“STUDIES ON EFFECT OF DIFFERENT ORGANIC SOURCES AND INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum graecum* L.)”

BY

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CERTIFICATE

Mr. M. MUTYALA NAIDU has satisfactorily prosecuted the course of research and that the thesis entitled **"STUDIES ON EFFECT OF DIFFERENT ORGANIC SOURCES AND INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum graecum* L.)"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

Place: HYDERABAD
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(Dr. D.V. RAGHAVA RAO)
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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON EFFECT OF DIFFERENT ORGANIC SOURCES AND INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum graecum* L.)"** submitted in partial fulfillment of the requirements for the degree of '**Doctor of Philosophy**' in the major field of **Horticulture** of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Mr. M. Mutyala Naidu** under our guidance and supervision. The subject of the thesis has been approved by the Students Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of investigation have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
@	:	At the rate of
a.i	:	Active ingredient
ac^{-1}	:	Per acre
AGR	:	Absolute growth rate
AMF	:	Arbuscular micorrhizal Fungi
Ca	:	Calcium
CAC	:	Cation exchange capacity
CD	:	Critical difference
cm	:	Centimeter
cm^2	:	Square centimeter
Cu	:	copper
cv	:	Cultivar
DAS	:	Days after sowing
day^{-1}	:	per day
et al.,	:	and others
Fe	:	Iron
Fig.	:	Figure
FYM	:	Farm yard manure
g	:	Gram
ha^{-1}	:	per hectare
HI	:	Harvest index
i.e.,	:	Which is to say, in other words
INM	:	Integrated nutrient management
K	:	Potassium
K_2O	:	Potassium dioxide
kg	:	Kilogram
LA	:	Leaf area
LAI	:	Leaf area index
lb	:	Pound
m	:	Meter

m^2	:	Square meter
mg	:	Milligram
ml ha^{-1}	:	Milliliter per hectare
ml lt^{-1}	:	Milliliter per liter
Mo	:	Molybdenum
N	:	Nitrogen
NAA	:	Naphthalene acetic acid
NC	:	Neem cake
^oC	:	Centigrade
P	:	Phosphorus
P_2O_5	:	Phosphorus pentoxide
pH	:	Potential of hydrogen ion concentration
$plant^{-1}$	:	Per plant
PM	:	Poultry manure
pod^{-1}	:	Per pod
ppm	:	Parts per million
PROM	:	Phosphorus rich organic manure
PSB	:	Phosphate solubilizing bacteria
q ha^{-1}	:	Quintal per hectare
RBD	:	Randomized block desigen
RDF	:	Recommended dose of fertilizer
R	:	*Rhizobium*
SEm	:	Standard Error mean
t ha^{-1}	:	Tonne per hectare
VAM	:	Vascecular arbicular micorrhiza
VC	:	Vermi compost
Viz.,	:	Namely
w/w	:	Weight by weight basis
Zn	:	zinc

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Place : Kovvur

Date : 20-10-2010.

(M. MUTYALA NAIDU)

DECLARATION

I, **M. MUTYALA NAIDU**, hereby declare that the thesis entitled **"STUDIES ON EFFECT OF DIFFERENT ORGANIC SOURCES AND INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF FENUGREEK (*Trigonella foenum graecum* L.)"** submitted to the Acharya N.G. Ranga Agricultural University for the degree of '**Doctor of Philosophy**' in the major field of **Horticulture** is a result of original research work done by me. It is further declared that the thesis or part thereof has not been published earlier in any manner.

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ABSTRACT

Present investigation entitled **'Studies on effect of different organic sources and Integrated Nutrient Management on growth, yield and quality of fenugreek'** was conducted at Horticultural Research Station, Kovvur (A.P). The study was divided into two field experiments and conducted for two *rabi* seasons (2008-09 and 2009-10) of each. In experiment-I entitled **'Effect of different organic sources on growth, yield and quality of fenugreek'** organic manures *viz.*, vermicompost (VC), farmyard manure (FYM), poultry manure (PM) and neem cake (NC), their combinations *viz.*, VC + FYM, VC + PM, VC + NC, FYM + PM, FYM + NC and PM + NC were evaluated for growth, yield and quality. The dosages of VC, FYM, PM and NC were 6.6 t, 5.7 t, 7.0 t and 5.0 t ha^{-1} respectively when applied individually and 50 % of the dose of each manure was applied in combined applications. The organic sources were compared with two inorganic fertilizer doses *viz.*, 100 % recommended dose of inorganic fertilizers (60-50-50 NPK kg ha^{-1}) and 50 % RDF. In experiment - II entitled **'Effect of Integrated Nutrient Management on growth, yield and quality of fenugreek'** the effects of inorganic

fertilizers, certain organic manures *viz.*, vermicompost, farm yard manure, poultry manure and neem cake combined with biofertilizers like *Rhizobium* and phosphate solubilizing bacteria (PSB) with an INM concept on growth, yield and quality were studied. In this experiment 50 % of the dose of each organic manure as stated for experiment - I was applied in combined application. Results obtained from the above experiments are summarized here under:

Effect of different organic sources on growth, yield and quality of fenugreek.

The application of 100 % RDF (T_{12}) recorded higher values for seed yield and yield attributing characters such as number of pods plant^{-1}, number of seeds pod^{-1}, test weight and seed yield plant^{-1} resulting in higher seed yield (12.01 q ha^{-1}). Next to (T_{12}) 100 % RDF, the better pod length, number of pods plant^{-1} were recorded with the application of (T_8) farmyard manure + poultry manure resulting in higher seed yield (9.60 q ha^{-1}). Similarly, the treatment consisting of (T_6) vermicompost + poultry manure also exhibited better performance in terms of test weight and seed yield plant^{-1} leading to higher seed yield (9.55 q ha^{-1}) next to T_8 *viz.*, farmyard manure and poultry manure and both the treatments were at par with each other.

Data pertaining to nutrient uptake in fenugreek with application of different organic manures revealed that application of (T_{12}) 100 % RDF significantly increased the NPK uptake followed by T_8 (FYM + PM) and T_6 (VC + PM). Similarly, in addition to above treatments, 50 % RDF also recorded better uptake of phosphorus and potassium comparable with T_8 and T_6.

Among quality attributes, crude protein content in seed was significantly influenced by the application of organic manures and their combinations. The treatment, 100 % RDF recorded highest crude protein (16.61%) as compared to other treatments. However, the treatments, T_6 (16.19 %), T_5 (15.98 %) and T_8 (15.87 %) also recorded better crude protein % comparable with (T_{12}) 100 % RDF. Similarly, the crude fibre (7.75 %) in seed was significantly higher with application of (T_9) farm yard manure + neem cake and it was at par with (T_{12}) 100 % RDF and (T_8) farm yard manure + poultry manure. It was found that the diosgenin content was not affected by various treatments.

Considering the seed yields and B : C ratio and nutritive value of seed and straw in view, it can be concluded that application of T_8: Farmyard manure @ 2.8 t ha^{-1} + Poultry manure @ 3.5 t ha^{-1} was found promising and can be recommended for obtaining higher yield with improved quality of fenugreek.

Effect of Integrated Nutrient Management on growth, yield and quality of fenugreek.

Application of (T_2) 100 % RDF + *Rhizobium* + PSB recorded higher grain yield of 12.50 q ha^{-1} as compared to rest of the treatments. The above treatment recorded higher values for yield attributing characters also such as number of seeds pod^{-1}, harvest index, straw yield and better pod length, test weight, number of pods $plant^{-1}$, seed yield $plant^{-1}$ and grain shelling % . Further, the number of pods $plant^{-1}$, grain shelling % were reported to be highest with application of (T_7) 75 % RDF + PM + *Rhizobium* + PSB, whereas the pod length, test weight, seed yield $plant^{-1}$ were found to highest with application of 75 % RDF + VC + *Rhizobium* + PSB (T_5). The above treatments (T_5 and T_7) recorded higher seed yield of 11.83 q ha^{-1} and 10.91 q ha^{-1} respectively. The treatments; T_2, T_5 and T_7 recorded 16.72 %, 12 % and 4.58 % increase in grain yield over T_1 (Control) respectively. In this study, lower yields were recorded by T_{10}, T_6 and T_4. The remaining treatments recorded intermediate values. The yield attributing characters such as number of seeds pod^{-1}, test weight and seed yield $plant^{-1}$ was found to be higher in T_2, T_7 and T_5 as compared to other treatments

The data pertaining to nutrient uptake in fenugreek with application of different organic manures revealed that application of (T_2) 100 % RDF + *Rhizobium* + PSB significantly increased the NPK uptake followed by T_5 (75 % RDF + VC + *Rhizobium* + PSB) and T_7 (75 % RDF + PM + *Rhizobium* + PSB).

With respect to grain quality, highest crude protein % was noticed in T_2: 100 % RDF + *Rhizobium* + PSB and it was at par with T_5: 75 % RDF + VC + *Rhizobium* + PSB, T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_3: 75 % RDF + FYM + *Rhizobium* +

PSB %. Interestingly, the crude fibre % in seed was found to be highest with T_9: 75 % RDF + NC + *Rhizobium* + PSB and it was at par with T_{10} and T_5. However, no significant differences were noticed among the treatments in case of diosgenin content in seed. Further, it was observed that T_{10}, T_8 for crude protein % in seed and T_4 and T_6 for crude fibre % in seed recorded lower values for above quality parameters.

Considering the higher seed yield and nutritional quality in view application of (T_5) 75 % RDF + vermicompost + *Rhizobium* + PSB and (T_7) 75 % RDF + poultry manure + *Rhizobium* + PSB was found promising and can be recommended to the farmers for popularizing the cultivation of fenugreek under agroclimatic conditions of Andhra Pradesh.

Chapter I

INTRODUCTION

CHAPTER I

INTRODUCTION

India, 'The land of spices' is the world's largest producer, consumer and exporter of spices. The area under spices is 2629.40 thousand ha with a production of 4144.9 thousand tonnes during 2009-2010. In Andhra Pradesh, the spices are grown in an area of 318.4 thousand ha with a production of 1225.3 thousand tonnes (CMIE, 2009). During 2009-10, India exported 5,02,750 tonnes of spices valued at Rs. 5,56,050 lakhs (Anonymous 2010, Spices India).

Fenugreek (*Trigonella foenum graecum* L.) belongs to the family Fabaceae. It has multifarious uses and its use as medicine, spice and condiment is known to Indians since time immemorial. Fenugreek is a multipurpose spice crop whose parts are utilized as leafy vegetable, fodder and condiment (Khiriya *et al*., 2003). Fenugreek seeds are known to lower blood glucose and blood cholesterol levels because they have large amounts of soluble fibre in them. Recent studies in England indicate that fenugreek seeds contain substantial amounts of steroidal substance 'disogenin' which is used as a starting material in the synthesis of sex hormones and as oral contraceptives. It is also used in many of the Ayurvedic medicines to cure diseases.

The leaves are rich in Vitamin-C (43.10 mg/100 g), protein (3-5%) and contain iron, carotene (Vitamin-A 6415 IU) and ascorbic acid. Fenugreek seeds are rich in protein (6.3 %), fat (9.5 %), carbohydrates (42.3%), Vitamin-A (1040 IU) and calories (370/100 g). Besides, it contains gum (22.06%), trionellin (0.13 - 0.35%), disogenin (1.0 g), gitogenin (0.1 g) and a trace of triogenin per every kg of dried seed.

Fenugreek occupies a prime position among the seed spices grown in India. It is a native of South East Europe and West Asia. It is extensively grown in India, Morocco, Australia, Turkey, Bulgaria, Pakistan, Bangladesh, Egypt, China, France, Africa, Lebanon and Ethiopea. India occupies an important position among the fenugreek growing countries of the world; while Morocco, Australia and Turkey are the India's competitors in the world market. In India, Rajasthan (84 %) and Gujarat (15 %) are major producing states followed by Uttar Pradesh (1 %). Fenugreek is cultivated over an area of 45,000 ha in India with an average production of 56,000 tons. During 2009-2010, India earned Rs. 6972 lakhs as foreign exchange by exporting 21,000 tonnes of fenugreek (Anonymous, 2010). It is also cultivated in Himachal Pradesh, Madhya Pradesh, Andhra Pradesh, Tamil Nadu and Karnataka mainly for vegetable purpose. Now, the cultivation of this crop is being spread to other states also. At present the productivity ha^{-1} is low *i.e.*, 1,044 kg ha^{-1} which can be increased to 1,700 kg ha^{-1} by following improved production technology. In Andhra Pradesh, it is grown as leafy vegetable and for grain in limited area throughout the state particularly in districts of Guntur, Prakasam, Karimnagar, Adilabad, Kurnool and Anantapur and the crop generates substantial income to the farmers.

Intensification of agriculture characterised by raising of more crops per unit time and space involving heavy dependence on fertilizers has progressively depleted the soil of their macro/micro nutrient reserves. Day by day decline in the already low soil fertility is the main cause of low productivity of most of the cultivated lands. According to soil test analysis in our country nitrogen deficiency is universal, phosphorus status is low in 50 % and medium in 48 % soils. Further, 48 % soils are low to medium in available potassium and its deficiency is rapidly increasing due to intensive cropping and imbalance use of fertilizers. The long term fertilizer experiments under different agro-climatic regions of the country have shown that K deficiency in future will become a limiting factor for crop production. It will also reduce the efficiency of other fertilizer nutrients (Singh *et al*., 2000). It has been reported by Rattan *et al.* (1999) that micronutrient deficiency of molybdenum, boron, manganese, zinc and iron is found in many parts of our country.

The grain yield and quality of fenugreek are known to be influenced by different factors such as nutrition, cultural practices etc. Among these, nutrition plays an important role which has great influence on vegetative growth as well as grain yield (Sharma *et al*., 2006). Of late, there is good market for organic produce of fenugreek both in the domestic and international market. To maintain and sustain a higher level of soil fertility and crop productivity, organic manures are very important in the present day system of crop production. The conjunctive use of organic manures will not only improve the soil health but also helps to increase seed yield and quality of fenugreek. Chemical fertilizers constitute the major component of inputs. Expenditure on this component is ever increasing and making the cultivation economically not viable .Besides, the continuous use of chemical fertilizers is posing new problems because of depletion of soil health. Microorganisms capable of making nutrients available to the plants offer great scope in alleviating this situation. Therefore, use of biofertilizers in conjunction with organic manures becomes a priority (Solaippan and Ramiah, 1990).

The concept of integrated nutrient management was proved successful in many horticultural crops like vegetables and fruits in reducing the cost of cultivation and improving soil health and reducing chemical residues (Jain and Choudary, 2006). Fenugreek is an important spice crop with good export value and the information on the effect of various organic sources of nutrients and integrated nutrient management practices is lacking under agro climatic conditions of Andhra Pradesh. In Andhra Pradesh, fenugreek is grown in marginal lands under irrigated conditions during *rabi* season and hence, there is a need to reduce its cost of cultivation by using organic sources for its nutrition.

Keeping the cost of production, INM concepts and importance of organic sources of manures in view, the present investigation was proposed to find out the effect of certain organic manures and integrated nutrient management on growth, yield and quality of fenugreek with the following objectives :

Objectives

1. To study the effect of organic manures on growth, yield and quality of fenugreek.
2. To study the effect of organic manures on nutrient uptake of fenugreek.
3. To study the effect of INM treatments i.e. organic and inorganic fertilizers in combination with bio-fertilizers on growth, yield and quality of fenugreek.
4. To find out the effect of organic and inorganic fertilizers in combination with bio-fertilizers on nutrient uptake of fenugreek.

Chapter II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Organic farming is considered to be a self sustaining system of agriculture, promotes agro ecosystem health with enhancement of soil biological activity, maintenance of soil productivity and control of pests and diseases in harmony with natural environment. Organic production system relies more on organic manures and composts, biofertilizers, crop rotations and biological pest control measures. However, agricultural production over few decades in conventional agriculture is based on the objective of maximizing the productivity of the crops with application of fertilizers and other chemical inputs.

The research work done in India and elsewhere in recent years on the effect of organic manures, fertilizers and biofertilizers on growth and yield of fenugreek and related crops are reviewed in this chapter.

In general it was found that use of organic residues such as farmyard manure, vermicompost, poultry manure *etc.*, and crop residues were reported to have beneficial effects in improving soil structure, organic matter content, water holding capacity, macro and micronutrient status apart from reducing the cost of production (Rao *et al.*, 1993).

2.1 Effect of organic manures on growth and yield

2.1.1 Effect of farmyard manure

Organic manure like FYM has been known to improve the physical, chemical and microbiological properties of soils and ultimately the crop yields. According to Palaniappan and Annadurai (1999), farmyard manure and compost contain 0.5-1.0 % N, 0.6 % P_2O_5 and 0.5 % K_2O. Ten tons of compost will thus supply 50-100 kg N, 20 kg P_2O_5 and 50 kg K_2O of which, about 15-30 kg N, 15 kg P_2O_5 and 35 kg K_2O become available during the first season of application.

Many farmers follow sheep penning to increase the organic manure in their fields. This is a low cost cultivation practice. Usually this is done just before the onset of monsoon so that it is beneficial to the crops (Sunil *et al.*, 1997). Estrada *et al.* (1997) reported that application of sheep manure @ 10 t ha^{-1} increased the yield in capsicum.

