-1}) and significantly the lowest phosphorus uptake of 3.01 kg ha^{-1} in control (T_1). However, phosphorus uptake in straw between treatments T_8 and T_4 did not differ significantly.

4.5.2.3 Total phosphorus uptake (seed + straw)

The perusal of data in Table 16 reveals that total phosphorus uptake (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments. The application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) registered significantly higher total phosphorus uptake (8.50 kg ha^{-1}) followed by T_4 (8.19 kg ha^{-1}), T_9 (7.65 kg ha^{-1}), T_2 (7.61 kg ha^{-1}), T_5 (7.39 kg ha^{-1}), T_{10} (7.23 kg ha^{-1}), T_6 (6.98 kg ha^{-1}), T_7 (6.78 kg ha^{-1}), T_3 (6.52 kg ha^{-1}) and significantly the lowest total phosphorus uptake of 5.55 kg ha^{-1} in control (T_1).

4.5.3 Potassium uptake

The data pertaining to potassium uptake in seed, straw and total phosphorus uptake (seed + straw) as influenced by different integrated nutrient management treatments was statistically analysed and presented in Table 16. The analysis of variance of potassium uptake in seed, straw and total potassium uptake (seed + straw) is given in Appendices LI - LIII.

4.5.3.1 Potassium uptake in seed

The perusal of data in Table 16 reveals that potassium uptake in seed (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments. The application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) exhibited significantly higher potassium uptake (9.79 kg ha^{-1}) in seed followed by T_4 (9.35 kg ha^{-1}), T_9 (8.98 kg ha^{-1}), T_5 (8.78 kg ha^{-1}), T_2 (8.78 kg ha^{-1}), T_{10} (8.44 kg ha^{-1}), T_6 (8.36 kg ha^{-1}), T_7 (8.11 kg ha^{-1}), T_3 (7.89 kg ha^{-1}) and significantly the lowest potassium uptake of 6.15 kg ha^{-1} in control (T_1).

4.5.3.2 Potassium uptake in straw

The perusal of data in Table 16 reveals that potassium uptake in straw (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments and followed the same trend as in potassium uptake in seed. The potassium uptake of 10.9 kg ha^{-1} in straw was recorded significantly higher with application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) followed by T_4 (10.7 kg ha^{-1}), T_2 (10.3 kg ha^{-1}), T_9 (10.1 kg ha^{-1}), T_5 (9.63 kg ha^{-1}), T_{10} (9.40 kg ha^{-1}), T_6 (8.97 kg ha^{-1}), T_7 (8.89 kg ha^{-1}), T_3 (8.49 kg ha^{-1}) and significantly the lowest potassium uptake of 8.02 kg ha^{-1} in control (T_1). However, potassium uptake in straw between treatments T_8 and T_4 did not differ significantly.

4.5.3.3 Total potassium uptake (seed + straw)

The perusal of data in Table 16 reveals that total potassium uptake (kg ha^{-1}) was significantly affected by different integrated nutrient management treatments and followed the same trend as in seed and straw. The application of 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) registered significantly higher total potassium uptake (20.7 kg ha^{-1}) followed by T_4 (20.1 kg ha^{-1}), T_2 (19.1 kg ha^{-1}), T_9 (19.0 kg ha^{-1}), T_5 (18.4 kg ha^{-1}), T_{10} (17.8 kg ha^{-1}), T_6 (17.3 kg ha^{-1}), T_7 (17.0 kg ha^{-1}), T_3 (16.4 kg ha^{-1}) and significantly the lowest total potassium uptake of 14.2 kg ha^{-1} in control (T_1).

4.6 Economics

The data pertaining to cost of cultivation (Appendix - LVII), gross monetary return (GMR), net monetary return (NMR) and B:C of green gram as influenced by different integrated nutrient management treatments was statistically analysed and

Table 16: Effect of different integrated nutrient management treatments on nutrients uptake (kg ha⁻¹)

Treatments	Nutrients uptake (kg ha ⁻¹)								
	In seed			In straw			Total (seed + straw)		
	N	P	K	N	P	K	N	P	K
T ₁ : Absolutely control	26.3	2.54	6.15	26.9	3.01	8.02	53.2	5.55	14.2
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	37.7	3.61	8.78	32.0	4.00	10.3	69.7	7.61	19.1
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	34.2	3.29	7.89	30.2	3.23	8.49	64.5	6.52	16.4
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	40.0	3.86	9.35	33.8	4.33	10.7	73.7	8.19	20.1
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	38.0	3.66	8.78	32.2	3.73	9.63	70.2	7.39	18.4
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	36.0	3.44	8.36	31.7	3.54	8.97	67.7	6.98	17.3
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	34.8	3.34	8.11	31.4	3.44	8.89	66.2	6.78	17.0
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	41.9	4.12	9.79	33.0	4.38	10.9	74.9	8.50	20.7
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	39.3	3.77	8.98	32.5	3.89	10.06	71.8	7.65	19.0
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	36.7	3.50	8.44	33.1	3.73	9.40	69.8	7.23	17.8
S.Em±	0.16	0.02	0.02	0.19	0.02	0.06	0.20	0.02	0.06
CD (P=0.05)	0.48	0.06	0.06	0.58	0.05	0.16	0.59	0.07	0.17

presented in Table 17 and depicted in Fig. 10. The analysis of variances of GMR, NMR and B:C are given in Appendices LIV – LVI.

4.7.1 Gross monetary return (₹ ha⁻¹)

The perusal of data in Table 17 reveals that gross monetary return (GMR) was significantly affected by different integrated nutrient management treatments. The 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) recorded the significantly higher GMR (₹ 62858 ha⁻¹) as compared to other integrated nutrient management treatments and found statistically at par with T₄ (₹ 60842 ha⁻¹), T₉ (₹ 59868 ha⁻¹) and T₅ (₹ 58404 ha⁻¹). Similarly, treatments T₂ (₹ 57456 ha⁻¹), T₃ (₹ 54074 ha⁻¹), T₆ (₹ 56011 ha⁻¹), T₇ (₹ 54871 ha⁻¹) and T₁₀ (₹ 56783 ha⁻¹) were also found non-significant among themselves. The significantly lowest GMR (₹ 41055 ha⁻¹) was recorded under control (T₁).

4.7.2 Net monetary return (₹ ha⁻¹)

The perusal of data in Table 17 reveals that net monetary return (NMR) was also significantly affected by different integrated nutrient management treatments. The application of 100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium* (T₄) recorded the significantly higher NMR (₹ 40382 ha⁻¹), which was found statistically at par with T₈ (₹ 38555 ha⁻¹), T₂ (₹ 38436 ha⁻¹), T₅ (₹ 38314 ha⁻¹), T₆ (₹ 36851 ha⁻¹) and T₉ (₹ 36778 ha⁻¹). Similarly, NMR among treatments T₂, T₄, T₅, T₆, T₈ and T₉ did not differ significantly. The significantly lowest NMR (₹ 25805 ha⁻¹) was recorded under control (T₁).

4.7.3 Benefit cost ratio (B:C)

The perusal of data in Table 17 reveals that benefit cost ratio (B:C) was also significantly affected by different integrated nutrient management treatments. The application of 100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium* (T₄) recorded the significantly higher benefit cost ratio (2.02) as compared to other treatments and found statistically at par with T₄ (1.97), T₅ (1.91) and T₆ (1.92). The lowest B:C (1.17) was recorded under T₇ (Vermicompost @ 2 t ha⁻¹ + *Rhizobium*).

Table 17: Effect of different integrated nutrient management treatments on economics

Treatments	Economics		
	Gross Monetary return (₹ ha ⁻¹)	Net monetary return (₹ ha ⁻¹)	B:C
T ₁ : Absolutely control	41055	25805	1.69
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	57456	38436	2.02
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	54074	34774	1.80
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	60842	40382	1.97
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	58404	38314	1.91
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	56011	36851	1.92
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	54871	29571	1.17
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	62585	38555	1.60
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	59868	36778	1.59
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	56783	34623	1.56
S.Em±	1327	1326	0.07
CD (P=0.05)	3971	3972	0.21

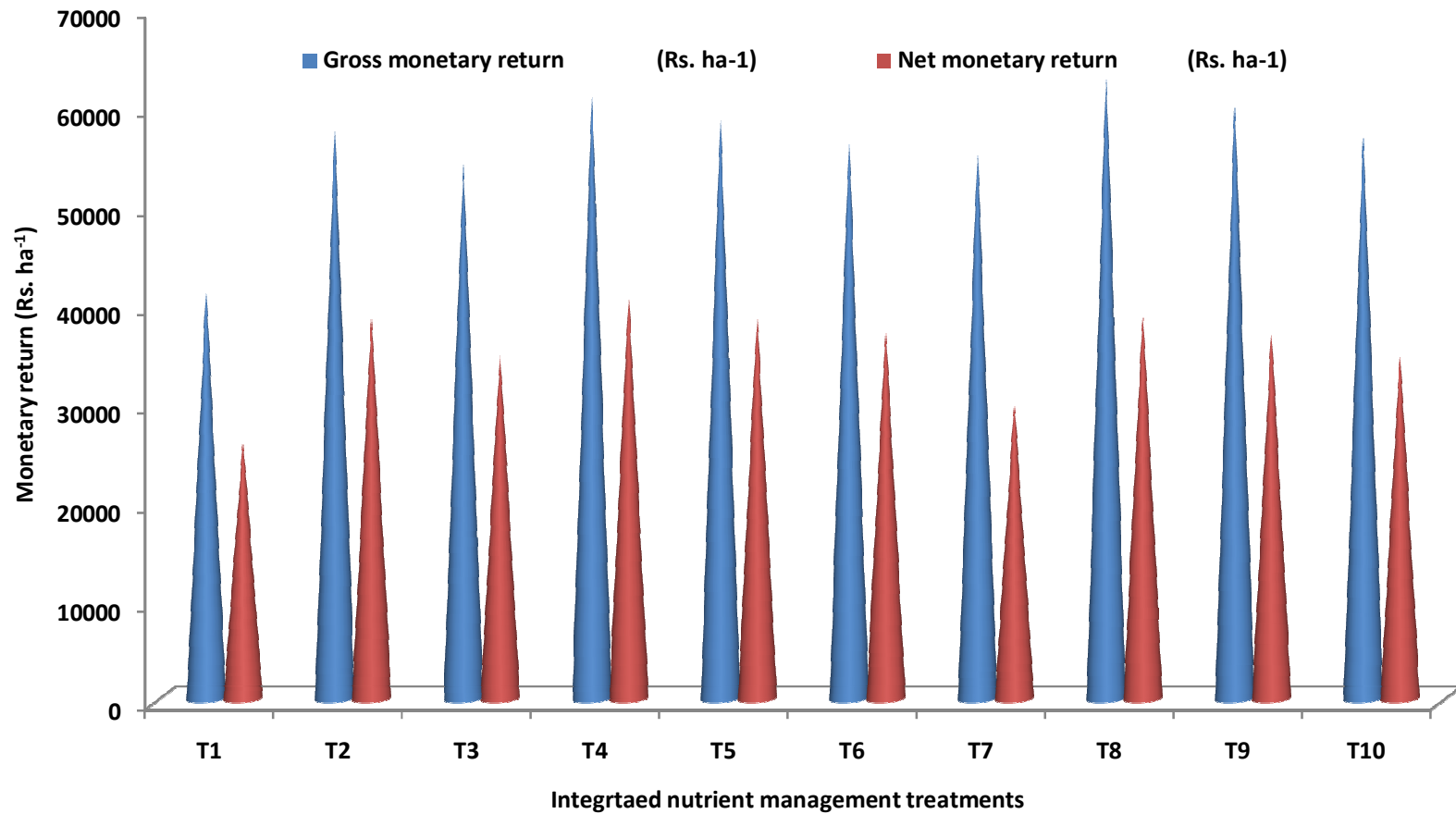


Fig. 10: Effect of different integrated nutrient management treatments on gross and net monetary return (₹ ha⁻¹)

Chapter-5

Discussion

DISCUSSION

In this chapter, an attempt has been made to discuss the salient findings of the research problem entitled, “**Effect of integrated nutrient management on growth, yield, quality and economics of summer green gram [*Vigna radiata* (L.) Wilczek]**” with proper explanations and experimental evidences, wherever, necessary for the observed variations in the experimental results.