Application of farmyard manure had a beneficial effect on the growth parameters of fenugreek. Each successive increase of FYM from 0 to 15 t ha^{-1} brought significant improvement in plant height, LAI, CGR, and dry matter accumulation at all stages of crop growth as reported by Khiriya *et al.* (2001).

For organic method of cultivation of fenugreek, the Spices Board has recommended the application of well rotten cattle manure or compost @ 4-5 t ha^{-1} at the time of sowing.

Bhati (1996) recommended the application of 10-15 t ha^{-1} of farmyard manure at the time of field preparation for getting higher yield in fenugreek.

Chattopadhyay and Chakrabarthy (1990) also reported higher yield in onion with the application of FYM @ 8 t ha^{-1}. Ahmed (1993) got maximum fruit yield of tomato (19.01 t ha^{-1}) with the application of farmyard manure @ 6 t ha^{-1}.

The seed yield in fennel was reported to be highest (1.05 t ha^{-1}) with application of FYM @ 10 t ha^{-1} + *Azospirillum* (Anonymous, 2006).

Subbaiah *et al.* (1983) recorded maximum yield of 59 t ha^{-1} in tomato with application of farmyard manure (12.5 ha^{-1}) along with 50:25:15 kg NPK ha^{-1}.

2.1.2 Effect of vermicompost

The vermicompost is an aerobically degraded organic matter which has undergone chemical disintegration by the enzymatic activity in the gut of earth worms and also enzymes of the associated microbial population (Kale *et al*., 1992). Vermicompost is rich in both macro nutrients and micro nutrients, besides having plant growth promoting substances, humus forming microbes and nitrogen fixers (Bano *et al.,* 1987).

Guled *et al*. (2003) reported that vermicast contains 1.88 % nitrogen, 0.60 % phosphorous and 1.00 % potash and provides required nutrients to the plants such as, nitrogen (0.74 ± 0.14 %), phosphorus (0.97 ± 0:11 %), potash (0.45 ± 0.15%) and Ca, Mg and micro-nutrients like Fe, Mo, Zn, Cu *etc*., Apart from this, it also contains plant growth regulators such as NAA, cytokinins, gibberllins, *etc*., it also harbours beneficial microflora within it.

Deshpande (1996) reported that in comparison to ordinary compost, the vermicompost has the distinct advantage such as it has three times more nitrogen, seven times more phosphorus, eleven times more potash, four times more nitrogen fixing bacteria, 8 to 9 times more actinomysites. Apart from this, it increases water holding capacity of the soil. The ordinary soil has 10 ml ha^{-1} water holding capacity, while in presence of earth worms it may increase upto 100 ml ha^{-1}. It also increases some useful micronutrients, lignin and linguine thereby, improving disease resistance capacity of the plant. One earth worm eats 1½ times more soil as compared to its weight and converts it to 100 % fertilizer. Application of vermicompost @ 1.0 to 2.5 t ha^{-1} in various crops resulted in substitution of inorganic fertilizers to the tune of 25 to 75 % (Pawar, 1996 and Kale, 1998).

Field trial conducted by Kamalesh *et al.* (2006) in fenugreek revealed that vermicompost (10 t ha^{-1}) significantly increased the yield (12 q ha^{-1}) over control (7.7 q ha^{-1}).

Application of vermicompost in cucumber increased the yield by 42.5 % over control (Huang and Zhao, 1987).

In paprika, fruit yield improved significantly due to the application of organic manures. The highest paprika yield of 259.48 q ha^{-1} was recorded in vermicompost treatment. The fruit yield of paprika increased significantly from 254.21 to 260.10 q ha^{-1} with *Azospirillum* inoculation. The quality parameters like TSS and ascorbic acid content were highest in paprika when *Azospirillum* was treated with vermicompost compared to farmyard manure (Vijaya Savanur, 1999).

Kale *et al.,* (1987) observed on increase in the number of inflorescence per plant as well as early flowering in salvia with the application of vermicompost. Kale *et al.* (1991) showed that the quantum of fertilizers could be reduced by 25 to 40 % with vermicompost in radish, tomato, carrot and brinjal.

Desai (1992) reported that the application of 1.0 t ha^{-1} vermicompost resulted in little less yield in capsicum compared to chemical plot but the net profit was more due to low input cost.

Vermicompost as potting mixture for cardamom seedlings significantly increased the plant height, number of leaves, number of roots $plant^{-1}$ and root length (Vadiraj *et al.,* 1992).

The result of the field experiment conducted by Anand *et al.* (1995) revealed that "vermiwash" the aqueous extract of vermicompost slightly enhanced the germination and shoot growth in tomato and radish.

Patil (1995) reported that RDF + 50 % vermicompost in tomato recorded significantly higher number of fruits plant^{-1} (26.33) and higher fruit yield (18.66 t ha^{-1}) over control.

2.1.3 Effect of poultry manure

The excreta of birds ferment very quickly and it left exposed, 50 % of its nitrogen is lost within 30 days. Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures. The average nutrient content is 3.03 % N, 2.63 % P_2O_5 and 1.4 % K_2O (Guled *et al.,* 2003).

Srivastava and Khanna (1974) reported that poultry manure (Deep litter) contains about 60 % of its N as uric acid, 30% more stable organic forms and less than 10 % as mineral nitrogen. The uric acid changes rapidly to ammonical form. It is further reported that it also contains growth promoting hormones that produces better root growth than fertilizers.

The rapid growth of poultry industry in recent years and the application of poultry waste to agricultural lands has resulted in excessive soil phosphorus in many locations. It has been reported that poultry litter ash is an inexpensive phosphorus source for agricultural crops (Codling *et al.*, 2001).

Application of poultry manure @ of 5 t ha^{-1} in fenugreek recorded increase in (7.03 g plant^{-1}) pod yield, (2.17 g plant^{-1}) seed yield and (1479 kg ha^{-1}) grain yield (Anonymous, 2004).

Abusaleha (1992 b) reported that poultry manure was the best as compared to FYM in producing bigger seeds and 100-seed weight in okra.

In Brinjal, the application of 20 t ha^{-1} of poultry manure or 30 t ha^{-1} of FYM in conjunction with *Azospirillum* and phosphate solubilizing bacteria yielded fruits of higher girth (19.38 cm) and greater number (17.96 $plant^{-1}$) respectively over 28 kg nitrogen + FYM @ 20 t ha^{-1} and vermicornpost @ 1.2 t ha^{-1} (Naidu *et al.*, 1999).

The increase in the level of poultry manure from 0 to 169.9 q ha^{-1} caused a progressive increase of yield and growth of cauliflower (Kirthi Singh *et al.*, 1967).

2.1.4 Effect of neem cake

Neem cake is considered as concentrated organic manure, since it contains higher per cent of major plant nutrients like nitrogen, phosphorus and potash compared to bulky organic manures like FYM and compost. Oil cakes are the quick acting organic manures, though insoluble in water, their nitrogen becomes quickly available to the plants in about a week or 10 days after application. Neem cake has 5.2 %, 1.0 % and 1.4 % N, P_2O_5 and K_20 respectively. De-oiled neem cake is a by product of the oil production and is being used as manure (Yawalkar *et al.,* 1996).

Plant nutrients present in oil cakes are in organic combination and are liberated in available form only after the oil cake undergoes decomposition in the soil. As it requires a certain amount of moisture for decomposition, the use of oil cake is limited to irrigated crops or high rainfall areas.

Neem cake is known to farmers as an insecticide or nematicide because of its toxic effect on soil borne pests and nematodes rather as a manure. In plantation crops like coconut, arecanut, tea, cardamom, pepper, coffee, rubber *etc.,* its use is more common to protect from soil insects and nematodes and also to get good yield. Farmers in India are aware of insecticidal properties of neem even before the invention of chemical pesticides. Neem cakes contain azadiractin, miliantriol *etc.,* having insecticidal and nematicidal properties.

Fenugreek plants grown in soil amended with *Azadirachta indica* were taller and had higher dry matter than plants grown in unamended soil. These plants also had higher concentrations of nitrogen and phosphorus compared with control plants (Krishnan *et al.*, 1995).

Neem cakes are traditionally used as soil amendments for the management of phytoparasitic nematodes. Theoretically, the toxic principles of neem reduce nematodes directly and also the chemicals released due to decomposition of neem cakes affect nematodes. The neem cake was found effective against *Meloidogyne incognita* in mungbean and chickpea (Mojumder, 1999).

Neem cake @ of 2 % w/w was very effective in reducing the population of *Meloidogyne incognita* as well as significantly increasing growth parameters (shoot length, shoot dry weight, root fresh weight and number of leaves) of Japanese mint. application of neem cake was also better than that of inoculated control and carbofuran @ 2 kg a.i. ha-^{1} in increasing some growth parameters of mint plants (Singh and Vinod Kumar, 1995).

In an experiment conducted to study the efficacy of organic amendments like FYM, poultry manure and neem cake, it was revealed that neem cake effectively lowered the root knot infestation and improved plant growth in okra both at 2.5 and 5 t ha^{-1} (Narpinderjeet Randhawa *et al.*, 2000).

The effect of different sources of nitrogen as neem cake, karanj cake, neem cake + urea and urea alone with their graded levels 100, 150, 200 kg ha^{-1} N on yield of betelvine was studied. Among various sources tried, application of nitrogen through neem cake produced significant response in increasing the yield and keeping quality of beetlevine. The highest net returns were also received with the application of 200 kg N ha^{-1} through neem cake *i.e.*, Rs. 34,000 year^{-1} (Srinivas, 2004).

The effect of partly decomposed neem leaves was investigated on the population of free nitrogen fixers and fungi. The treatment of soil with *Azadirachta indica* (1%) increased the population of free nitrogen fixers and fungi (Krishnan *et al.*, 1995).

2.2 Effect of integrated nutrient management on growth and yield

The basic concept underlying integrated nutrient management is the maintenance or adjustment of soil fertility and plant nutrient supply above optimum level to get the benefits from all possible sources of plant nutrients in an integrated manner. Integrated nutrient management envisages the exploitation and use of all the locally available sources of nutrients such as farmyard manure, vermicompost, green manure, neem cake, sewage sludge, press mud, biologically fixed nitrogen in combination with fertilizer levels (Subba Rao and Chandrasekhar Rao, 1980).

Use of biofertilizers has become popular especially among spices. The biofertilizers not only aid in nitrogen fixation but also produce growth substances like auxins, gibberellins and cytokinins and thereby improve crop production. Integrated nutrient management comprises application of organic manures, biofertilizers along with minimum use of chemical fertilizers to produce optimum crop yield without deterioration of the soil health.

Literature pertaining to the effects of INM practices on growth, yield, quality and nutrient uptake of fenugreek and other crops has been reviewed and presented in this chapter as detailed below.

The highest seed yield of 690 kg ha^{-1} was recorded in fenugreek with application of FYM @ 5 t ha^{-1} + inorganic N (100 %) + *Azospirillum* (Anonymous, 2006). As reported by Patil *et al.* (2008), application of organic manures and inorganic manures influenced the growth parameters in fenugreek. Application of FYM @ 5 t ha^{-1} with 75 % RDF recorded higher seed and straw yield over other treatments.

Lakpale *et al.* (2007) reported maximum grain and straw yield in fenugreek and organic carbon content was also increased with application of 25 % P_2O_5 + cow dung.

Balanced fertilization significantly increased all the yield attributes, yield and NPK uptake in fenugreek (Chaudhary, 2007).

Jat *et al.* (2006) who studied the integrated nutrient management in fenugreek recommended application of FYM 5 t ha^{-1} along with *Rhizobium* (1.5 kg ha^{-1}) and 100 % inorganic fertilizers for improvement of seed yield.

Tarun *et al.* (2006) found that integrated use of NPK with *Rhizobium* and PSB in fenugreek improved post-harvest soil fertility along with high values for residual organic carbon content, available N, P and K. However, the use of only biological sources was marginally effective in conserving the fertility status of the soil.

Balanced fertilizer application and use of Agrochemicals like Thiourea significantly improved seed yield in fenugreek as reported by Chaudhary (2006).

Damke *et al.* (1988) reported the highest yield of dry pods (22.76 q ha^{-1}) and maximum plant height (78.4 cm) by the application of 9 t ha^{-1} of FYM and 50 kg each of NPK ha^{-1} in chilli cv. CA 960 at Akola. Shanmugavelu (1989) also opined that application of organic manures exhibited a positive influence on chilli yield. Meena Nair and Peter (1990) studied the effect of organic and inorganic fertilisers and their combinations in Kerala and concluded that the application of 15 t ha^{-1} FYM + 175:40:25 kg NPK ha^{-1} was the optimum dose for high yield of chilli crop.

Zaharah (1986) carried out a trial to determine the optimum rates of chicken dung and inorganic fertilizer for chilli (M.C.4) grown on bris soil at Telong in Malaysia and reported that 2 t ha^{-1} of chicken dung and 2000 kg ha^{-1} of NPK and S compound fertilizer (12:12:17:2) gave the highest yields by increasing the number of fruits $plant^{-1}$.

Maynard (1991) studied the effect of organic amendments, poultry manure, compost and inorganic fertilizers on several vegetable crops and reported that the yields of egg plant, capsicum, tomatoes etc exhibited the maximum yields with poultry manure applied @ 50 t ha^{-1}.

Giardini *et al.* (1992) reported that the highest yield of 25 t ha^{-1} tomatoes was obtained with poultry manure @ of 8 t ha^{-1} in combination with fertilizers at the highest nutrient rates.

Abusaleha (1992 b) observed that application of equal amount of organic and inorganic sources (poultry manure, 20 kg N) resulted in higher seed weight in fruit, number of seeds $fruit^{-1}$ and 100 seed weight in okra.

In coriander the highest seed yield of 631 kg ha^{-1} was recorded with application of inorganic nitrogen (50 %) + FYM @ 5 t ha^{-1} (Anonymous, 2006). In cumin also, highest seed yield of 320 kg ha^{-1} was recorded with application of inorganic nitrogen (100 %) with *Azospirillum* and FYM @ 5 t ha^{-1} (Anonymous, 2003).

2.2.1 Effect of biofertilizers on growth and yield

Application of biofertilizers is of great significance in organic farming as they play a nutritional stimulatory and the therapeutic role in improving growth, yield and quality of vegetable crops and spices. Organic manures can reduce over dependence on chemical fertilizers thereby eliminating the incidence of toxicity and residual effects of hazardous nitrates and amines in spices, vegetables and processed products.

Basavanna Gowda (1980) reported that inoculation of phosphate solublizing micro organisms along with insoluble phosphate sources increased the root growth, dry matter yield, phosphorous content and uptake by maize plants under pot culture conditions. Ahmed *et al.* (2003) stated that phosphorus solubilizers can also save in general 40 % phosphorous fertilizers and can enhance the crop yield from 4.7 to 51 % in cow pea, peas, brinjal, cabbage, garlic, tomato, onion and radish *etc.* Phosphorus is an important key element next only to nitrogen in plant nutrition. It is necessary to supply this element in available form through fertilizers to meet the requirement of plants. However, in general the applied phosphorus gets fixed in the soil and becomes unavailable. There are certain micro organisms in soil which are capable of solubilizing insoluble inorganic phosphates and make them available for plant growth and development. They include *Bacillus megaterium, Bacillus polymyxa, Pseudomonas striata, Aspergillus awamori, Aspergillus niger, Penicelilum digitatum* etc. These organisms produce organic acids such as citric acid, fumaric acid, tartaric acid, glyoxalic acid, oxybutyric acid, malic acid, succinic acid *etc.,* from simple carbohydrates. By virtue of these organic acids, they solubilize inorganic phosphates and make them available to plants (Patil and Alagawadi, 1992).

Seed treatment and soil application of *Rhizobacteria* increased the yield (919 kg ha^{-1}) in fenugreek (Anonymous, 2003).

Field experiment conducted on fenugreek revealed that the integrated use of recommended dose of fertilizers in combination with *Rhizobium* and PSB resulted in significant increase in all yield attributes (Tarun adak *et al*., 2007).

Ramadan (2004) observed higher content of Fe and Mn at harvest time in fenugreek when biofertilizers, VAM and Yeast were applied to soil.

An experiment was conducted to evaluate effect of Phosphorus rich organic manure (PROM) with *Rhizobium* and PSB on growth and yield of fenugreek and the results revealed that maximum plant height was noticed with PROM, 75 % P_2O_5 of RDF + *Rhizobium* and PSB (Sharma *et al.*, 2006).

Neeraj and Anuj Chauhan (2006) investigated the relative performance of different AM fungi and inorganic phosphorus fertilizers on growth and yield of fenugreek. The application of chemical phosphorous along with the AM fungi was found to be effective in increasing the dry matter of root, shoot and leaves.

Sharangi *et al.* (2005) reported that seed inoculation of fenugreek with *Rhizobium melatoti* resulted in marked increase in nodule number (222.9), while the maximum nodule dry weight (0.832 g) was obtained under 40 kg N ha^{-1}.