5.1 General weather condition during crop season

Yield potential can be exploited if the yield determining processes operating under three phase of plants life viz., vegetative, reproductive and seed development are in optimum balance and good match with the prevailing weather conditions. However, no formula could be evolved for achieving this goal under field conditions (Evans and Wardlaw, 1976). The rainfall received during the crop season was 113.2 mm, out of which 130.4 mm received during maturity period of the crop. This rainfall at maturity period delayed the maturity of green gram by 4-5 days. The other weather parameters like mean minimum, mean maximum temperature and relative humidity during the crop growth period were optimum for growth of green gram crop.

5.2 Effect of integrated nutrient management on growth

Growth parameters like plant height and number of primary branches(plant⁻¹) differed significantly due to integrated nutrient management (combined application of organic and inorganic manures) treatments at different growth intervals. Significantly greater plant height and more number of primary branches (plant⁻¹) at 30, 45 DAS and at harvest was recorded with application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈), which was found statistically at par with T₄ (100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*), T₉ (75% RDF + vermicompost 1.0 @ t ha⁻¹ + *Rhizobium*) and T₅ (75% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*). Similarly, application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈), which was found statistically at par with T₄ (100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*), T₉ (75% RDF + vermicompost 1.0 @ t ha⁻¹ + *Rhizobium*) and T₅ (75% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*) recorded significantly higher LAI, total biomass and its partitioning into leaves, stem and pods at 15, 30, 45 DAS and at

harvest. Kinkar (2007) and Vadgave (2010) also reported similar results in green gram.

The significantly better growth of green gram with the treatments of nutrient management in combination either with FYM (T₄: 100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium* and T₅: 75% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*) or vermicompost (T₈: 100% RDF + vermicompost @ 1 t ha⁻¹ + *Rhizobium* and T₉: 100% RDF + vermicompost @ 1 t ha⁻¹ + *Rhizobium*) clearly indicated the need for adding organic manures to soil conjunctive with inorganic fertilizers, which increased the availability of nutrients over a long period, have positive effect on growth parameters. The earlier findings of Vadgave (2010) in green gram, Channaveerswami (2005) in groundnut and Rajkhowa *et al.* (2002) in green gram corroborate these results.

The control plot (T₁) in which no inorganic fertilizers, manures and *Rhizobium* were applied, recorded significantly poor growth in term of plant height, number of primary branches (plant⁻¹), LAI and total dry biomass accumulation and its partitioning at all growth intervals. When fertilizer supply is limited, plants became thin, leaf enlargement and thickness of branching and inter node elongation were adversely affected, which ultimately affected the dry matter production and its partitioning to different plant parts and reduced growth of plants. Vadgave (2010) and Rajkhowa *et al.* (2002) in green gram, Channaveerswami (2005) in groundnut and Kushwaha (2013) in sesame had also reported similar poor growth of green gram under control plots.

5.3 Effect of integrated nutrient management on yield attributes and yield

Seed yield is more important than total biological yield, which resulted in different combination of many physiological processes based on the environment under in which the crop is grown. The final yield of any crop species depends on the source and sink relationship and on different components of sink *viz.*, number of pods (plant⁻¹), number of seeds (pod⁻¹) and test weight (1000-seeds weight). Source components could be the number of leaves, LAI and pre-anthesis assimilate reserves before flowering. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as source to sink relation and also on plant growth and development during early stage of crop growth. Since, final yield is a function of all components of source and sink operating at different phenophase of growth during life cycle of plant.

In the present investigation seed yield of green gram differed significantly due to different inorganic fertilizers, organic manures and biofertilizers. Among different integrated nutrient management treatments, significantly higher seed yield of 1187.6 kg ha⁻¹ was recorded with application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈), which was found statistically at par with T₄ (100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*), T₉ (75% RDF + vermicompost 1.0 @ t ha⁻¹ + *Rhizobium*) and T₅ (75% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*). These treatments increased the seed yield by 54.7%, 50%, 47.8% and 44.3%, respectively over control and 9.26%, 5.93%, 4.40% and 1.87%, respectively over application of RDF.

The significantly highest seed yield of summer green gram in treatment T₈, T₄, T₉ and T₅ may be attributed to the increased yield components, which ultimately decide the seed yield. Significantly maximum number of pods plant⁻¹), number of seeds pod⁻¹ and 1000-seed weight was recorded in treatment T₈ with the application of 100% RDF + vermicompost @1.0 t ha⁻¹ + *Rhizobium* and found at par with treatments 100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium* (T₄), 75% RDF + vermicompost @1.0 t ha⁻¹ + *Rhizobium* (T₉) and 75% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium* (T₅).

The favourable effect of combined use of organic and inorganic manures on sink component could be attributed to better development of the plants in terms of plant height and dry matter production leading to increased bearing capacity due to optimum growth and development of plants on account of synergistic effect of combined use of organic and inorganic manures. The increase in the 1000 seed weight due to application either of RDF + FYM + *Rhizobium* or RDF + vermicompost + *Rhizobium* may be due to supply of more nutrients interns resulted in proper development of seed. Further, increased availability of nutrients with application of inorganic fertilizers, organic manures and *Rhizobium* might have enhanced the nutrient uptake and consequently, seed yield. Similar results were reported by Rajkhowa *et al.* (2002 and 2003), Kinkar (2007), Vadgave (2010) in green gram and Kushwaha (2013) in sesame.

The control plot in which no inorganic fertilizers and manures were applied, recorded significantly lower seed yield (kg ha⁻¹). The reduction in the seed yield (767.5 kg ha⁻¹) in control plots could be attributed to poor yield attributes *viz.*, number

of pods (plant^{-1}), number of seeds (pod^{-1}) and 1000-seed weight on account of decreased growth in term of biomass accumulation during vegetative phases leading to decreased bearing capacity (number of pods plant^{-1} , number of seeds pod^{-1} and 1000-seed weight), which ultimately decreased the seed yield (kg ha^{-1}). Kinkar (2007) and Vadgave (2010) had also reported the similar results, which support the results of present investigation.