Response of fenugreek to bioinoculants was studied by Purbey and Sen (2005) and results indicated higher plant height (75 cm), dry matter production (21g) and seed yield (17q ha^{-1}) with inoculation with *Rhizobium* + PSB.

Jat (2004 b) observed increase in mean number of nodules $plant^{-1}$ by 3.84 and 3.65 % with *Rhizobium* and *Rhizobium* + PSB as seed treatment respectively. The above treatment significantly increased biological yield, N uptake (5 % increase) and P uptake (6 % increase) over control, *Rhizobium* alone and PSB alone in fenugreek. The highest seed and grain yields of fenugreek and pearl millet were obtained with 80 kg P_2O_5 ha^{-1}, 100 kg S ha^{-1} and *Rhizobium* + PSB. Similarly, Jat and Shakhawat (2003) observed apparent and actual gain in nitrogen content in soil after harvest of fenugreek with increasing Sulphur levels.

Kumawat *et al.* (2003) reported that application of Fe at 3 kg ha^{-1}, Mo at 0.5 kg ha^{-1} and *Rhizobium* inoculation significantly increased yield and yield attributing characters in fenugreek.

The nodular mass, shoot height and yield (10.7 q ha^{-1}) were greatly influenced by inoculation of *Azotobactor* with *Pseudomonas striata* which gave highest incremental cost benefit ratio (1:5) in fenugreek. The bacterization of seed could sustain the NPK content in soil (Parakhia *et al*., 2000).

Chaudhary (1999) reported that *Rhizobium* inoculation in fenugreek resulted in significant increase in number of branches $plant^{-1}$, Pod length, test weight and yield with net return of Rs. 15,407 ha^{-1}. Similarly, highest yield of 1340 kg ha^{-1} was recorded with application of 20 kg N + *Rhizobium* seed treatment (Shivaran *et al*., 1995).

El-Ghany *et al.* (1997) conducted trial on effect on *Rhizobium* inoculation, sheep dung and P-fertilization on microbiological changes and yield of fenugreek in Saline soils. The results indicated that bacterial population, aerobic cellulose decomposers, asymbiotic nitrogen fixers increased with increasing rate of phosphorus application using sheep dung and biofertilization. Fenugreek production increased by 237 % over control.

Seed inoculation with *Rhizobium* significantly increased pods $plant^{-1}$, seeds pod^{-1}, seed yield and straw yield. The highest seed yield (1.34 t ha^{-1}) was obtained by applying 30 kg N ha^{-1} combined with seed inoculation (Shivran *et al*., 1995).

2.2.2 Effect of organic manures, inorganic fertilizers and biofertilizers on quality in fenugreek and other crops

Fenugreek seed contains crude protein, crude fibre and "diosgenin", a sex hormone used in oral contraceptives. Seed quality is very important as it is used in pharmaceutical preparations and consumed as condiment. Baphna (1992) reported that *insitu* vermiculture of 2 lakhs earthworms per acre gave 15 tonnes of best manure which was sufficient for sapota plantation and it improved quality, sweetness and keeping quality and harvesting period.

In *Coccinia cordifolia*, the application of vermicompost resulted in better quality produce (Khamkar, 1992), while the application of vermicompost along with oil cake in sapota plantation resulted in better yield both quantity wise and quality wise (Patel, 1992).

The increase in the level of poultry manure from 0 to 170 q ha^{-1} increased the protein content, Ca, Mg and ash contents in cauliflower curd (Kirthi Singh *et al.*, 1967).

2.2.2.1 Crude protein content in seed

Application of phosphorus rich organic manure (75 % RDF) + FYM @ 6 t ha^{-1} recorded 18.63 % crude protein in seed of fenugreek as reported by Sharma *et al.* (2006). The increase in protein content was also reported by Wang *et al.* (1994) and Deora and Jitender Singh (2008) with application of FYM and vermicompost respectively. Khiriya *et al.* (2003) reported that crude protein content (22.81 %) was found to be increased significantly with increasing levels of FYM up to 15 t ha^{-1}. The beneficial effect of FYM on protein yield was ascribed to increased nitrogen content in seed.

2.2.2.2 Crude fibre content in seed

The crude fibre in fenugreek seed is very important in human nutrition as it adds roughage to human diet and in fenugreek. In the study conducted by Nasri and Tiney (2007) on functional properties of fenugreek protein concentrate, 9.3 % crude fibre in seed was recorded.

Sridevi and Sumathi (2008) reported increase in crude fibre in tomatos with application of organic manures. Similar increase in crude fibre was also reported in cucumber by Bindhya (2004). However, in okra improvement in crude fibre was reported with application of inorganic fertilizers (Premshekar and Rajashree, 2009).

2.2.2.3 Diosgenin content in seed

Diosgenin in fenugreek seed is a sex hormone used in pharmaceutical preparations. The diosgenin content was found to vary from 0.33 to 1.90 % depending upon the geographical region and it was found to be low in Indian varieties (0.1 %) as compared to exotic varieties from Algeria, Morocco and Ethiopia (0.20 to 0.35 %). It also varies depending on genotypes and as well as on cultural practices (Bhavasar *et al.*, 1980). Significant improvement was observed in diosgenin content of seed under foliar application of bioregulators. However, bioinoculants failed to significantly influence the diosgenin content of the seed (Purbey and Sen, 2005).

2.2.3 Effect of organic manures, inorganic fertilizers and biofertilizers on nutrient uptake and its content

Application of recommended dose of nitrogen through poultry manure increased the nutrient uptake in tomato as compared to FYM and press mud (Prabakaran, 2003). However, there was a significant increase in the uptake of magnesium in the treatment combination with poultry manure than FYM in okra (Abuseleha, 1992 a).

An experiment was conducted in fenugreek to study the effect of fertilizers and vermicompost on total nutrient uptake by the plant and nutrient content in seed and straw. The results showed that application of vermicompost significantly increased the NPK uptake and their contents in the seed as well as straw in fenugreek (Deora and Jitender singh, 2008). Rathore and Porwal (2008) reported that application of *Rhizobium* + PSB in fenugreek enhanced the N and P contents as well as their uptake by seed and haulm.

Application of 100 % inorganic N + *Rhizobium* + FYM @ 5 t ha^{-1} recorded higher nitrogen (65 kg ha^{-1}) and phosphorus uptake (9.4 kg ha^{-1}) comparable with 100 % inorganic N + biofertilizers (Jat *et al.*, 2006). As reported by Khriya *et al.* (2003), application of FYM @ 15 t ha^{-1} + inorganic fertilizers increased the nitrogen (129 kg ha^{-1}), phosphorus (20 kg ha^{-1}) and potash (66 kg ha^{-1}) uptake in fenugreek. Further, the above treatment also recorded 3.65 % nitrogen, 0.52 % phosphorus and 1.23% potassium in fenugreek seed. Bhunia *et al.* (2006) recorded increase in nitrogen (31 kg ha^{-1}), phosphorus (5.5 kg ha^{-1}) and potash uptake (37.9 kg ha^{-1}) with *Rhizobium* inoculation in fenugreek.

The nitrogen and phosphorus contents of fenugreek in seed and straw and their total uptake increased significantly with increase in phosphorus upto 50 kg ha^{-1}. Application of phosphorus @ 50 kg ha^{-1} recorded 3.32 % N in seed and 1.2 % N in straw with a nitrogen uptake of 109 kg ha^{-1}. Further, the phosphorus content was reported to 0.43 % in seed and 0.14% in straw with an uptake of 14 kg phosphorus ha^{-1} (Nehara *et al.*, 2006).

2.3 Effect of inorganic fertilizers on growth and yield of fenugreek

It has been reported that fenugreek responds to varying doses of NPK @ of 15 : 15 : 20 to 60 : 90 : 50 kg ha^{-1} (Halesh, 1997). The Spices board recommended NPK dose of 40 : 20 : 0 kg ha^{-1} while, a recommendation of 60 : 50 : 50 kg ha^{-1} NPK was made by Acharya N.G.Ranga Agricultural University, Hyderabad. Similarly, Rajastan Agricultural University, Bikaneer recommended the application of 40 kg N and 40 kg P_2O_5 in fenugreek (Anonymous, 2004).

Banafar *et al.* (1995) studied the response of fenugreek to nitrogen and phosphorus in soils of Madhya Pradesh. They reported that seed yield increased from 806 to 1200 kg ha^{-1} at nitrogen application rates of 0 and 80 kg ha^{-1} respectively (excluding basal applications) and from 776 to 1105 kg ha^{-1} at phosphorus application rates of 0 and 45 kg ha^{-1} respectively. Choudhary (1999) studied response of fenugreek to nitrogen and phosphorus. Application of 40 kg N ha^{-1} significantly increasd the mean plant height, branches, pods $plant^{-1}$, pod length, test weight and straw yield compared with 0 and 20 kg N ha^{-1}. Seeds pod^{-1} and seed yield increased significantly with the application of 40 kg N ha^{-1} compared with the control. Phosphorus at 40 kg ha^{-1} produced significantly higher mean number of branches, pods $plant^{-1}$, test weight, straw and seed yields than 20 kg ha^{-1}.

2.4 Effect of organic manures, inorganic fertilizers and biofertilizers on available nitrogen, phosphorus and potassium in soil after harvest of fenugreek.

Soil inoculation with *Rhizobium* and *Rhizobium* + PSB significantly increased nitrogen content in soil after harvest of fenugreek by 3.5 % (Jat and Shakhawat, 2003).

Soil treatment of *Rhizobium* + PSB in fenugreek was reported to result in improvement of available phosphorus after harvest of fenugreek as reported by Jat *et al.* (2003).

Nethra *et al.* (1999) conducted an experiment using vermicompost as an organic amendment at 5, 10 and 15 t ha^{-1} alone or in combination with 50 or 100 per cent recommended NPK on the growth of *Callistephus chinensis*. The highest available nitrogen in the soil (493.31 kg ha-^{1}) was observed in the plot receiving 5 t vermicompost ha^{-1} + 100 % NPK.

FYM application increased the soil organic matter content in soil by growing vegetables (Blanc *et al*., 1989). Further, they have reported that mineral fertilizers were more efficient in short term but organic manure had greater residual effect. On long term basis, incorporation of straw with nitrogen application was found to give increased yield by non legume crops.

2.5 Correlation studies in fenugreek

Correlation in sixty promising genotypes of fenugreek indicated that the yield was closely associated with number of grains pod^{-1}, pod length and 1000 grain weight (Singh and Pramila, 2009).

Sarada *et al*. (2008) reported that seed yield showed highly significant positive association with plant height, number of pods plant^{-1}, pod length and number of seed pod^{-1}. Among yield component characters, plant height with number of pods plant^{-1}, pod length, number of seeds pod^{-1}; number of pods plant^{-1} with pod length, number of seeds pod^{-1} and pod length with number of seeds pod^{-1} showed significant positive association both at phenotypic and genotypic level.

Kole and Mishra (2006) reported that branches plant^{-1}, pods plant^{-1}, seeds pod^{-1}, biological yield, seed weight, husk weight, straw yield plant^{-1}, biological yield plant^{-1} and harvest index showed highly positive correlation with seed yield, while days from flowering to maturity and plant height had negative correlation with seed yield.

Seed yield and biological yield was positively and significantly correlated with nitrogen and phosphorus uptake as reported by Jat (2004 a).

2.6 Comments on review of literature

In the recent past, many hazardous effects due to injudicious and continuous application of inorganic fertilizers in production of horticultural crops are documented leading to low productivity and spoilage of soil health. In this connection, efforts have been initiated by researchers searching alternate systems and nutritional practices giving due importance to the usage of organic manures and INM concepts.

As per the forgoing literature on spices, it is imperative that many positive responses and the beneficial effects of organic manures and INM practices are reported recently in many spices. The work done on seed spices *viz.,* coriander, fenugreek, fennel, cumin demonstrated that application of nutrients in an organic form either through farmyard manure or vermicompost or poultry manure or neem cake or cattle manure *etc.,* promoted the vegetative growth and enhanced the yield and quality of seed and straw compared to application of inorganic fertilizers alone (Ahmed, 1993; Abusaleha, 1992b; Bhati, 1996; Kirthi Singh *et al.*, 1967; Kale, 1998; Naidu *et al.,* 1999; Patil, 1995; Pawar, 1996; Sunil *et al.* 1997).

Applications of nutrients in an integrated manner along with organic manures and biofertilizers also showed certain beneficial effects *viz.,* increased yields, quality, retention of soil fertility in spice crops (Chaudhary, 1999; Lakple *et al.*, 2007; Jat, 2004 b; purbey and Sen, 2005; Sharangi *et al.*, 2005; Sharma *et al.*, 2006; Shivaran *et al.*, 1995; Tarun *et al.*, 2007) and most of these reports pertained to Rajastan and Gujarat conditions. Among biofertilizers, beneficial effects have been recorded with usage of *Rhizobium* supplement and PSB applications. In certain cases, INM practices found to have enhanced the seed and straw quality of fenugreek in terms of enhanced protein content. However, the research work pertaining to fenugreek under agroclimates of Andhra Pradesh in respect of the effects of organic manures (or) INM practices seem to be scarce as also evident from the reports of the AICRP on seed spices (ICAR) with one centre in Andhra Pradesh (Guntur) and where the research was mostly confined to coriander. Among the Southern states, Andhra Pradesh is an important producer of seed spices like coriander and fenugreek grown in black soils and semi-arid areas under irrigated conditions.

From the forgoing review of work on spices, it can be concluded that precise information on the response of fenugreek under Andhra Pradesh conditions to organic manures and INM practices is rather scattered and yet to be generated. Therefore, keeping the above lacunae of crop research in view, two field experiments were planned in the present investigation to study effects of certain organic manures and INM practices in fenugreek under agroclimatic condition of Andhra Pradesh.

Chapter III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The investigation on "Studies on effect of different organic sources and integrated nutrient management on growth, yield and quality of fenugreek (*Trigonella foenum graecum* L.)" was carried out during *rabi*, 2008-09 and 2009-10 at Horticultural Research Station, Kovvur (West Godavari District), Andhra Pradesh. The investigation was divided into two field experiments and both were repeated for two seasons. The materials used and methods followed in this investigation are described hereunder.

3.1 Geographical location of the experimental site

The Horticultural Research Station, Kovvur, the site of investigation is located at $17^0$00' N latitude, $81^0$43' E longitude and 15.66 m above mean sea level.

3.2 Climate

Weather data recorded during the crop period (15-10-2008 to 28-1-2009 and 15-10-2009 to 28-1-2010) are presented in Appendix-1. The average weekly maximum temperature ranged from 29.42^0C to 34.57^0C during 2008-09 and 29.14^0C to 35.42^0C during 2009-10, while the minimum mean temperature varied between 18.57^0C to 24.14^0C and 18.57^0C to 24.42^0C during 2008-09 and 2009-10 respectively. Similarly, the weekly mean relative humidity ranged from 74.00 to 85. 71 per cent at 7.16 hr. and 47.00 to 66.71 per cent at 14.00 hr. during 2008-09 and 66.71 to 88.42 per cent at 7.16 hr. and 41.57 to 69.28 per cent at 14.00 hr. during 2009-10. The total rainfall received during the crop period (2008-09) was 46.8 mm in 5 rainy days, while it was 45.1 mm in 5 rainy days during 2009-10.

3.3 Soil

Prior to preparatory cultivation, soil samples were collected at random from zero to 30 cm depth from the experimental field and a composite sample was analyzed for physico-chemical properties by following standard methods (Table-1). The experimental soil was sandy loam in texture, neutral in reaction, low in organic carbon, low in available nitrogen, medium in available phosphorus and high in available potassium.

3.4 Experiment details

The investigation was divided into two experiments. The first experiment was conducted to study the effect of different organic manures on growth, yield and quality of fenugreek and the second experiment was conducted to study the effect of integrated nutrient management on growth, yield and quality of fenugreek.

3.4.1 Experiment - I :

Effect of different organic sources on growth, yield and quality of fenugreek (*Trigonella foenum graecum* L.)

Details of Treatments:

T_1 : Vermicompost @ 6.6 t ha^{-1}

T_2 : Farm yard manure @ 5.7 t ha^{-1}

T_3 : Poultry manure @ 7.0 t ha^{-1}

T_4 : Neem cake @ 5.0 t ha^{-1}

T_5 : Vermicompost @ 3.3 t ha^{-1}+ Farm yard manure @ 2.8 t ha^{-1}

T_6 : Vermicompost @ 3.3 t ha^{-1} + Poultry manure @ 3.5 t ha^{-1}

T_7 : Vermicompost @ 3.3 t ha^{-1} + Neem cake @ 2.5 t ha^{-1}

T_8 : Farm yard manure @ 2.8 t ha^{-1} + Poultry manure @ 3.5 t ha^{-1}

T_9 : Farm yard manure @ 2.8 t ha^{-1} + Neem cake @ 2.5 t ha^{-1}

Layout plan of the Experiment-I "Effect of different organic sources on growth, yield and quality of fenugreek (*Trigonella foenum graecum* L)".