The biological yield of $4426.9 \text{ kg ha}^{-1}$ was significantly higher with application of 100% RDF + FYM @ 2 t ha^{-1} + *Rhizobium* (T_4), which was at par with 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8), 75% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_9) and 75% RDF + FYM @ 2.0 t ha^{-1} + *Rhizobium* (T_5). The better growth in these treatments primarily due to the increased in growth characters in terms of plant height, number of branches plant^{-1} , LAI and higher biomass buildup plant^{-1} with the combined application of organic, inorganic fertilizer and biofertilizer. On the contrary, reduced growth and lower biomass buildup due to poor nutrition of the crop in control plots resulted in significantly lowest biological yield. The earlier findings of Rajkhowa *et al.* (2002 and 2003), Kinkar (2007), Vadgave (2010) in green gram and Kushwaha (2013) in sesame corroborate these results.

Similarly, the significantly higher harvest index with application of organic, inorganic fertilizer and biofertilizer in combinations was due to relatively greater seed yield as compared to other application of organic, inorganic fertilizer and biofertilizer in combinations exhibited higher harvest index than other nutrient management treatments. The earlier findings of Kinkar (2007) and Vadgave (2010) in green gram corroborate these results.

5.4 Effect of integrated nutrient management on quality parameters

The protein content (%) in seed did not differ significantly due to different treatments. However, protein yield of 262.1 kg ha^{-1} was significantly higher with 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) followed by 100% RDF + FYM @ 2 t ha^{-1} + *Rhizobium* (T_4), 75% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_9) and 75% RDF + FYM @ 2.0 t ha^{-1} + *Rhizobium* (T_5). The higher protein yield (kg ha^{-1}) in these treatments might be due to higher seed yield (kg ha^{-1}) as compared to other treatments. On the contrary, lowest protein yield in control plots might be due to lower seed yield (kg ha^{-1}) on account of reduced growth and development of summer green gram crop due to poor nutrition of the crop resulted in

poor development of grain and consequently, reflected in lower protein yield. These results are in conformity with the findings of Kinkar (2007), Vadgave (2010) in green gram, Malik *et al.* (2003) and Kushwaha (2013) in sesame.

5.5 Nutrients uptake

The NPK uptake (kg ha^{-1}) in seed as well as straw was significantly affected by different nutrient management treatments. NPK uptake (kg ha^{-1}) in seed and straw was recorded with the application of % RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8), which was at par with application of 100% RDF + FYM @ 2 t ha^{-1} + *Rhizobium* (T_4), 75% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_9) and 75% RDF + FYM @ 2.0 t ha^{-1} + *Rhizobium* (T_5). The higher availability of nutrients to the plants under application of organic, inorganic fertilizers and biofertilizer reflected into higher uptakes of NPK. On the other hand, nutrient availability was the limiting factor under control plots resulted in lower uptake of NPK by summer green gram crop. Earlier Kinkar (2007) and Vadgave (2010), had also reported that application of organic, inorganic fertilizers and biofertilizer exhibited higher uptake of NPK in seed as well straw over other nutrient management treatments.

5.6 Economics

The data clearly revealed that gross monetary return was higher with 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8), which was at par with 100% RDF + FYM @ 2 t ha^{-1} + *Rhizobium* (T_4), 75% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_9) and 75% RDF + FYM @ 2.0 t ha^{-1} + *Rhizobium* (T_5). Similarly, net monetary return was maximum with 100% RDF + FYM @ 2 t ha^{-1} + *Rhizobium* (T_4), which was at par with 100% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_8) followed by 75% RDF + vermicompost @ 1.0 t ha^{-1} + *Rhizobium* (T_9) and 75% RDF + FYM @ 2.0 t ha^{-1} + *Rhizobium* (T_5). The higher GMR with these treatments was due to higher seed and straw yields in this treatment. However, minimum gross monetary return was recorded in control plots on account of lower seed yield (kg ha^{-1}) and straw yield (kg ha^{-1}). Similarly, net monetary return (NMR) of ₹ 40382 ha^{-1} was recorded with application of 100% RDF + FYM @ 2 t ha^{-1} + *Rhizobium* (T_4) and found at par with T_8 , T_5 , T_6 and T_9 .

Economics of different treatments clearly revealed that the application of RDF (20:60:20 kg NPK ha^{-1} + *Rhizobium*) resulted in maximum benefit cost ratio of 2.02,

but found significantly at par with T₄ (1.97), T₅ (1.91) and T₆ (1.92). The minimum value of B:C ratio of 1.17 was recorded in T₇ (application of vermicompost @ 2 t ha⁻¹ + *Rhizobium*) on account of high cost of vermicompost . The similar results were also observed by Kinkar (2007), Vadgave (2010) in green gram and Verma *et al.* (2013) in sesame.

Chapter-6

Summary, Conclusions and Suggestions for further work

Summary, Conclusions and Suggestions for further work

The field experiment entitled, “**Effect of integrated nutrient management on growth, yield, quality and economics of summer green gram [*Vigna radiata* (L.) Wilczek]**” was conducted at Research Farm, J.N.K.V.V., College of Agriculture, Tikamgarh (M. P.) during *kharif* 2013. The experiment was laid out in randomized block design with three replications. The field experiment was conducted with 10 different integrated nutrient management treatments *viz.*,

T₁: Absolute control

T₂: RDF (20:60:20 kg N, P₂O₅ and K₂O ha⁻¹) + *Rhizobium*

T₃: FYM @ 4 t ha⁻¹ + *Rhizobium*

T₄: 100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*

T₅: 75% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*

T₆: 50% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium*

T₇: Vermicompost @ 2 t ha⁻¹ + *Rhizobium*

T₈: 100% RDF + Vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*

T₉: 75% RDF + Vermicompost 1.0 @ t ha⁻¹ + *Rhizobium*

T₁₀: 50% RDF + Vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*

The objectives of the experiment were as follows:

1. To evaluate the effect of integrated nutrient management on crop growth, development and nodulation in green gram.
2. To assess the effect of integrated nutrient management on yield attributes, yield and quality of green gram.
3. To determine the effect of integrated nutrient management on nutrients uptake by the crop.
4. To workout the economics of different treatments.

6.1 Summary

6.1.1 Plant population (m⁻²) did not differ significantly among all the integrated nutrient management treatments at both 15 DAS and at harvest.

6.1.2 Irrespective of different treatments, plant height increased with the

advancement in the age of the plant and reached the maximum at harvest.