R1	R2	R3
T_1	T_{12}	T_{11}
T_2	T_{11}	T_9
T_3	T_{10}	T_{12}
T_4	T_7	T_2
T_5	T_9	T_3
T_6	T_8	T_1
T_7	T_6	T_4
T_8	T_1	T_5
T_9	T_2	T_{10}
T_{10}	T_3	T_8
T_{11}	T_4	T_6
T_{12}	T_5	T_7

Design	:	Randomized block design
Treatments	:	12
Replications	:	3
Gross plot size	:	5.3 x 3.6 m
Net plot size	:	5.0 x 3.3 m
Spacing	:	30 x 10 cm

Plate : 1 : Field view of fenugreek crop (Expt-1)

Layout plan of the Experiment-II "Effect of Integrated Nutrient Management on growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L)".

R1	R2	R3
T_1	T_9	T_5
T_2	T_{10}	T_1
T_3	T_6	T_2
T_4	T_8	T_3
T_5	T_1	T_{10}
T_6	T_7	T_9
T_7	T_3	T_6
T_8	T_4	T_7
T_9	T_2	T_8
T_{10}	T_5	T_4

Design	:	Randomized block design
Treatments	:	10
Replications	:	3
Gross plot size	:	5.3 x 3.6 m
Net plot size	:	5.0 x 3.3 m
Spacing	:	30 x 10 cm

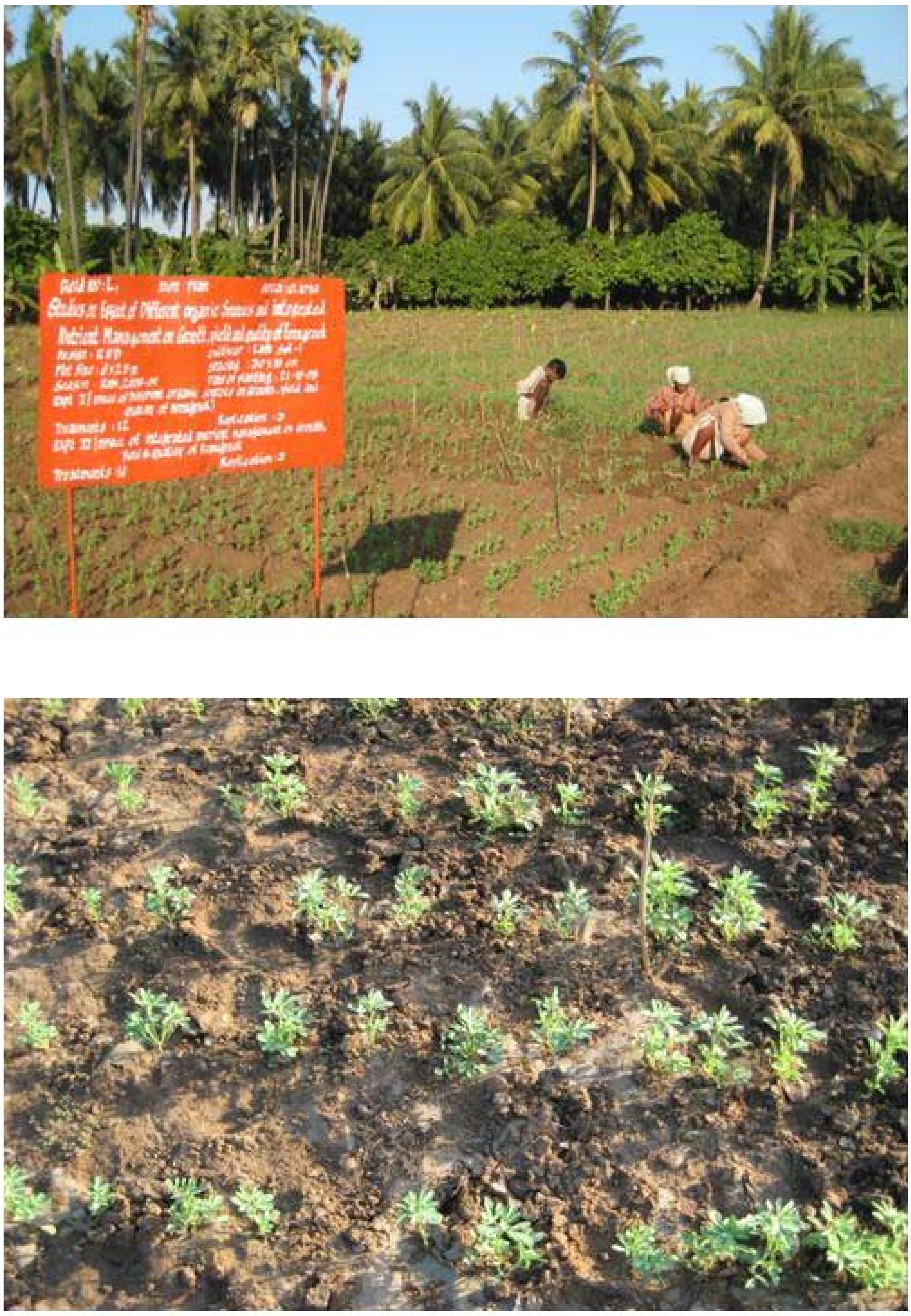


Plate : 2 : Field view of fenugreek crop (Expt-2)

T_{10} : Poultry manure @ 3.5 t ha^{-1} + Neem cake @ 2.5 t ha^{-1}

T_{11} : 50% RDF (30 – 25 – 25 NPK kg ha^{-1})

T_{12} : 100% RDF (60 – 50 – 50 NPK kg ha^{-1})

3.4.2 Experiment - II :

Effect of Integrated Nutrient Management on growth, yield and quality of fenugreek (*Trigonella foenum-graecum*).

Details of Treatments:

T_1 : 100 % RDF (60 – 50 – 50 NPK kg ha^{-1})-control

T_2 : 100 % RDF (60 – 50 – 50 NPK kg ha^{-1}) + *Rhizobium* + PSB

T_3 : 75 % RDF + Farm yard manure @ 2.8 t ha^{-1} + *Rhizobium* + PSB

T_4 : 50 % RDF + Farm yard manure @ 2.8 t ha^{-1} + *Rhizobium* + PSB

T_5 : 75 % RDF + Vermicompost @ 3.3 t ha^{-1} + *Rhizobium* + PSB

T_6 : 50 % RDF + Vermicompost @ 3.3 t ha^{-1} + *Rhizobium* + PSB

T_7 : 75 % RDF + Poultry manure @ 3.5 t ha^{-1} + *Rhizobium* + PSB

T_8 : 50 % RDF + Poultry manure @ 3.5 t ha^{-1} + *Rhizobium* + PSB

T_9 : 75 % RDF + Neem cake @ 2.5 t ha^{-1} + *Rhizobium* + PSB

T_{10}: 50 % RDF + Neem cake @ 2.5 t ha^{-1} + *Rhizobium* + PSB

The experiment I and II were repeated in another field during 2009-10 in similar type of soil.

3.5 Cultivation details

3.5.1 Raising exhaust crop

An exhaustive crop (maize) was raised in the experiment fields before laying out the experiments during both the years of study to obtain optimum response to applied nutrients to the crop.

3.5.2 Raising green manure crop

The green manure crop, *Crotalaria juncea* (Sunhemp) was grown as preceding crop in experimental field and was incorporated at flowering stage which has wide adaptability and supplies the greatest bulk of succulent organic matter with a low C : N ratio.

3.5.3 Fenugreek

Fenugreek cv. Lam Sel-1, developed by Acharya N.G. Ranga Agricultural University grown in the experiment is a popular variety in Andhra Pradesh. The plants are bushy with medium sized golden yellow seeds. It matures in 90-95 days.

3.5.3.1 Preparatory cultivation

The experimental field was thoroughly ploughed with tractor drawn mouldboard plough to a depth of 30 cm and harrowed twice to a fine tilth. The field was leveled and divided into plots as per the layouts of the respective experiments.

3.5.3.2 Imposing treatments

3.5.3.2.1 Inorganic fertilizers

In inorganic treatments (50 % and 100 % recommended dose of fertilizers) nitrogen, phosphorus and potassium nutrients were applied in the form of urea, single super phosphate and muriate of potash respectively. Nitrogen was applied in two equal splits as ½ basal and remaining 20 days after sowing. Entire phosphorus and potassium were applied as basal.

3.5.3.2.2 Source of organic manures

Vermicompost was obtained by culturing *Eisenia foetida* earthworms on cocoa and other weed waste along with fresh animal dung and was used. Farmyard manure was obtained by composting different crop residues along with animal dung and used fully decomposed manure. Poultry droppings were collected from cages type of poultry units and allowed to decompose fully and used. Neem cake was obtained by crushing neem seed kernels and used. Nutrient concentrations of organic manures used in the investigation are presented below.

Table-2 Nutrient concentrations of organic manures

Organic manure	Nutrient concentration (%)			Moisture
	Nitrogen	Phosphorus	Potassium	(%)
Vermicompost	1.35	0.31	0.88	36.5
Farmyard manure	1.57	0.26	0.70	26.0
Poultry manure	1.28	0.90	0.91	24.2
Neem cake	1.80	0.60	1.15	2.30

3.5.3.2.3 Inoculation of biofertilizers

For this study, biofertilizers, *viz*., *Rhizobium melolot*i and phosphate solubilizing bacteria (PSB) *Bacillus megatherium* were obtained from Agricultural Research Station (Acharya N G Ranga Agricultural University), Amaravathi, Andhra Pradesh. Commercial formulations of PSB with colony forming unit (CFU) of 1x 10^8 were used. PSB @ 5 kg ha^{-1} was inoculated (one week before application in the field) in the respective organic manures and thoroughly incorporated in to soil before sowing of the crop. The *Rhizobium* culture @ 1.5 kg ha^{-1} mixed in thick jaggery solution and applied to the fenugreek seed(25 kg ha^{-1}).

3.5.3.3 Sowing

The treated seed was dropped in the furrows opened with hand marker at a distance of 30 cm and later, the furrows were covered with soil and then irrigated.

3.5.3.4 Cultural operations

The seedlings were thinned at 3 to 4 leaves stage to retain the plant distance to the required spacing leaving one seedling $hill^{-1}$. Need based irrigations were given through out the crop period and light irrigations were given after application of manures/fertilizers. Weeds were kept under control by regular manual weeding.

3.5.3.5 Weeding and irrigation

Weeds were removed manually as and when they emerged to keep plot free from weeds. The crop was irrigated soon after sowing. Thereafter, it was irrigated twice in a week for first four weeks and subsequently, irrigation was given at weekly intervals depending up on the moisture status of the soil.

3.5.3.6 Plant protection

During early stages, the crop suffered from root rot disease and it was controlled by spraying and drenching of copper oxychloride @ 3 g lt^{-1}. Insecticidal spray using neem oil @ 3 ml lt^{-1} was given to control aphids.

3.5.3.7 Harvesting

The crop was harvested at maturity stage *i.e.*, as and when the leaves and pods attained yellowish colour. The five labeled plants per plot were harvested for biometric observations just above the ground level. The plants in border rows were harvested. The rest of the plants of net plot were harvested plot wise separately. The plants were sun dried and the seeds were separated by gently beating with sticks. Seeds were winnowed, cleaned and weight of the seeds from each plot was recorded. Later, seeds were sun dried for storage.

3.6 Biometric observations on fenugreek

3.6.1 Observations on growth parameters

Five plants were selected at random from each plot and labelled for data recording. The following biometric observations and their mean value were expressed.

3.6.1.1 Plant height

Plant height was measured from the ground level to the growing tip of the main branch or tallest branch at 25, 50, 75 DAS and at harvest and expressed in centimeters (cm).

3.6.1.2 Number of branches

The branches arising from the main stem of the labelled plants were counted at 50 and 75 DAS and the average number of branches plant^{-1} was arrived.

3.6.1.3 Leaf number

The total number of leaves plant^{-1} was counted at 25, 50 and 75 DAS from five randomly selected labelled plants and mean values were calculated.

3.6.1.4 Leaf area

The total leaf area plant^{-1} was measured by leaf area meter at 75 DAS and expressed in cm^2 plant^{-1}.

3.6.1.5 Dry matter production

Five plants at random outside the net plot area were carefully dugout with roots at 25, 50, 75 DAS and at harvest stage and then dried in hot air oven. Sample dry weights were recorded and summed up to arrive mean dry matter content and expressed in g plant^{-1}.

3.6.1.6 Leaf area index

The leaf area index was calculated using the formula given by Watson (1958).

$$\text{LAI} = \frac{\text{Leaf area plant}^{-1}}{\text{Ground area occupied by the plant (m}^2\text{)}}$$

3.6.1.7 Absolute growth rate (AGR) for plant height

Absolute growth rate for plant height was calculated using formula suggested by Radford (1967) and expressed as cm day^{-1}.

$$\text{AGR for plant height} = \frac{H_2 - H_1}{t_2 - t_1}$$

Where H_1 and H_2 are plant heights at times t_1 and t_2 respectively.

3.6.1.8 Crop growth rate (CGR) for dry matter production

Crop growth rate was calculated using the formula given by Watson (1958) and expressed as g m^2 day^{-1}.

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

Where,

W_1 = Whole plant dry weight at t_1 (g)

W_2 = Whole plant dry weight at t_2 (g)

$(t_2 - t_1)$ = Time interval in days between stages

P = Land area occupied by the plant (m^2)

3.6.2 Observations on yield parameters

3.6.2.1 Days to 50 per cent flowering

Number of days taken from sowing to flowering of 50 per cent of the plants in a plot, in each treatment was recorded.

3.6.2.2 Number of pods $plant^{-1}$

The total number of pods from the labelled plants was counted at harvest and expressed as average number of pods $plant^{-1}$.

3.6.2.3 Pod length

Length of five randomly selected pods in each tagged plant was measured and expressed as average pod length in centimeters.

3.6.2.4 Number of seeds pod^{-1}

The average number of seeds present in twenty five randomly selected pods on randomly selected plants were counted and recorded as mean number of seeds pod^{-1}.

3.6.2.5 Grain filling percentage

Twenty five randomly selected pods from five labelled plants were collected and pods were opened and properly filled grains and total cavities in pod were counted and expressed in percentage.

$$\text{Grain filling percentage} = \frac{\text{Properly filled grains}}{\text{Total cavities in pod}} \times 100$$

3.6.2.6 Grain shelling percentage

Twenty five randomly selected pods were collected from labeled plants and weight of the pods was taken. Dry weight of the grain after shelling of pods was also taken.

$$\text{Grain shelling percentage} = \frac{\text{Weight of grain}}{\text{Weight of pods}} \times 100$$

3.6.2.7 Test weight

Weight of 1000 seeds from a composite sample made by mixing the seeds of five labelled plants was recorded and expressed in grams.

3.6.2.8 Seed yield $plant^{-1}$

Five randomly selected and labelled plants from each plot were harvested and the seeds were threshed and weighed separately. The average seed weight per plant was arrived and expressed in g $plant^{-1}$.

3.6.2.9 Seed yield

The seed yield per plot was recorded at harvest by taking the weight of seeds collected from the net plot area and the data on seed yield per plot were used to compute the seed yield and expressed in q ha^{-1}.

3.6.2.10 Straw yield

Leftover straw after threshing was weighed from each net plot and expressed in q ha^{-1}.

3.6.2.11 Biological yield

Biological yield was arrived by adding seed yield and straw yield and expressed in q ha^{-1}.

3.6.2.12 Harvest index

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6.3 Quality parameters

3.6.3.1 Crude protein content

For estimating protein content in fenugreek seed, first the per cent of nitrogen in the seed was estimated by Micro-kjeldahl method and it was multiplied by 6.25 as suggested by Sadasivam and Manickam (1996) by using the following formula.

Crude protein content (%) = Nitrogen % x 6.25

3.6.3.2 Crude fibre content

Fibre content of the fenugreek seed was estimated by the crude fibre content estimation method as indicated by Maynard (1970) and the results expressed as per cent.

3.6.3.3 Diosgenin content

Diosgenin content in fenugreek seed was estimated by High performance liquid chromatography method (Harris., 1975).

3.7 Chemical analysis

The seed and straw samples were collected from different treatments at harvest stage of fenugreek and were ground into powder and used for chemical analysis.

3.7.1 Nutrient content in seed and straw

The nitrogen content in seed and straw at harvest stage was estimated separately by modified micro Kjeldhal method as outlined by Piper (1966). For estimation of phosphorus content in seed and straw, Vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973) was followed. Similarly, seed and straw samples were also analysed for estimation of potassium content by using flame photometer (Muhr *et al*., 1965).

3.7.2 Nutrient Uptake

The seed and straw samples were analysed for nitrogen, phosphorus and potassium content and uptake was calculated and expressed as kg ha^{-1}.

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

3.7.3 Soil analysis

Soil samples after the harvest of fenugreek crop were drawn from each of the individual treatments and processed for available nutrients (N, P_2o, K_2O) in the soil by adopting the methods as listed in table -1.

3.8 Economics

The gross returns for both the experiments (I and II) during the two years of study were worked out with the then existing prices of the produce. Deducting the cost of cultivation from the gross returns, net returns were arrived for each treatment., The benefit cost ratio (BCR) was calculated by dividing the net returns with cost of production for all the treatments.

$$\text{Benefit cost ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

3.9 Statistical analysis of data

The experimental data were statistically analyzed following the standard procedures (Panse and Sukhatme, 1978) and significance was tested by 'F' value at 5 per cent level of probability. Critical difference (CD) values were calculated wherever the F test was found to be significant and rigorous treatment comparisons were made. Correlations of different variables with yield were also worked out.

Chapter IV

RESULTS

CHAPTER - IV

RESULTS

Two experiments were conducted to study the effect of certain Organic manures and certain Integrated nutrient management practices (inorganic chemicals, biofertilizers and organic manures) on growth, yield and quality of fenugreek (*Trigonella foenum-graecum* L.) at Horticultural Research station, Kovvur (West Godavary district, A.P) of Andhra Pradesh Horticultural University for two consecutive *rabi* seasons during 2008-09 and 2009-10. The data collected on different parameters were statistically analysed and the results are presented hereunder:

4.1 EXPERIMENT- I: EFFECT OF DIFFERENT ORGANIC SOURCES ON GROWTH, YIELD AND QUALITY OF FENUGREEK

4.1.1 Growth parameters

4.1.1.1 Plant height

Data pertaining to the effect of different treatments on plant height are presented in table-3. In this study, application of manures through different sources, their combinations and RDF (recommended dose of fertilizers) significantly influenced the height of the plant at different stages of the crop growth *i.e.,* from 25 DAS to harvest during both the seasons (2008-09 and 2009-10).

It was found that the plant height increased with the age of the crop reaching maximum at harvest. Further, a rapid rate of increase was observed between 25-50 DAS. Thereafter, the plant height increased slowly upto 75 DAS and marginally between 75 DAS-harvest.

It is evident from the data (Table-3) that during 2008-09 at 25 DAS, among different treatments, T_{12}: 100 % RDF recorded significantly highest plant height of

Table 3: Effect of organic manures on plant height at various stages of growth in fenugreek

Treatments	Plant height (cm)											
	25DAS			50DAS			75DAS			at harvest		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	6.70	7.30	7.00	27.00	30.00	28.50	34.00	32.00	33.00	37.00	36.00	36.50
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	7.10	7.80	7.45	27.66	30.50	29.08	34.06	32.00	33.03	37.06	36.30	36.68
T_3 : Poultry manure (PM) @7.0t ha^{-1}	6.96	7.66	7.31	27.26	30.10	28.68	34.43	32.50	33.46	37.43	41.20	39.31
T_4 : Neem cake (NC) @5.0 t ha^{-1}	6.60	7.30	6.95	25.23	28.00	26.61	32.83	30.00	31.41	36.33	36.00	36.16
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	7.73	7.93	7.83	26.66	29.60	28.13	34.53	32.33	33.43	37.53	36.00	36.76
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	7.90	8.10	8.00	32.73	35.70	34.21	35.96	37.20	36.58	39.96	40.00	39.98
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	7.76	7.90	7.83	27.46	30.00	28.73	32.53	33.50	33.01	35.03	36.83	35.93
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	8.40	9.20	8.80	33.16	35.50	34.33	36.53	36.00	36.26	38.83	39.00	38.91
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	8.43	9.20	8.81	28.33	31.20	29.76	33.56	33.50	33.53	37.06	36.83	36.94
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	7.20	7.90	7.55	26.50	28.20	27.35	32.56	33.20	32.88	36.06	36.00	36.03
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	8.76	9.00	8.88	27.43	30.00	28.71	34.46	35.20	34.83	37.46	36.00	36.73
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	9.91	9.50	9.70	29.66	33.30	31.48	37.33	40.16	38.74	41.33	40.00	40.66
Mean	7.79	8.23	8.01	28.26	31.01	29.63	34.40	33.97	34.18	37.59	37.51	37.55
Sem±	0.26	0.46	0.38	1.44	0.88	1.20	0.74	2.13	1.60	0.70	1.39	1.10
CD (P=0.05)	0.77	1.37	1.05	4.20	2.60	3.31	2.16	6.27	4.43	2.05	4.07	3.05

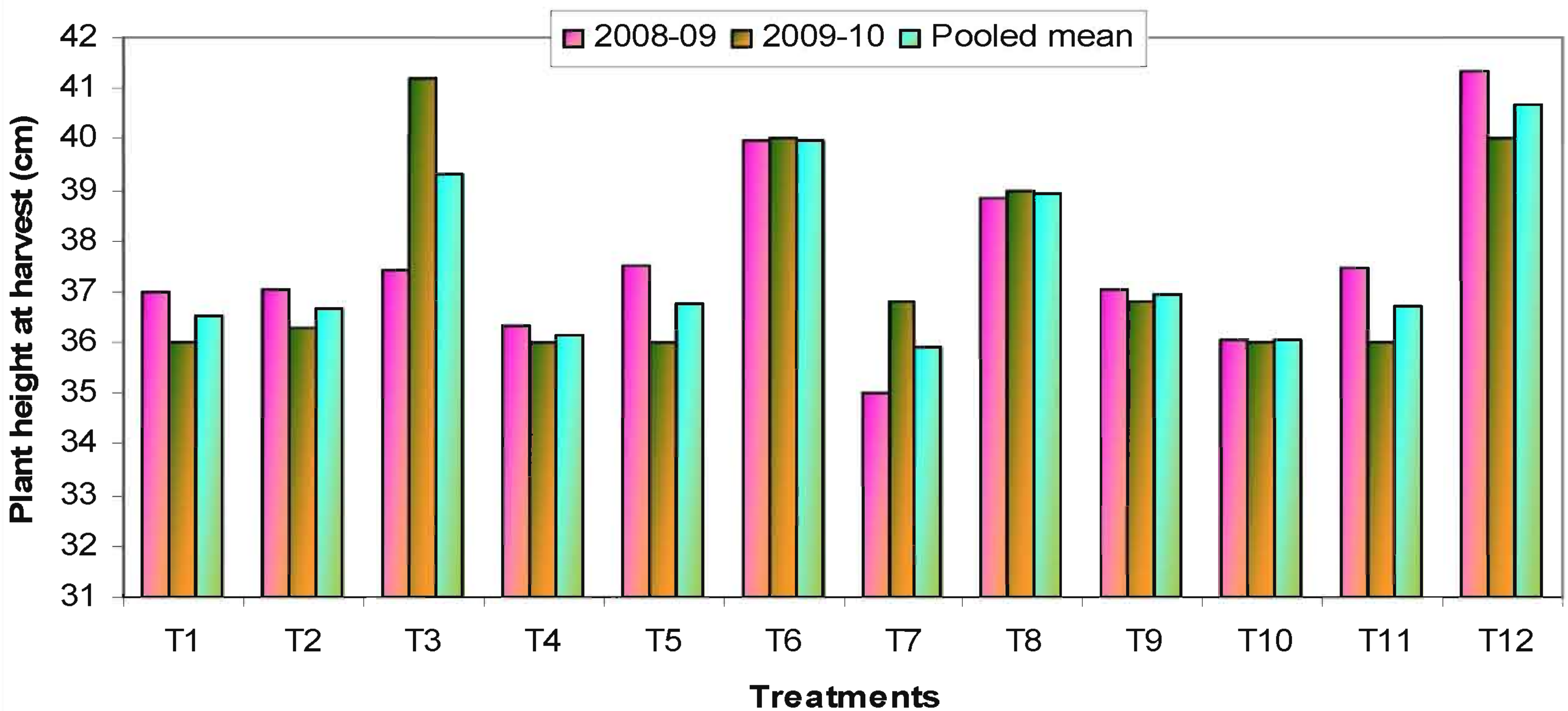


Fig.1: Effect of organic manures on plant height at harvest in fenugreek

9.91 cm over rest of the treatments followed by T_{11}: 50 % RDF, T_9: FYM + NC and T_8: FYM + PM recording 8.76 cm, 8.43 cm and 8.40 cm respectively. Further T_6 recorded significantly higher plant height compared to T_1, T_2, T_3 and T_4 and it was at par with T_7, T_5 and T_{10}. The lowest plant height of 6.6 cm was observed in T_4 which was on par with T_2, T_3 and T_1.

A similar trend in plant height was also observed during second season (2009-10). Significantly higher plant height of 9.5 cm in T_{12} was recorded over other treatments but it was at par with T_8, T_9, and T_{11}. However, there was no significant difference among other treatments *viz.*, T_1, T2, T_3, T_4, T_5, T_6, T_7, T_{10}. The lowest plant height was recorded in T_4 and T_1.

A consideration of pooled values of two years revealed that application of different organic manures, their combinations and RDF significantly influenced the plant height in T_{12}, T_{11}, T_8, and T_9. Significantly higher plant height was recorded in T_{12}: 100 % RDF (9.7 cm), but it was on par with T_{11}, T_8, and T_9. Among organic manures, significantly highest plant height was recorded by T_9: FYM + NC (8.81 cm) as compared to T_2, T_3, T_1 and T_4 and it was on par with T_8, T_6, T_5, and T_7. No significant difference was observed among the treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_{10}. The plant height was found to be lowest in T_4 (6.95 cm) followed by T_1 (7.00 cm).

At 50 DAS, it is evident from the data (Table-3) that during 2008-09 significantly higher plant height was recorded by T_8 : FYM + PM (33.16 cm) followed by T_6 : VC + PM (32.73 cm) as compared to rest of the treatments but were on par with T_{12}. The lowest plant height was observed in T_4.

During 2009-10, T_6 and T_8 recorded significantly higher plant height as compared to rest of the treatments and above two treatments were on par with T_{12}.

The lowest plant height was recorded in T_4.

Similarly, with regard to pooled mean values also T_8 and T_6 recorded significantly higher plant height as compared to other treatments (except T_{12}) recording 34.33 cm and 34.21 cm respectively and above treatments were at par with T_{12}. The lowest plant height was observed in T_4 (26.61 cm) and it was on par with other treatments except T_{12}, T_6, and T_8.

It was found that at 75 DAS (Table-3) among different treatments, T_{12}: 100 % RDF (37.33 cm) recorded significantly higher plant height during 2008-09 as compared to other treatments except T_8 and T_6 which were on par with T_{12}. The plant height was lowest in T_7 (32.53 cm) and among other treatments *viz*., T_1, T_2, T_3, T_4, T_5, T_7, T_9, T_{10}, T_{11}, no significant differences were observed.

During 2009-10 also, T_{12} recorded highest plant height of 40.16 cm which was significantly superior to other treatments except T_6, T_{11}, and T_8. The treatments T_{12}, T_6, T_{11} and T8 were on par with each other. The lowest plant height was recorded in T_4.

The pooled analysis of both the years revealed that plant height ranged from 31.41cm to 38.74 cm and among different treatments, T_{12} recorded significantly higher plant height as compared to other treatments except T_8, T_6 and T_{11} which were on par with T_{12}. The lowest plant height was recorded in T_4.

At harvest stage during 2008-09 (Table-3) significantly highest plant height was recorded by T_{12}: 100 % RDF (41.33 cm) as compared to other treatments but it was at par with T_6: VC + PM. The plant height was found to be lowest in T_{10}. Similarly, among organic treatments, T_6 recorded higher plant height as compared to other treatments and it was on par with T_8.

During 2009-10, the plant height was significantly higher in T_3: PM (41.2 cm) as compared to other treatments except T_6, T_{12} and T_8 which were on par with T_3. The plant height was lowest in T_{10} followed by T_{11}, T_4, T_5, and T_1. Further it was observed that among organic treatments also, T_3 recorded significantly higher plant height as compared to other treatments.

The plant height ranged from 35.93 cm to 40.66 cm and it was lowest in T_7 and T_{10} It is evident from the pooled values that plant height was significantly higher in T_{12}: 100 % RDF (40.66 cm) as compared to other treatments but it was at par with T_6, T_3 and T_8. Among organic treatments, T_6 recorded significantly highest plant height and it was at par with T_3 and T_8.

4.1.1.2 Absolute growth rate for plant height

The data pertaining to AGR for plant height is presented in table-4. The absolute growth rate (AGR) for plant height increased rapidly between 25-50 DAS and thereafter decreased between 50-75 DAS. It was observed from the data that no significant differences were noticed among treatments with respect to AGR for plant height at 25-50 DAS during 2008-09. However, during 2009-10 significantly higher values were registered by T_6: VC + PM (1.104 cm day^{-1}) and it was at par with T_8: FYM + PM (1.053 cm day^{-1}). Further, the treatments T_{12}, T_1, T_2, T_3, T_4, T_5, T_7, T_9 and T_{11} were on par with each other. The lowest AGR for plant height was recorded by T_{10} (0.813 cm day^{-1}).

The AGR for plant height at 25-50 DAS ranged from 0.786 cm day^{-1} to 1.049 cm day^{-1}. It was evident from pooled data that higher AGR for plant height was registered by T_6 (1.049 cm day^{-1}) followed by T_8 (1.022 cm day^{-1}) and the above treatments were on par with each other. Further, there was no significant difference among rest of the treatments with respect to AGR for plant height. T_4 (0.786 cm

Treatments	AGR AT 25-50 DAS (cm day^{-1})			AGR AT 50-75 DAS (cm day^{-1})		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	0.812	0.907	0.859	0.280	0.100	0.190
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	0.823	0.908	0.865	0.256	0.256	0.073
T_3 : Poultry manure (PM) @7.0t ha^{-1}	0.812	0.896	0.854	0.287	0.137	0.212
T_4 : Neem cake (NC) @5.0 t ha^{-1}	0.745	0.827	0.786	0.304	0.304	0.107
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	0.757	0.863	0.810	0.315	0.315	0.247
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	0.993	1.104	1.049	0.129	0.129	0.124
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	0.788	0.883	0.835	0.203	0.193	0.198
T_8 : FYM @2.8 t ha^{-1}+ PM @ 3.5 t ha^{-1}	0.991	1.053	1.022	0.135	0.087	0.111
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	0.796	0.880	0.838	0.209	0.156	0.183
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	0.772	0.813	0.793	0.243	0.197	0.220
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	0.747	0.843	0.795	0.281	0.205	0.243
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	0.790	0.953	0.872	0.307	0.273	0.290
Mean	0.819	0.910	0.865	0.240	0.158	0.199
Sem±	0.058	0.045	0.047	0.06	0.07	0.063
CD (P=0.05)	NS	0.134	0.135	NS	NS	NS

day^{-1}) and T_{10} (0.793 cm day^{-1}) recorded lower AGR for plant height.

It was evident from the data that no significant differences were observed among treatments with respect to AGR for plant height at 50-75 DAS.

4.1.1.3 Number of leaves

Data pertaining to leaf number under the influence of the treatments are given in tables-5. At 25 DAS, different organic sources and their combinations did not exert any significant influence on number of leaves in fenugreek. However, the average number of leaves (pooled) ranged from 3.50 to 3.76.

At 50 DAS, during 2008-09 highest number of leaves (95.57) were recorded by T_{12} (100 % RDF) which was significantly superior over other treatments and it was on par with T_8: FYM + PM (83.33) and T_6: VC + PM (83.33). The lowest number of leaves was recorded in T_1.

Similarly during 2009-10 also, T_{12} (100 % RDF) continued to maintain superiority over other treatments recording higher value for leaf number at 97.50 leaves followed by T_6 (85.50), T_8 (85.35) and T_3 (83.00). Similarly, T_5 also recorded significantly higher number of leaves plant^{-1} over T_1, T_2, T_4, T_7, T_{10} during 2009-10. The number of leaves was found to be lowest in T_4.

It was evident from pooled data that significantly higher leaf number was observed in T_{12}: 100 % RDF (96.53) and it was on par with T6: VC + PM (84.41) and T_8: FYM + PM (84.34). On the other hand, T_4 recorded the lowest leaf number plant^{-1} and it was on par with other treatments except T_{12}, T_6, and T_8.

At 75 DAS (Table-5), the number of leaves plant^{-1} during 2008-09 was also significantly higher in T_{12}: 100 % RDF (116.00) and it was at par with T_8: FYM + PM (113.31) and T_6: VC + PM (112.75). Further there was no significant difference

Table 5: Effect of organic manures on number of leaves plant^{-1} at various stages of growth in fenugreek

Treatments	Number of leaves plant^{-1}								
	25DAS			50DAS			75DAS		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	3.70	3.65	3.67	70.33	72.33	71.33	95.82	98.90	97.36
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	3.63	3.70	3.66	71.00	73.00	72.00	95.56	98.40	96.98
T_3 : Poultry manure (PM) @7.0t ha^{-1}	3.56	3.45	3.50	81.00	83.00	82.00	93.75	96.80	95.27
T_4 : Neem cake (NC) @5.0 t ha^{-1}	3.73	3.80	3.76	69.74	72.00	70.87	90.65	93.70	92.17
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	3.73	3.80	3.76	74.66	76.60	75.63	94.21	97.30	95.75
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	3.73	3.70	3.71	83.33	85.50	84.41	112.75	115.60	114.17
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	3.70	3.65	3.67	69.33	70.50	69.91	89.41	92.30	90.85
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	3.66	3.66	3.66	83.33	85.35	84.34	113.31	116.40	114.85
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	3.76	3.70	3.73	75.51	76.50	76.00	94.85	97.90	96.37
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	3.73	3.55	3.64	72.43	73.50	72.96	95.33	98.20	96.76
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	3.66	3.60	3.63	73.82	74.90	74.36	95.76	98.60	97.18
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	3.66	3.60	3.63	95.57	97.50	96.53	116.00	119.00	117.5
Mean	3.69	3.66	3.67	76.67	78.39	77.53	98.95	101.93	100.43
Sem±	0.20	0.12	0.17	6.65	0.96	4.75	6.17	0.93	2.00
CD (P=0.05)	NS	NS	NS	19.51	2.82	13.17	10.8	2.72	5.53

among treatments *viz*., T_1, T_2, T_3, T_4, T_5, T_7, T_9, T_{10}, T_{11} with respect to number of leaves plant^{-1}. The lowest number of leaves was recorded in T_7.