- 6.1.3** All the integrated nutrient management treatments were failed to affect plant height significantly at 15 DAS. Plant height at 30 DAS, 45 DAS and at harvest was recorded significantly greater under T₈ (100% RDF + vermicompost @ 1.0 t ha⁻¹ + *rhizobium*) as compared to other treatments and found statistically at par with T₄, T₉ and T₅.
- 6.1.4** The significantly lowest plant height at 30, 45 DAS and at harvest was recorded under T₁ (control).
- 6.1.5** The number of primary branches (plant⁻¹) at 30, 45 DAS and at harvest was registered significantly more under T₈ (100% RDF + vermicompost @ 1.0 t ha⁻¹ + *rhizobium*), which was found statistically at par with T₄, T₉ and T₅.
- 6.1.6** The significantly lowest number of primary branches (plant⁻¹) at 30, 45 and at harvest was recorded under T₁ (control).
- 6.1.7** Irrespective of treatments, leaf area index increased steadily up to 45 DAS and declined thereafter towards maturity among all the treatments.
- 6.1.8** Leaf area index at 15, 30, 45 and at harvest was recorded significantly higher under T₈ (100% RDF + vermicompost @ 1.0 t ha⁻¹ + *rhizobium*) as compared to other treatments found non-significant with T₄.
- 6.1.9** The significantly lowest LAI at 15, 30, 45 and at harvest was recorded under T₁ (control).
- 6.1.10** Irrespective of treatments, the biomass allocation towards leaves was higher as compared to stem and pods up to harvest. The allocation of biomass to reproductive part (pod) continued to increase from 45 DAS to maturity.
- 6.1.11** At 15 DAS, application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) produced significantly higher total dry biomass and its partitioning into leaves and stem as compared to other treatments and found statistically at par with T₄, T₉ and T₅. The significantly lowest total dry biomass and its partitioning into leaves and stem was recorded in control (T₁).
- 6.1.12** At 15 DAS, stem dry biomass did not differ significantly among all treatments.
- 6.1.13** At 30 DAS, application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ +

Rhizobium (T₈), which found statistically at par with T₄, T₉ and T₅ produced significantly higher total dry biomass and its partitioning into leaves and stem as compared to other integrated nutrient management treatments.

6.1.14 The significantly lowest total dry biomass and its partitioning into leaves and stem was recorded in control (T₁).

6.1.15 At 45 DAS and at harvest, application of 100% RDF + vermicompost @ 1.0 t h^{a-1} + *Rhizobium* (T₈) recorded significantly higher total dry biomass and its partitioning into leaves, stem and pods as compared to other treatments and found statistically at par with T₄, T₉ and T₅.

6.1.16 The significantly lowest total dry biomass and its partitioning at 45 DAS and at harvest was recorded in control (T₁).

6.1.17 Irrespective of treatments, number of nodules (plant⁻¹) increased up to 45 DAS and declined thereafter at 60 DAS among all the treatments.

6.1.18 The application of FYM @ 4.0 t ha⁻¹ (T₃) registered significantly more number of root nodules plant⁻¹ followed by T₇, T₁₀, T₅, T₉, T₁, T₄ and the lowest number of root nodules plant⁻¹ was recorded with the application of RDF (20:60:20 kg N, P₂O₅ and K₂O ha⁻¹ + *Rhizobium* (T₂) at 30, 45 and 60 DAS.

6.1.19 Number of root nodules (plant⁻¹) between treatments T₃ and T₇ and between T₇ and T₆ did not differ significantly. Similarly, number of root nodules (plant⁻¹) among treatments T₅, T₆ and T₁₀ was also found non-significant.

6.1.20 Irrespective of treatments, dry weight of nodules (mg plant⁻¹) increased up to 45 DAS and declined thereafter at 60 DAS among all the treatments.

6.1.21 The application of FYM @ 4.0 t ha⁻¹ (T₃) recorded significantly higher dry weight of root nodules (mg plant⁻¹) followed by T₇, T₆, T₁₀, T₅, T₉, T₁, T₄, T₈ and significantly the lowest dry weight of root nodules was recorded in treatment T₂ at 30, 45 and 60 DAS.

6.1.22 Dry weight of root nodules (mg plant⁻¹) between treatments T₁ and T₄, between T₄ and T₅, between T₆ and T₇ and between T₉ and T₁₀ did not differ significantly at 30 and 45 DAS. Similarly, dry weight of root nodules (mg plant⁻¹) between treatments T₆ and T₇ was also found non-significant at 60 DAS.

6.1.23 The application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈)

produced significantly higher number of pods as compared to other treatments and found statistically at par with T₄, T₉ and T₅. The significantly the lowest pods plant⁻¹ was recorded in control (T₁).

6.1.24 The number of pods (plant⁻¹) among treatments T₃ (11.0 pods plant⁻¹), T₆ (11.3 pods plant⁻¹), T₇ (11.1 pods plant⁻¹) and T₁₀ (11.4 pods plant⁻¹) did not differ significantly.

6.1.25 The application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) recorded significantly higher number of seeds (10.6 pod⁻¹), which was found statistically at par with T₄ (10.4 pod⁻¹), T₂ (10.2 pod⁻¹), T₉ (10.2 pod⁻¹), T₅ (10.1 pod⁻¹), T₁₀ (9.9 pod⁻¹), T₆ (9.8 pod⁻¹), T₇ (9.8 pod⁻¹) and T₃ (9.6 pod⁻¹). The significantly lowest number of seeds pods⁻¹ was recorded in control (T₁).

6.1.26 The application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) exhibited significantly higher 1000-seeds weight (36.6 g), which was found statistically at par with T₄ (36.4), T₉ (36.3 g), T₅ (36.1 g), T₂ (36.1 g), T₆ (35.7 g plant⁻¹), T₇ (35.3 g plant⁻¹) and T₁₀ (36.1 g plant⁻¹). The significantly lowest 1000-seeds weight was recorded in control (T₁) and found statistically at par with T₃.

6.1.27 The seed yield of 1187.6 kg ha⁻¹ was recorded significantly higher with application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈), which found statistically at par with T₄ (1151.3 kg ha⁻¹), T₉ (1134.7 kg ha⁻¹) and T₅ (1107.2 kg ha⁻¹). Similarly, the seed yield among treatments T₃, T₅, T₆, T₇ and T₁₀ did not differ significantly. The significantly the lowest seed yield in control (T₁).

6.1.28 All the integrated nutrient management treatments were failed to show significant affect on stover yield (kg ha⁻¹).

6.1.29 The biological yield (kg ha⁻¹) was recorded significantly higher with application of 100% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium* (T₄), which found statistically at par with T₈, T₉, T₂, T₅ and T₁₀. The significantly lowest biological yield of 3444.1 kg ha⁻¹ was recorded in control (T₁).

6.1.30 The harvest index was recorded significantly higher with application of 100% vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈), which was found statistically at

par with all other treatments except T₁, which had the significantly lowest harvest index.

6.1.31 All the integrated nutrient management treatments were failed to show significant affect on protein content (%) in seed.

6.1.32 The application of 50% RDF + vermicompost @ 1.0 t ha⁻¹ (T₁₀) recorded significantly higher protein content in straw, which found statistically at par with T₆, T₇, T₅, T₃, T₄, T₉ and T₈. The significantly lowest value of protein content was recorded under control (T₁) followed by T₂.

6.1.33 The protein yield in seed was recorded significantly higher with the application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) followed by T₄, T₉, T₅, T₂, , T₁₀, T₆, T₇, T₃ and significantly lowest protein yield in control (T₁).

6.1.34 The protein yield in straw was recorded significantly higher with application of 100% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium* (T₄) followed by T₁₀, T₈, T₉, T₅, T₂, T₆, T₇, T₃ and significantly the lowest protein yield in control (T₁).

6.1.35 The nitrogen uptake in seed was recorded significantly higher with application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) followed by T₄, T₅, T₂, T₁₀, T₆, T₇, T₃ and significantly the lowest nitrogen uptake in control (T₁).

6.1.36 The nitrogen uptake in straw was recorded significantly higher with application of 100% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium* (T₈) followed by T₁₀, T₈, T₉, T₅, T₂, T₆, T₇, T₃ and significantly the lowest nitrogen uptake in control (T₁). Nitrogen uptake in straw among treatments T₂, T₅, T₆ and T₉ did not differ significantly. Similarly, nitrogen uptake in straw between treatments T₈ and T₄ was also found non-significant.

6.1.37 The application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) registered significantly higher total nitrogen uptake followed by T₄, T₉, T₅, T₁₀, T₂, T₆, T₇, T₃ and significantly the lowest total nitrogen uptake in control (T₁).

6.1.38 The application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) exhibited significantly higher phosphorus uptake in seed followed by T₄, T₉, T₅, T₂, T₁₀, T₆, T₇, T₃ and significantly the lowest phosphorus uptake in control (T₁).

- 6.1.39** The phosphorus uptake in straw was recorded significantly higher with application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) followed by T₄, T₂, T₉, T₅, T₁₀, T₆, T₇, T₃ and significantly the lowest phosphorus uptake in control (T₁). However, phosphorus uptake in straw between treatments T₈ and T₄ did not differ significantly.
- 6.1.40** The application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) registered significantly higher total phosphorus uptake followed by T₄, T₉, T₂, T₅, T₁₀, T₆, T₇, T₃ and significantly the lowest total phosphorus uptake in control (T₁).
- 6.1.41** The application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) exhibited significantly higher potassium uptake in seed followed by T₄, T₉, T₅, T₂, T₁₀, T₆, T₇, T₃ and significantly the lowest potassium uptake in control (T₁).
- 6.1.42** The potassium uptake in straw was recorded significantly higher with application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) followed by T₄, T₂, T₉, T₅, T₁₀, T₆, T₇, T₃ and significantly the lowest potassium uptake in control (T₁). However, potassium uptake in straw between treatments T₈ and T₄ did not differ significantly.
- 6.1.43** The application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) registered significantly higher total potassium uptake followed by T₄, T₂, T₉, T₅, T₁₀, T₆, T₇, T₃ and significantly the lowest total potassium uptake in control (T₁).
- 6.1.44** The 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium* (T₈) recorded the significantly higher GMR as compared to other integrated nutrient management treatments and found statistically at par with T₄, T₉ and T₅. Similarly, treatments T₂, T₃, T₆, T₇ and T₁₀ were also found non-significant among themselves. The significantly lowest GMR (₹ 41055 ha⁻¹) was recorded under control (T₁).
- 6.1.45** The application of 100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium* (T₄) recorded the significantly higher NMR, which was found statistically at par with T₈, T₂, T₅, T₆ and T₉. Similarly, NMR among treatments T₂, T₄, T₅, T₆, T₈ and T₉ did not differ significantly. The significantly lowest NMR was recorded under control (T₁).

6.1.46 The application of 100% RDF + FYM @ 2 t ha⁻¹ + *Rhizobium* (T₄) recorded the significantly higher benefit cost ratio as compared to other treatments and found statistically at par with T₄, T₅ and T₆. The lowest B:C was recorded under T₇ (Vermicompost @ 2 t ha⁻¹ + *Rhizobium*).

6.2 Conclusion

On the basis of one-year field investigation during summer 2013, it could be concluded that the application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*, which was found statistically at par with T₄ (100% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium*), T₉ (75% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*) and T₅ (75% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium*) was more remunerative as it resulted into significantly higher seed yield (1187.6 kg ha⁻¹) over other treatments. These treatments increased the seed yield by 54.7%, 50%, 47.8% and 44.3%, respectively over control and 9.26%, 5.93%, 4.40% and 1.87%, respectively over application of RDF.

Similarly, protein yield (262.1 kg ha⁻¹) in seed, NPK uptake in seed (41.9:4.12:9.79 kg ha⁻¹) and GMR (₹ 62858 ha⁻¹) recorded higher with application of 100% RDF + vermicompost @ 1.0 t ha⁻¹ + *Rhizobium*. However, NMR (₹ 40382 ha⁻¹) was recorded with application of 100% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium*. The benefit cost ratio (2.02) was recorded higher with application of RDF (20:60:20 kg NPK ha⁻¹) + *Rhizobium*, which was statistically at par with application of 100% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium*, 75% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium* and 50% RDF + FYM @ 2.0 t ha⁻¹ + *Rhizobium*.