During 2009-10 also, the number of leaves plant^{-1} were highest in T_{12}: 100 % RDF (119) and it was at par with T_8: FYM + PM (116.4) closely followed by T_6: VC + PM (115.6). Further it was observed that the treatments *viz*., T_1, T_2, T_3, T_5, T_9, T_{10}, T_{11} were on par with each other. The lowest number of leaves was found in T_7 (92.30).

The number of leaves ranged from 90.85 to 117.5. A perusal of the pooled data of two seasons revealed that the number of leaves plant^{-1} were significantly higher in T_{12}: 100 % RDF (117.50) and it was on par with T_8: VC + PM (114.85) and T_6: FYM + PM (114.17). Among the organic treatments, T_8 recorded significantly higher number of leaves over other treatments and it was at par with T_6. On the other hand, the leaf number was lower in treatments, T_7 (90.85), T_4 (92.17) and T_3 (95.27).

4.1.1.4 Leaf area plant^{-1}

Data on leaf area as influenced by various treatments is presented in table-6. Among various treatments, T_{12}: 100 % RDF (370.55 cm^2) recorded significantly higher leaf area plant^{-1} as compared to other treatments during 2008-09 and it was on par with T_6: VC + PM (348.77 cm^2). Similarly the treatments, T_8 and T_{10} were also at par with each other. Further, T_4 and T_7 recorded lower leaf area plant^{-1}.

During 2009-10 also similar trend was exhibited by T_{12} (345.10 cm^2) and recorded significantly higher leaf area as compared to other treatments. Next to T_{12}: 100 % RDF, T_6 and T_8 also recorded higher value for leaf area and these treatments were on par with each other. The lowest leaf area plant^{-1} was recorded by T_7 and T_4.

From pooled data, it was evident that T_{12} (357.83 cm^2) followed by T_6 (342.01 cm^2)recorded significantly higher leaf area plant^{-1} as compared to other treatments and both were at par with each other. The treatment, T_8 also recorded

Table 6: Effect of organic manures on leaf area at 75 DAS in fenugreek

Treatments	Leaf area (cm^2)		
	2008-09	**2009-10**	**Mean**
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	287.47	287.77	287.62
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	303.92	285.36	294.64
T_3 : Poultry manure (PM) @7.0t ha^{-1}	281.25	280.72	280.99
T_4 : Neem cake (NC) @5.0 t ha^{-1}	271.95	271.73	271.84
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	282.65	282.17	282.41
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	348.77	335.24	342.01
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	277.25	267.67	272.46
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	342.50	337.56	340.03
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	317.80	284.20	301.00
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	324.55	284.20	304.38
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	317.85	285.94	301.90
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	370.55	345.10	357.83
Mean	310.54	295.63	303.09
Sem±	7.96	2.46	5.91
CD (P=0.05)	23.36	7.22	16.39

significantly higher value for leaf area over rest of the treatments except T_{12} and T_6. The lower leaf area plant^{-1} was recorded by T_4 followed by T_7.

4.1.1.5Leaf area index

Results pertaining to leaf area index are presented in table-7. During 2008-09, T_{12} (1.235) recorded significantly higher LAI as compared to other treatments and it was on par with T_6 (1.163). The treatments T_8 and T_{10} also recorded higher LAI and these treatments were at par with each other. T_4 and T_7 recorded lower LAI.

During 2009-10 also, T_{12} exhibited similar trend and recorded significantly higher value for LAI as compared to rest of the treatments. Further, T_6 also recorded higher LAI over rest of the treatments except T_{12} and T_6 was on par with T_8. The lower LAI was observed in T_7 and T_4.

In pooled data also, T_{12} and T_6 maintained superiority over rest of the treatments. Further, T_8 recorded significantly higher LAI as compared to other treatments except T_{12} and T_6. T_4 and T_7 recorded lower LAI.

4.1.1.6 Number of branches plant^{-1}

Data on number of branches in fenugreek as influenced by the treatments are presented in Table 8. In this study application of different organic sources and their combinations did not exert any significant effect on number of branches. However, the rate of increase of branches was rapid between 25-50 DAS than 50-75 DAS.

4.1.1.7 Dry matter production plant^{-1}

Results pertaining to dry matter production plant^{-1} as influenced by the treatments are presented in table 9. The dry matter production plant^{-1} was also significantly influenced by application of organic manures and their combinations at different stages of crop growth. The dry matter production increased with age of the

Table 7: Effect of organic manures on leaf area index in fenugreek

Treatments	Leaf area index		
	2008-09	2009-10	Pooled Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	0.958	0.959	0.959
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	1.013	0.951	0.982
T_3 : Poultry manure (PM) @7.0t ha^{-1}	0.938	0.936	0.937
T_4 : Neem cake (NC) @5.0 t ha^{-1}	0.907	0.906	0.906
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	0.942	0.941	0.941
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	1.163	1.117	1.140
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	0.924	0.892	0.908
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	1.142	1.125	1.133
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	1.059	0.947	1.003
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	1.082	0.947	1.015
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	1.060	0.953	1.006
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	1.235	1.150	1.193
Mean	1.035	0.985	1.010
Sem±	0.026	0.008	0.019
CD (P=0.05)	0.077	0.024	0.054

Table 8: Effect of organic manures on number of branches plant^{-1} at various stages of growth in fenugreek

Treatments	Number of branches plant^{-1}					
	50DAS			75DAS		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	4.73	4.93	4.83	6.20	6.10	6.15
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	5.26	5.46	5.36	5.66	5.56	5.61
T_3 : Poultry manure (PM) @7.0t ha^{-1}	5.13	5.86	5.50	6.76	6.66	6.71
T_4 : Neem cake (NC) @5.0 t ha^{-1}	4.73	4.93	4.83	6.00	5.90	5.95
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	5.00	5.20	5.10	6.06	6.96	6.51
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	4.46	4.66	4.56	5.93	5.83	5.88
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	4.50	4.70	4.60	5.63	5.53	5.58
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	4.93	5.13	5.03	6.00	5.90	5.95
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	5.00	5.20	5.10	6.00	5.83	5.91
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	4.73	4.93	4.83	5.46	5.46	5.46
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	4.00	4.26	4.13	5.60	5.50	5.55
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	4.50	4.70	4.60	5.13	5.44	5.28
Mean	4.75	5.00	4.87	5.87	5.89	5.88
Sem±	0.40	0.41	0.40	0.45	0.51	0.48
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 9: Effect of organic manures on dry matter plant^{-1} at various stages of growth in fenugreek

Treatments	Dry matter (g) plant^{-1}											
	25DAS			50DAS			75DAS			at harvest		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	0.28	0.30	0.29	2.27	2.40	2.33	6.42	6.61	6.51	10.00	10.5	10.25
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	0.23	0.30	0.28	2.18	2.48	2.33	7.11	7.41	7.26	10.52	11.02	10.77
T_3 : Poultry manure (PM) @7.0t ha^{-1}	0.27	0.30	0.28	2.43	2.44	2.43	6.83	7.13	6.98	9.35	9.85	9.60
T_4 : Neem cake (NC) @5.0 t ha^{-1}	0.29	0.31	0.30	2.39	2.40	2.39	5.96	6.82	6.39	9.53	9.96	9.74
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	0.25	0.30	0.28	2.28	3.22	2.75	6.22	6.65	6.43	10.91	11.35	11.13
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	0.33	0.33	0.33	3.52	2.92	3.22	8.35	8.65	8.50	11.93	12.43	12.18
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	0.29	0.31	0.30	2.87	3.20	3.03	7.03	7.33	7.18	9.79	10.29	10.04
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	0.34	0.34	0.34	3.50	2.90	3.20	8.30	8.60	8.45	12.18	12.68	12.43
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	0.34	0.34	0.34	2.85	2.91	2.88	6.86	7.20	7.03	9.56	10.06	9.81
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	0.28	0.30	0.29	2.86	2.82	2.84	7.06	7.36	7.21	10.70	11.20	10.95
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	0.27	0.30	0.28	2.77	3.00	2.88	7.10	7.40	7.25	11.25	11.75	11.5
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	0.33	0.33	0.33	3.75	3.25	3.50	8.41	8.65	8.53	12.22	12.72	12.47
Mean	0.29	0.31	0.30	2.81	2.83	2.82	7.14	7.48	7.31	10.66	11.15	10.91
Sem±	0.01	0.02	0.01	0.20	0.29	0.25	0.05	0.19	0.13	0.18	0.18	0.18
CD (P=0.05)	0.03	NS	0.04	0.58	NS	0.70	0.14	0.56	0.38	0.53	0.54	0.51

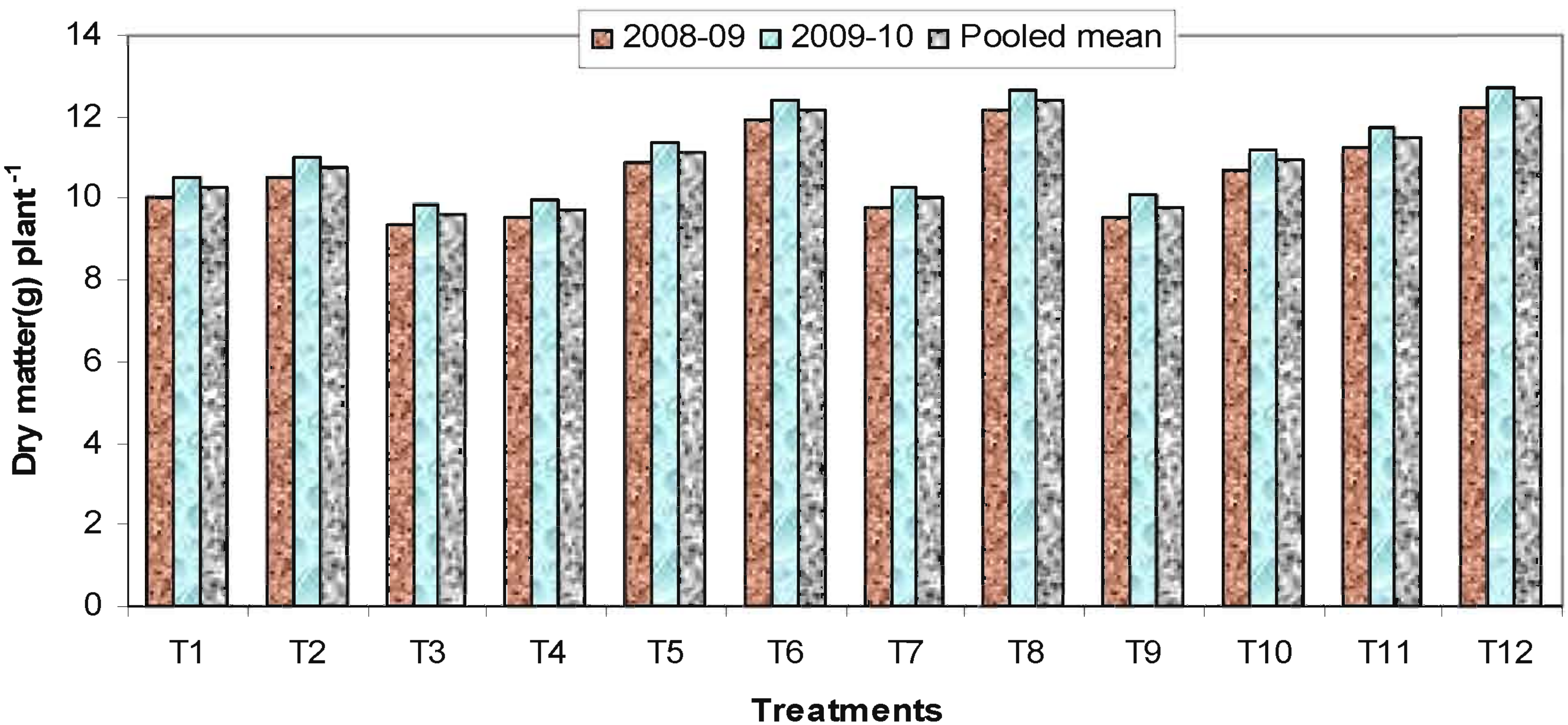


Fig.2: Effect of organic manures on dry matter plant^{-1} at harvest stage in fenugreek

crop registering maximum at harvest. The rate of dry matter accumulation was found to be slow upto 50 DAS and thereafter, it increased markedly.

The dry matter content ranged from 0.23 g to 0.34 g. During 2008-09 at 25-DAS (Table-9) significantly higher value for dry matter accumulation was observed in T_8: FYM + PM (0.34 g), T_9 (0.34 g) and were on par with T_6: VC + PM (0.33 g) and T_{12}: 100 % RDF (0.33 g). However, during 2009-10 the dry matter accumulation was not significantly influenced by the various treatments and the differences in dry matter were non significant.

A perusal of pooled data revealed that significantly highest dry matter content plant^{-1} (0.34 g) was recorded by T_8 : FYM + PM and T_9 : FYM + NC and these treatments were also at par with T_6, T_{12}, T_7 and T_4. The lowest dry matter was observed in T_2, T_3, T_5 and T_{11}.

At 50 DAS (Table-9), T_{12}: 100 % RDF (3.75 g plant^{-1}), T_6: VC + PM (3.52 g plant^{-1}) and T_8: FYM + PM (3.5 g plant^{-1}) registered higher values for dry matter during 2008-09 and were significantly superior over other treatments. The dry matter was lowest in T_2. However, during 2009-10 there were no significant differences among treatments with respect to dry matter production.

The dry matter content plant^{-1} ranged from 2.33 g to 3.50 g and it was evident from pooled data that T_{12}: 100 % RDF (3.50 g) recorded significantly higher dry matter as compared to T_1, T_2, T_3, T_4 and T_5 and it was at par with T_6, T_8, T_7, T_9, T_{10} and T_{11}. The lowest dry matter was recorded by T_1 (2.33 g) and T_2 (2.33 g).

At 75 DAS (Table-9) also, T_{12}: 100 % RDF, T_6: VC + PM and T_8: FYM + PM recorded higher values for dry matter plant^{-1} and maintained superiority over other treatments during 2008-09 with dry matter production of 8.41 g plant^{-1}, 8.35 g plant^{-1} and 8.30 g plant^{-1} respectively. During 2009-10, T_6: VC + PM and T_{12}: 100 %

RDF recorded significantly higher dry matter and these treatments were on par with T_8: FYM + PM. The lowest dry matter was observed in T_1 and T_5.

The dry matter plant^{-1} ranged from 6.39 g to 8.53 g and significant differences were observed among treatments on pooled values recording significantly higher dry matter of 8.53 g plant^{-1}, 8.50 g plant^{-1} and 8.45 g plant^{-1} in T_{12}: 100 % RDF, T_6: VC + PM and T_8: FYM + PM treatments respectively over rest of the treatments. The dry matter plant^{-1} was lowest in T_4 (6.39 g).

At harvest (Table-9), T_{12}: 100 % RDF continued to register significantly higher dry matter of 12.22 g plant^{-1} over other treatments during 2008-09 followed by T_8 (12.18 g) and T_6 (11.93 g). However, T_{12} was on par with T_8: FYM + PM and T_6: VC + PM. Similarly, T_{11} was also significantly superior over other treatments except T_{12}, T_8, T_6 and T_5. The lowest dry matter was recorded in T_3 (9.35 g) followed by T_4 (9.53 g).

A similar trend was also noticed during 2009-10 recording dry matter content of 12.72, 12.68 and 12.43 g plant^{-1} by T_{12}: 100 % RDF, T_8: FYM + PM and T_6: VC + PM respectively.

Pooled values also exhibited similar trends as that of 2009-10. Lower values for dry matter production were recorded by T_3 (9.60 g), T_4 (9.74 g) and T_9 (9.81 g).

4.1.1.8 Crop growth rate for dry matter production

The results on CGR for dry matter production are presented in table-10. The crop growth rate, an indicator of dry matter production per unit time increased with age of crop recording a maximum between 50-75 DAS. It was observed from data that during 2008-09 the treatment, T_{12}: 100 % RDF (4.556 g m^{-2} day^{-1}) recorded significantly higher CGR for dry matter content at 25-50 DAS as compared to other

Table 10: Effect of organic manures on crop growth rate for dry matter at different growth stages in fenugreek

Treatments	CGR AT 25-50 DAS (g m^{-2} day^{-1})			CGR AT 50-75 DAS (g m^{-2} day^{-1})		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	2.653	2.800	2.727	5.538	5.613	5.576
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	2.596	2.907	2.751	6.578	6.578	6.578
T_3 : Poultry manure (PM) @7.0t ha^{-1}	2.880	2.849	2.864	5.867	6.258	6.062
T_4 : Neem cake (NC) @5.0 t ha^{-1}	2.791	2.804	2.798	4.760	5.876	5.318
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	2.707	3.898	3.302	5.249	4.578	4.913
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	4.258	3.458	3.858	6.444	7.644	7.044
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	3.436	3.844	3.640	5.547	5.511	5.529
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	4.204	3.404	3.804	6.400	7.600	7.000
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	3.338	3.427	3.382	5.356	5.667	5.511
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	3.444	3.364	3.404	5.600	6.053	5.827
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	3.342	3.613	3.478	5.764	5.867	5.816
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	4.556	3.889	4.222	6.222	7.200	6.711
Mean	3.350	3.350	3.350	5.77	6.20	5.98
Sem±	0.265	0.394	0.350	0.261	0.454	0.420
CD (P=0.05)	0.779	NS	0.992	0.768	1.33	1.200

treatments and it was at par with T_6 (4.258 g m^{-2} day^{-1}) and T_8 (4.204 g m^{-2} day^{-1}). The lowest CGR for dry matter content was observed in T_2 (2.596 g m^{-2} day^{-1}) followed by T_1 (2.653 g m^{-2} day^{-1}).

Further, it was observed that no significant differences existed among treatments with respect to CGR for dry matter content at 25-50 DAS during 2009-10.

A consideration of pooled data revealed that T_{12}: 100 % RDF (4.222 g m^{-2} day^{-1}) recorded higher CGR for dry matter content at 25-50 DAS and it was on par with T_5, T_6, T_7, T_8, T_9, T_{10} and T_{11}. Further, T_1 and T_2 recorded lower CGR for dry matter content.

It was evident from the data that during 2008-09 highest CGR for dry matter content at 50-75 DAS was recorded by T_2: FYM (6.578 g m^{-2} day^{-1}) followed by T_6, T_8, T_{12} and T_3. The above treatments were at par with T_2. The lowest CGR for dry matter content was registered by T_4.

During 2009-10, T_6: VC + PM (7.644 g m^{-2} day^{-1}) recorded higher CGR for dry matter content at 50-75 DAS followed by T_8, T_{12} and T_2. The treatment, T_6 was on par with T_8, T_{12} and T_2. The lowest CGR for dry matter content was recorded by T_5 (4.578 g m^{-2} day^{-1}).

In pooled data also higher CGR for dry matter content was recorded by T_6 and it was on par with T_8, T_{12}, T_2 and T_3. The treatment, T_5 recorded the lowest CGR for dry matter content.

4.1.2 Yield and yield attributing parameters

4.1.2.1 Days to 50 % flowering

The results on days to 50 % flowering are presented in the table-11. It was observed from data that there were significant differences in the days taken to 50 % flowering due to various organic treatments. During 2008-09, higher number of days

Table 11: Effect of organic manures on days to 50% flowering in fenugreek

Treatments	Days to 50 % flowering		
	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	38.85	39.35	39.10
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	39.66	39.93	39.79
T_3 : Poultry manure (PM) @7.0t ha^{-1}	40.40	40.91	40.65
T_4 : Neem cake (NC) @5.0 t ha^{-1}	40.60	40.20	40.40
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	40.00	38.50	39.25
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	38.95	39.16	39.05
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	39.26	38.80	39.03
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	38.75	38.75	38.75
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	39.91	40.16	40.03
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	39.42	39.43	39.42
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	37.61	36.83	37.22
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	37.38	37.38	37.38
Mean	39.23	39.11	39.17
Sem±	0.43	0.41	0.42
CD (P=0.05)	1.27	1.22	1.18

were taken for flowering and flowering was delayed significantly in T_4: NC, T_3: FYM, T_5: PM, T_9: VC, T_2: FYM + NC and T_{10}: PM + NC treatments, while it was advanced in plots receiving T_{12}: 100 % RDF and T_{11}: 50 % RDF.

Further in second season it was observed that flowering was delayed in T_3: PM, T_4: NC, T_9: FYM + NC and T_2: FYM treatments. Lesser number of days to flowering was recorded in T_{11}: 50 % RDF and T_{12}: 100 % RDF advancing the flowering.

In pooled data, the average number of days taken to 50 % flowering ranged from 37.22 days to 40.65 days. The data revealed that lesser number of days to flowering was taken and flowering was advanced in T_{11} and T_{12} recording 37.22 and 37.38 days respectively. Higher number of days to flowering was recorded by T_3, T_4, and T_9 thereby flowering was delayed in these treatments recording 40.65, 40.40 and 40.03 days respectively.

4.1.2.2 Pods plant^{-1}

Data on pods plant^{-1} as influenced by organic treatments are presented in table-12. A perusal of data revealed that the average number of pods per plant ranged from 29.33 to 41.33 during 2008-09. Significantly higher number of pods were registered in T_{12}: 100 % RDF (41.33 pods plant^{-1}) and it was on par with T_7: VC + FYM (38.50 pods plant^{-1}), T_8: VC + PM (37.83 pods plant^{-1}) and T_6: FYM + PM (37.31 pods plant^{-1}). T_3 recorded significantly higher no of pods as compared to T_{11} and T_3 was on par with T_1, T_2, T_4, T_5, T_9, and T_{10}.

During 2009-10 also, T_{12}: 100 % RDF, T_7: VC + NC, T_8: FYM + PM and T_6: FYM + PM recorded higher number of pods plant^{-1}. Further T_{11} recorded significantly lower values for number of pods plant^{-1} when compared to T_3, T_4 and T_5 but it was on par with T_9, T_{10}, T_1 and T_2.

The number of pods plant^{-1} ranged from 29.82 to 41.83 and it is clear from

Table 12: Effect of organic manures on number of pods plant^{-1} in fenugreek

Treatments	Pods plant^{-1}		
	2008-09	**2009-10**	**Pooled mean**
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	33.20	34.20	33.70
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	33.50	34.50	34.00
T_3 : Poultry manure (PM) @7.0t ha^{-1}	34.53	35.53	35.03
T_4 : Neem cake (NC) @5.0 t ha^{-1}	33.91	34.91	34.41
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	34.18	35.18	34.68
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	37.31	38.31	37.81
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	38.50	39.50	39.00
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	37.83	38.89	38.36
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	33.43	34.43	33.93
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	32.25	33.25	32.75
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	29.33	30.31	29.82
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	41.33	42.33	41.83
Mean	34.94	35.94	35.44
Sem±	1.46	1.46	1.40
CD (P=0.05)	4.29	4.29	4.06

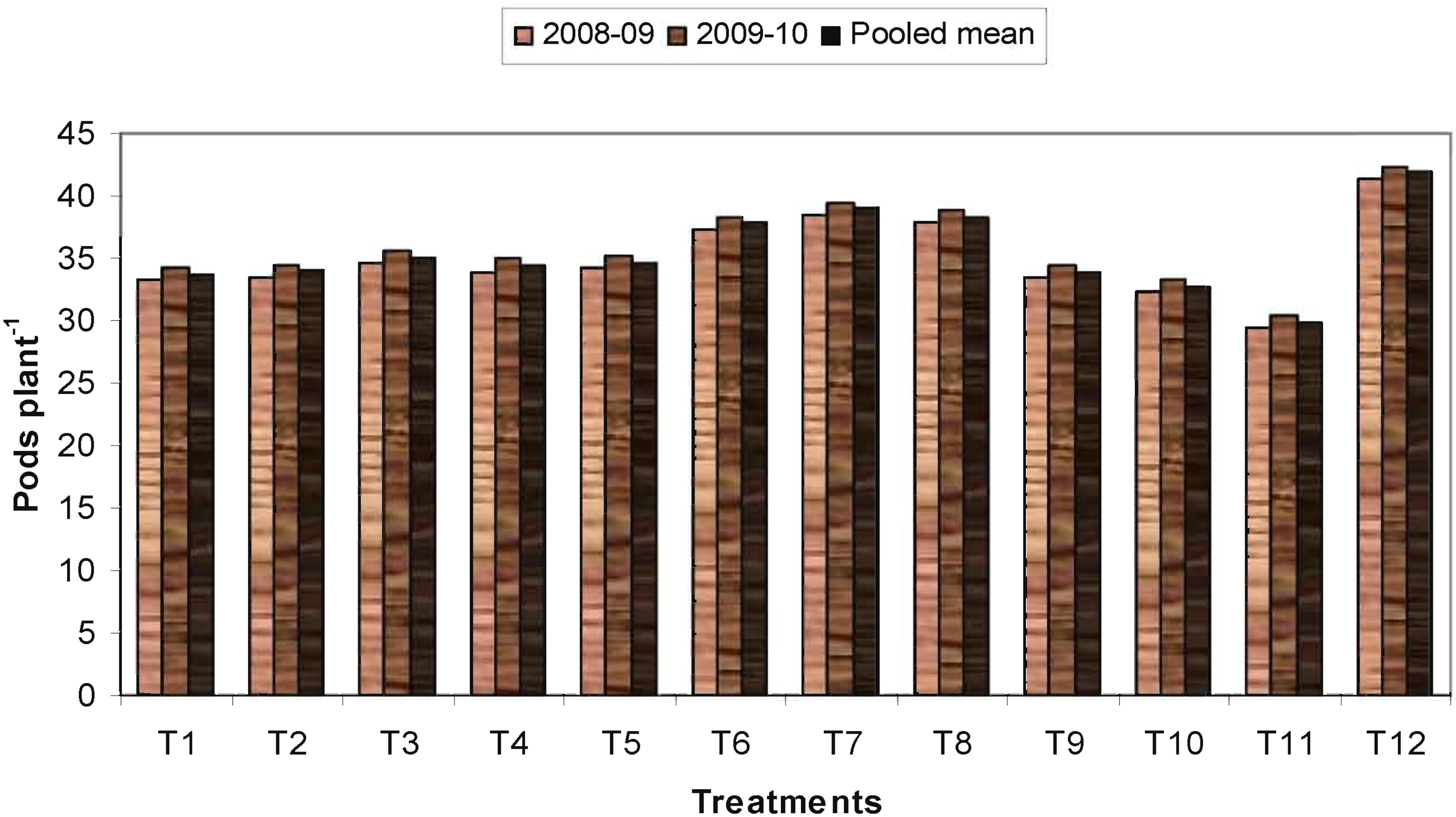


Fig.3: Effect of organic manures on number of pods plant^{-1} in fenugreek

T_8 (FYM + PM)

T_{11} (50 % RDF)

Plate: 3: Number of pods in fenugreek as influenced by treatments (Expt 1)

pooled data that T_{12}: 100 % RDF with 41.83 pods plant^{-1} recorded significantly higher number of pods plant^{-1} and it was on par with T_7, T_8 and T_6. The lower number of pods was recorded by T_{11}: 50 % RDF (29.82 pods plant^{-1}) which was on par with T_1, T_3 and T_{10}.

4.1.2.3 Pod length (cm)

Results on pod length as influenced by the treatments are furnished in table-13. It was observed from the data that pod length was significantly influenced by different organic sources. The highest pod length was noticed in T_{10}: PM + NC (10.29 cm) during 2008-09 which was significantly superior over other treatments except the treatments T_{12}, T_8, T_9 which were on par with T_{10}. T_7 also recorded significantly higher pod length compared to T_{11}, T_1, T_2, T_3, T_4, and T_5. Significantly lower pod length was recorded in T_1 (8.00 cm).

During 2009-10 also T_{10} maintained significantly higher pod length over other treatments. However, it was on par with T_{12}, T_8 and T_9. Further, it was observed that pod length was lowest with T_1 (8.05 cm) followed by T_4 (9.08 cm).

It was evident from pooled data that pod length ranged from 8.02 to 10.27 cm. The treatments T_{10} and T_{12} recorded significantly higher pod length of 10.27 cm and 10.20 cm respectively as compared to other treatments and were on par with T_8 and T_9. Significantly lower values for pod length were recorded by T_1 (8.02 cm) followed by T_4 (9.05 cm).

4.1.2.4 Seeds pod^{-1}

Data relating to number of seeds pod^{-1} as influenced by treatments are presented in table-14. The data on seeds pod^{-1} revealed that significant differences were observed among treatments during 2008-09. The number of seeds pod^{-1} was found to be higher in T_{12}: 100 % RDF (11.10 seeds pod^{-1}) followed by T_8. Further

Table 13: Effect of organic manures on pod length in fenugreek

Treatments	Pod length (cm)		
	2008-09	2009-10	Pooled Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	8.00	8.05	8.02
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	9.10	9.15	9.12
T_3 : Poultry manure (PM) @7.0t ha^{-1}	9.28	9.33	9.30
T_4 : Neem cake (NC) @5.0 t ha^{-1}	9.03	9.08	9.05
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	9.45	9.41	9.43
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	9.75	9.80	9.77
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	9.86	9.88	9.87
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	10.16	10.05	10.10
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	10.12	10.06	10.09
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	10.29	10.25	10.27
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	9.30	9.20	9.25
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	10.25	10.16	10.20
Mean	9.55	9.53	9.54
Sem±	0.09	0.11	0.10
CD (P=0.05)	0.26	0.34	0.29

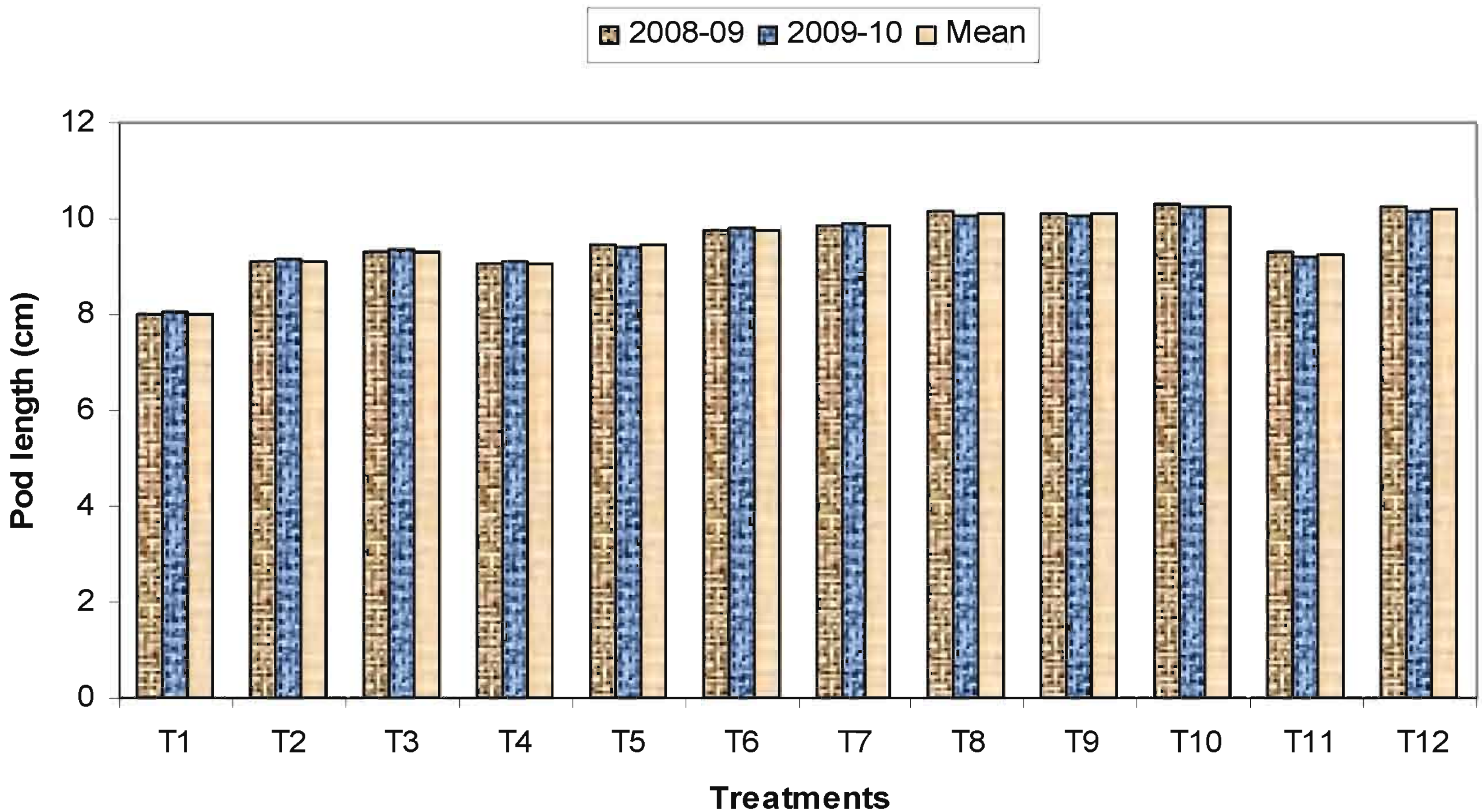


Fig.4: Effect of organic manures on pod length in fenugreek

Table 14: Effect of organic manures on number of seeds pod^{-1} in fenugreek

Treatments	Number of seeds pod^{-1}		
	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	6.77	7.23	7.00
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	7.35	8.00	7.67
T_3 : Poultry manure (PM) @7.0t ha^{-1}	9.55	9.53	9.54
T_4 : Neem cake (NC) @5.0 t ha^{-1}	9.74	9.62	9.68
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	9.73	9.56	9.64
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	10.33	10.11	10.22
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	9.41	9.55	9.48
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	10.53	10.25	10.39
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	10.25	10.23	10.24
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	10.25	10.23	10.24
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	10.18	9.80	9.99
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	11.10	10.71	10.90
Mean	9.60	9.56	9.58
Sem±	0.07	0.33	0.06
CD (P=0.05)	0.20	0.98	0.19