The overall results of the study showed that the application of FYM, Vermicompost and biofertilizer in combination *i.e.*, integrated nutrient management would be useful to enhance the productivity of summer green gram. However, keeping cost benefit cost ratio in mind, it is advised to use either 75% or 50% dose of RDF with FYM @ 2 t ha⁻¹ and *Rhizobium* for maximizing the profit of farmer.

6.3 Suggestions for further work

Looking to the results of the present study, it is suggested that the experiment should be repeated further two or three years to validate the findings of present study as well as to find out suitable combination of inorganic and organic manures for higher productivity of summer green gram under agro-climatic condition of Tikamgarh.

Chapter-7

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APPENDICES

Appendix – I

Plant population (m⁻²) at 15 DAS

Analysis of variance Table

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.001		
Treatment	9	9.879	1.098	823.093
Error	18	0.024	0.001	
Total	29	9.890		

Appendix - II

Plant population (m⁻²) at harvest

Analysis of variance Table

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2			
Treatment	9			
Error	18			
Total	29			

Appendix- III

Plant height (cm) at 15 DAS

Analysis of variance Table

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.649		
Treatment	9	4.279	0.475	2.383
Error	18	3.591	0.200	
Total	29	8.519		

Appendix- IV

Plant height (cm) at 30 DAS

Analysis of variance Table

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.348		
Treatment	9	14.445	1.605	5.325
Error	18	5.425	0.301	
Total	29	20.218		

Appendix- V

Plant height (cm) at 45 DAS

Analysis of variance Table

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.813		
Treatment	9	100.749	11.194	7.752
Error	18	25.994	1.444	
Total	29	127.555		

Appendix- VI

Plant height (cm) at harvest

Analysis of variance Table

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	13.695		
Treatment	9	308.306	34.256	134.082
Error	18	4.599	0.255	
Total	29	326.599		

Appendix- VII

Number of primary branches (plant⁻¹) at 30 DAS

Analysis of variance Table

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.369		
Treatment	9	1.621	0.180	3.293
Error	18	0.985	0.055	
Total	29	2.975		

Appendix- VIII**Number of primary branches (plant⁻¹) at 45 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	1.317		
Treatment	9	3.500	0.389	3.415
Error	18	2.050	0.114	
Total	29	6.867		

Appendix- IX**Number of primary branches (plant⁻¹) at harvest****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.211		
Treatment	9	3.425	0.381	6.326
Error	18	1.083	0.060	
Total	29	4.718		

Appendix- X**Leaf are index at 15 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.001		
Treatment	9	0.021	0.002	7.812
Error	18	0.005	0.001	
Total	29	0.027		

Appendix- XI**Leaf are index at 30 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.004		
Treatment	9	0.146	0.016	5.642
Error	18	0.052	0.003	
Total	29	0.202		

Appendix- XII**Leaf are index at 45 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.076		
Treatment	9	1.765	0.196	18.814
Error	18	0.188	0.010	
Total	29	2.028		

Appendix- XIII**Leaf are index at harvest****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.031		
Treatment	9	1.772	0.197	14.621
Error	18	0.242	0.013	
Total	29	2.045		

Appendix- XIV**Leaf dry biomass at 15 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.001		
Treatment	9	0.049	0.005	4.200
Error	18	0.023	0.001	
Total	29	0.072		

Appendix- XV**Stem dry biomass at 15 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.001		
Treatment	9	0.001	0.001	0.682
Error	18	0.002	0.001	
Total	29	0.003		

Appendix- XVI**Total dry biomass at 15 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.001		
Treatment	9	0.060	0.007	4.246
Error	18	0.028	0.002	
Total	29	0.089		

Appendix- XVII**Leaf dry biomass at 30 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.011		
Treatment	9	0.231	0.026	9.555
Error	18	0.048	0.003	
Total	29	0.291		

Appendix- XVIII**Stem dry biomass at 30 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.001		
Treatment	9	0.026	0.003	15.852
Error	18	0.003	0.000	
Total	29	0.030		

Appendix- XIX**Total dry biomass at 30 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.012		
Treatment	9	0.406	0.045	12.098
Error	18	0.067	0.004	
Total	29	0.485		

Appendix- XX**Leaf dry biomass at 45 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.161		
Treatment	9	13.471	1.497	16.612
Error	18	1.622	0.090	
Total	29	15.254		

Appendix- XXI**Stem dry biomass at 45 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.011		
Treatment	9	0.237	0.026	2.939
Error	18	0.161	0.009	
Total	29	0.408		

Appendix- XXII**Pod dry biomass at 45 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.000		
Treatment	9	0.898	0.100	305.782
Error	18	0.006	0.000	
Total	29	0.905		

Appendix-XXIII**Total dry biomass at 45 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.246		
Treatment	9	24.279	2.698	27.718
Error	18	1.752	0.097	
Total	29	26.276		

Appendix- XXIV**Leaf dry biomass at harvest****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.204		
Treatment	9	5.774	0.642	5.759
Error	18	2.005	0.111	
Total	29	7.983		

Appendix- XXV**Stem dry biomass at harvest****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.117		
Treatment	9	4.809	0.534	37.382
Error	18	0.257	0.014	
Total	29	5.183		

Appendix- XXVI**Pod dry biomass at harvest****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.082		
Treatment	9	22.753	2.528	51.768
Error	18	0.879	0.049	
Total	29	23.714		

Appendix- XXVII**Total dry biomass at harvest****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.236		
Treatment	9	83.708	9.301	54.597
Error	18	3.066	0.170	
Total	29	87.010		

Appendix- XXVIII**Number of root nodules (plant⁻¹) at 30 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.056		
Treatment	9	49.294	5.477	12.421
Error	18	7.937	0.441	
Total	29	57.287		

Appendix- XXIX**Number of root nodules (plant⁻¹) at 45 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.602		
Treatment	9	89.283	9.920	31.897
Error	18	5.598	0.311	
Total	29	95.483		

Appendix- XXX**Number of root nodules (plant⁻¹) at 60 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.263		
Treatment	9	80.386	8.932	15.020
Error	18	10.704	0.595	
Total	29	91.352		

Appendix- XXXI**Dry biomass of root nodules (mg plant⁻¹) at 30 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.649		
Treatment	9	114.376	12.708	65.161
Error	18	3.511	0.195	
Total	29	118.535		

Appendix- XXXII**Dry biomass of root nodules (mg plant⁻¹) at 45 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	1.431		
Treatment	9	100.440	11.160	25.376
Error	18	7.916	0.440	
Total	29	109.787		

Appendix- XXXIII**Dry biomass of root nodules (mg plant⁻¹) at 60 DAS****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	1.543		
Treatment	9	208.568	23.174	78.463
Error	18	5.316	0.295	
Total	29	215.428		

Appendix- XXXIV**Number of pods (plant⁻¹)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.845		
Treatment	9	19.415	2.157	6.763
Error	18	5.742	0.319	
Total	29	26.002		

Appendix- XXXV**Number of seeds (pod⁻¹)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.610		
Treatment	9	7.110	0.790	2.184
Error	18	6.510	0.362	
Total	29	14.230		

Appendix- XXXVI**1000-seed weight (g)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.245		
Treatment	9	20.846	2.316	3.212
Error	18	12.981	0.721	
Total	29	34.072		

Appendix- XXXVII**Seed yield (kg ha⁻¹)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	21,755.735		
Treatment	9	361,654.505	40,183.834	23.571
Error	18	30,687.034	1,704.835	
Total	29	414,097.274		

Appendix- XXXVIII**Stover yield (kg ha⁻¹)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	4,892.537		
Treatment	9	386,922.971	42,991.441	1.727
Error	18	448,108.879	24,894.938	
Total	29	839,924.387		

Appendix- XXXIX**Biological yield (kg ha⁻¹)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	38,706.437		
Treatment	9	1,480,960.404	164,551.156	6.696
Error	18	442,328.983	24,573.832	
Total	29	1,961,995.824		

Appendix- XL**Harvest index (%)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	6.065		
Treatment	9	62.768	6.974	3.731
Error	18	33.650	1.869	
Total	29	102.483		

Appendix- XLI**Protein content (%) in seed****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	9.510		
Treatment	9	6.242	0.694	1.942
Error	18	6.428	0.357	
Total	29	22.179		

Appendix- XLII**Protein content (%) in straw****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.057		
Treatment	9	1.330	0.148	5.454
Error	18	0.488	0.027	
Total	29	1.874		

Appendix- XLIII**Protein yield (kg ha⁻¹) in seed****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	34.382		
Treatment	9	4180.492	464.497	149.498
Error	18	56.685	3.149	
Total	29	4271.540		

Appendix- XLIV**Protein yield (kg ha⁻¹) in straw****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.309		
Treatment	9	96.375	10.708	137.228
Error	18	1.405	0.078	
Total	29	98.088		

Appendix- XLV**Nitrogen uptake (kg ha⁻¹) in seed****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.318		
Treatment	9	412.744	45.860	590.988
Error	18	1.397	0.078	
Total	29	414.459		

Appendix- XLVI**Nitrogen uptake (kg ha⁻¹) in straw****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.050		
Treatment	9	18.239	2.027	18.039
Error	18	2.022	0.112	
Total	29	20.311		

Appendix- XLVII**Total nitrogen uptake (kg ha⁻¹)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.147		
Treatment	9	568.748	63.194	535.529
Error	18	2.124	0.118	
Total	29	571.019		

Appendix- XLVIII**Phosphorus uptake (kg ha⁻¹) in seed****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.000		
Treatment	9	4.202	0.467	424.862
Error	18	0.020	0.001	
Total	29	4.222		

Appendix- XLIX**Phosphorus uptake (kg ha⁻¹) in straw****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.000		
Treatment	9	4.054	0.450	650.049
Error	18	0.012	0.001	
Total	29	4.066		

Appendix- L**Total phosphorus uptake (kg ha⁻¹)****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.001		
Treatment	9	15.981	1.776	1,081.087
Error	18	0.030	0.002	
Total	29	16.011		

Appendix- LI**Potassium uptake (kg ha⁻¹) in seed****Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.001		
Treatment	9	26.982	2.998	2,805.718
Error	18	0.019	0.001	
Total	29	27.002		

Appendix- LII

**Potassium uptake (kg ha⁻¹) in straw
Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.071		
Treatment	9	21.742	2.416	269.234
Error	18	0.162	0.009	
Total	29	21.974		

Appendix- LIII

**Total potassium uptake (kg ha⁻¹)
Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.055		
Treatment	9	94.021	10.447	1,138.648
Error	18	0.165	0.009	
Total	29	94.241		

Appendix- LIV

**Gross monetary return (Rs. ha⁻¹)
Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	68,922,412.196		
Treatment	9	949,161,031.161	105,462,336.796	19.977
Error	18	95,027,561.031	5,279,308.946	
Total	29	1,113,111,004.387		

Appendix- LV

**Net monetary return (Rs. ha⁻¹)
Analysis of variance Table**

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	68,913,297.362		
Treatment	9	643,017,206.756	71,446,356.306	13.532
Error	18	95,037,146.301	5,279,841.461	
Total	29	806,967,650.419		

Appendix- LVI

Benefit cost ration (B:C)

Analysis of variance Table

Source of variation	DF	Sum of square	Mean square	F-calculated
Replication	2	0.189		
Treatment	9	2.749	0.305	21.131
Error	18	0.260	0.014	
Total	29	3.199		

Appendix- LVII

Cost of cultivation (₹ ha⁻¹)

Treatments	(₹ ha ⁻¹)
T ₁ : Absolutely control	15250
T ₂ : RDF (20:60:20 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹) + <i>Rhizobium</i>	19020
T ₃ : FYM @ 4 t ha ⁻¹ + <i>Rhizobium</i>	19300
T ₄ : 100% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	20460
T ₅ : 75% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	20090
T ₆ : 50% RDF + FYM @ 2 t ha ⁻¹ + <i>Rhizobium</i>	19160
T ₇ : Vermicompost @ 2 t ha ⁻¹ + <i>Rhizobium</i>	25300
T ₈ : 100% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	24030
T ₉ : 75% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	23090
T ₁₀ : 50% RDF + Vermicompost @ 1.0 t ha ⁻¹ + <i>Rhizobium</i>	22160

- ▶ Market price of green gram seeds ₹ 50 kg⁻¹
- ▶ Green gram straw sale price ₹ 1.0 kg⁻¹
- ▶ Rate of FYM ₹ 1.0 kg⁻¹