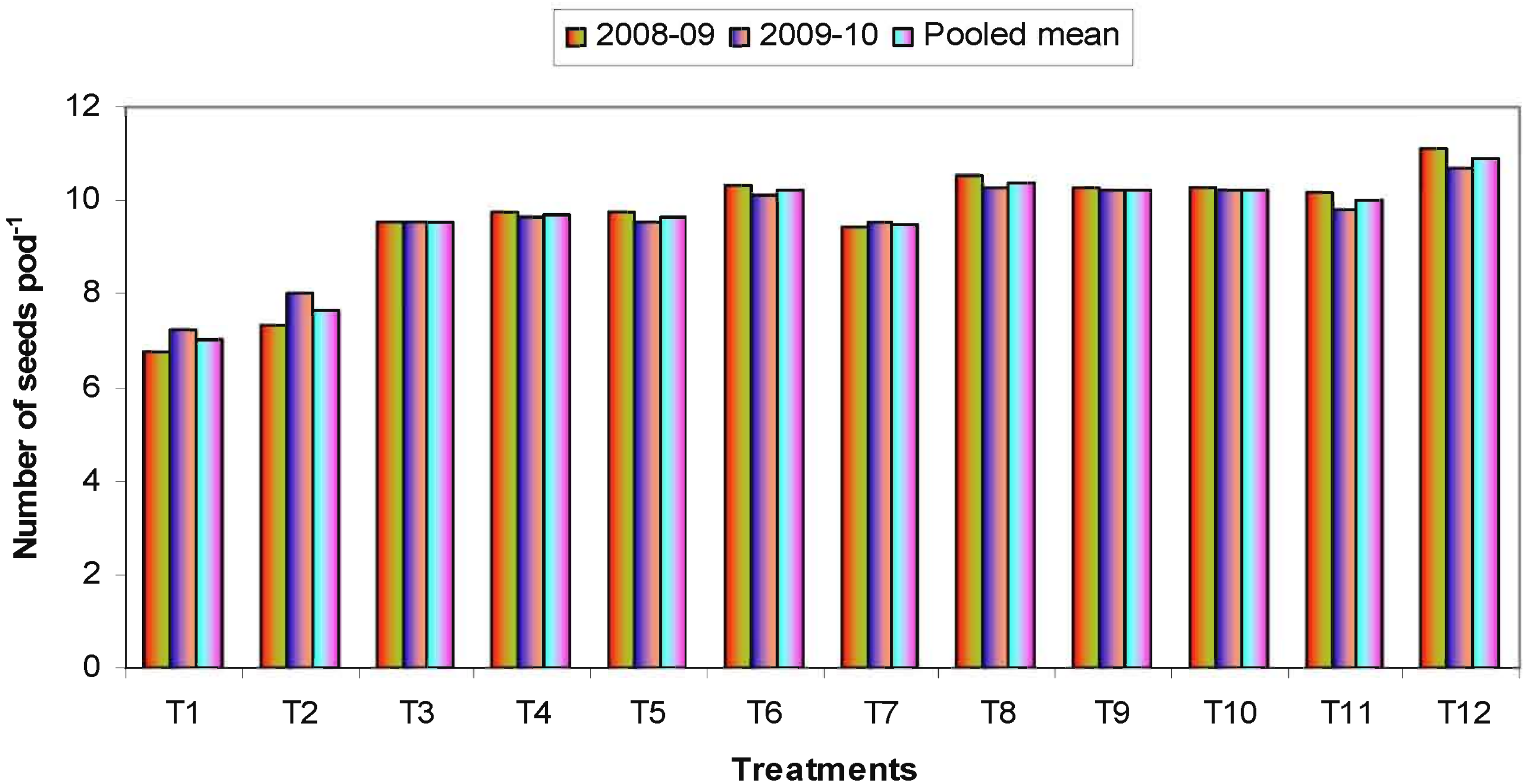


Fig.5: Effect of organic manures on number of seeds pod^{-1} in fenugreek

treatments *viz.*, T_6, T_9, T_{10}, T_{11} were significantly superior over other treatments except T_{12} and T_8. Significantly lower number of seeds pod^{-1} were recorded in T_1 (6.77 seeds pod^{-1}) followed by T_2 (7.35 seeds pod^{-1}) when compared to other treatments.

During 2009-10, significantly higher number of seeds pod^{-1} was recorded by T_{12}: 100 % RDF (10.71 seeds pod^{-1}) as compared to other treatments except T_8, T_9, T_{10}, T_6 and T_{11} which were on par with T_{12}. Further T_1 and T_2 recorded significantly lower number of seeds as compared to other treatments.

From the pooled data, it can be observed that number of seeds pod^{-1} ranged from 7.00 to 10.90 and T_{12}: 100 % RDF (10.90 seeds pod^{-1}) recorded the highest seed number and was significantly superior over other treatments closely followed by T_8, T_9, T_{10} and T_6. Significantly lower values for seed number were registered by T_1 (7.00 seeds pod^{-1}) and T_2 (7.67 seeds pod^{-1}).

4.1.2.5 Grain filling %

Data on grain filling as influenced by various treatments is presented in Table-15. It could be observed from the data that no significant differences could be observed in grain filling under the influence of various treatments. However, during 2008-09 highest grain filling % was observed in T_{12}: 100 % RDF (92.8) and lowest grain filling % was recorded in T_7 (85.80). In pooled data there was a tendency to record highest grain filling by T_8: FYM + PM (93.83 %).

4.1.2.6 Grain shelling %

Results pertaining to shelling percentage are presented in table-16. A perusal of data indicated significant differences among treatments. During 2008-09, significantly higher values for grain shelling (41.88 %) were found in T_8: FYM + PM closely followed by T_7 and T_{12}. Significantly lower shelling percentage was recorded

Table 15: Effect of organic manures on grain filling percentage in fenugreek

Treatments	Grain filling (%)		
	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	89.30	92.10	90.70
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	90.50	89.83	90.16
T_3 : Poultry manure (PM) @7.0t ha^{-1}	89.50	90.16	89.83
T_4 : Neem cake (NC) @5.0 t ha^{-1}	90.25	89.75	90.00
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	86.15	88.05	87.10
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	94.00	90.33	92.16
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	85.80	88.01	86.90
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	94.00	93.66	93.83
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	88.25	89.75	89.00
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	86.80	87.93	87.36
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	88.80	88.26	88.53
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	92.80	92.43	92.61
Mean	89.67	90.02	89.84
Sem±	2.98	2.97	2.98
CD (P=0.05)	NS	NS	NS

Table 16: Effect of organic manures on grain shelling percentage in fenugreek

Treatments	Grain shelling (%)		
	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	36.83	37.03	36.93
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	37.53	37.33	37.43
T_3 : Poultry manure (PM) @7.0t ha^{-1}	39.08	39.28	39.18
T_4 : Neem cake (NC) @5.0 t ha^{-1}	37.76	37.56	37.66
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	39.16	39.36	39.26
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	38.85	38.68	38.76
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	40.43	40.65	40.54
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	41.88	41.71	41.79
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	39.25	39.45	39.35
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	37.78	37.58	37.68
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	38.78	38.96	38.87
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	39.50	39.30	39.40
Mean	38.90	38.91	38.90
Sem±	0.34	0.34	0.34
CD (P=0.05)	0.98	1.00	0.94

in T_1 (36.83 %) which was on par with T_2, T_4 and T_{10}.

During 2009-10 also, T_8: FYM + PM recorded highest shelling (41.71 %) closely followed by T_7. The treatments *viz*., T_3, T_5, T_6, T_9, T_{11}, T_{12} were on par with each other and T_9 recorded higher shelling % over other treatments except T_8 and T_7. T_1 (37.03 %) and T_2 (37.33 %) recorded significantly lower shelling % as compared to other treatments.

It is evident from pooled data that T_8: FYM + PM (41.79 %) and T_7: VC + NC (40.54 %) registered significantly higher shelling % over other treatments. Further T_{12} was significantly superior over other treatments *viz*., T_1, T_2, T_4, T_6 and it was on par with T_3, T_5, T_9 and T_{11}. Grain shelling was lower in treatments *viz*., T_1 (36.93 %), T_2 (37.43 %), T_4 (37.66 %) and T_{10} (37.68 %) and these treatments were on par with each other.

4.1.2.7 Test weight

Data relating to test weight (*i.e.*, 1000 seed weight) of fenugreek as influenced by the treatments are furnished in table-17. The data revealed significant differences among treatments in test weight of the grain of fenugreek. During 2008-09 significantly higher value for test weight was registered by T_{12}: 100 % RDF (11.25 g) closely followed by T_6: VC + PM (11.03 g) which were significantly superior over rest of the treatments. It was also observed that the treatment, T_8 was significantly superior over other treatments *viz*., T_1, T_2, T_3, T_4, T_5, T_9 and T_{10}. However, it was on par with T_7 and T_{11}.

During second season (2009-10), T_{12}: 100 % RDF (11.15 g) and T_6: VC + PM (10.9 g) recorded higher values for test weight when compared with other treatments. Test weight was observed to be lowest in T_3 (9.10 g) and T_5 (9.15 g)

Table 17: Effect of organic manures on test weight in fenugreek

Treatments	Test weight (g)		
	2008-09	2009-10	Pooled Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	9.78	9.88	9.83
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	9.98	9.88	9.93
T_3 : Poultry manure (PM) @7.0t ha^{-1}	9.00	9.10	9.05
T_4 : Neem cake (NC) @5.0 t ha^{-1}	9.96	9.86	9.91
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	9.05	9.15	9.10
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	11.03	10.90	10.96
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	10.30	10.40	10.35
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	10.58	10.48	10.53
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	9.51	9.61	9.56
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	9.80	9.70	9.75
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	10.45	10.43	10.44
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	11.25	11.15	11.20
Mean	10.06	10.04	10.05
Sem±	0.09	0.15	0.13
CD (P=0.05)	0.27	0.46	0.36

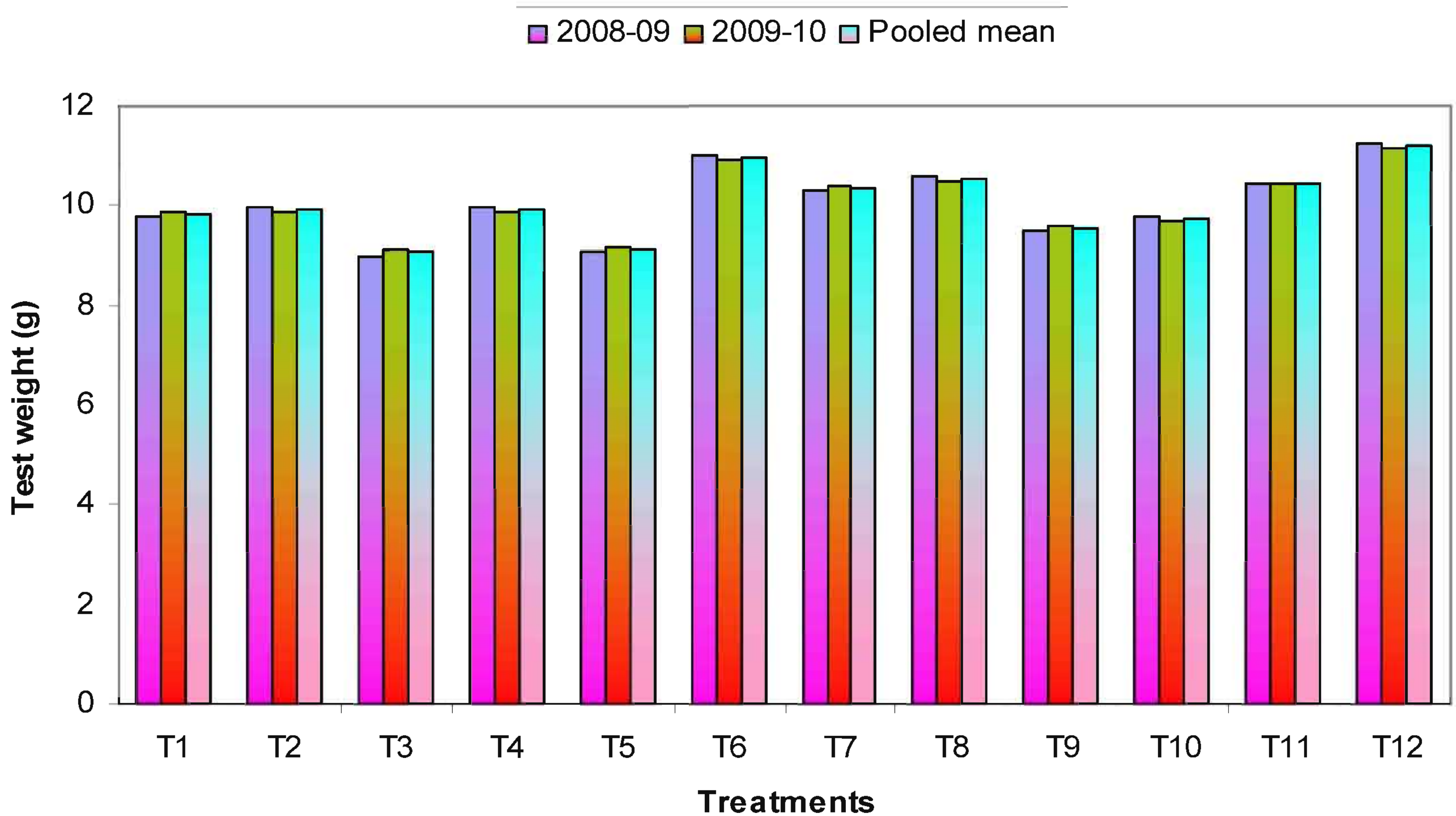


Fig.6: Effect of organic manures on test weight in fenugreek

which were significantly inferior to other treatments.

In pooled data, the test weight ranged from 9.05 to 11.20 g. The pooled data revealed that T_{12}: 100 % RDF (11.20 g) and T_6: VC + PM (10.96 g) recorded significantly higher values for test weight. Further, T_7, T_8 and T_{11} recorded higher values of weight over other treatments except T_{12} and T_6. Test weight values were lowest in treatment *viz.*, T_3 (9.05 g), T_5 (9.10 g) which were significantly inferior to other treatments.

4.1.2.8 Seed yield plant^{-1}

Results pertaining to seed yield plant^{-1} are furnished in table-18. It can be observed from the data that significant difference in seed yield was observed among treatments due to application of different organic manures and their combinations.

During first season (2008-09), highest seed yield plant^{-1} was obtained in T_{12}: 100 % RDF (3.85 g) when compared with other treatments closely followed by T_6: VC + PM (3.13 g). Similarly, T_1 and T10 also recorded significantly higher seed yield over other treatments *viz.*, T_2, T_3, T_4, T_5, T_7, T_8, T_9, T_{11}. Significantly lower values for seed yield plant^{-1} were recorded by T_{11} (2.41 g), T_3 (2.48 g) and T_7 (2.50 g).

During second season (2009-10) also, significantly higher seed yield plant^{-1} was registered by the treatment T_{12}: 100 % RDF (3.95 g) followed by T_6: VC + PM and T_8: FYM + PM which recorded 3.23 g and 3.13 g respectively. Treatments *viz.*, T_{11}, T_3, T_7 recorded significantly lower values for seed yield plant^{-1} over other treatments.

In pooled data, it was observed that the mean seed yield plant^{-1} ranged from 2.46 g to 3.90 g. The treatment, T_{12}: 100 % RDF recorded highest seed yield (3.90 g) which was significantly superior over other treatments followed by T_6: VC + PM.

Table 15: Effect of organic manures on grain filling percentage in fenugreek

Treatments	Grain filling (%)		
	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	89.30	92.10	90.70
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	90.50	89.83	90.16
T_3 : Poultry manure (PM) @7.0t ha^{-1}	89.50	90.16	89.83
T_4 : Neem cake (NC) @5.0 t ha^{-1}	90.25	89.75	90.00
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	86.15	88.05	87.10
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	94.00	90.33	92.16
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	85.80	88.01	86.90
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	94.00	93.66	93.83
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	88.25	89.75	89.00
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	86.80	87.93	87.36
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	88.80	88.26	88.53
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	92.80	92.43	92.61
Mean	89.67	90.02	89.84
Sem±	2.98	2.97	2.98
CD (P=0.05)	NS	NS	NS

Lower values for seed yield was recorded by the treatments, T_{11} (2.46 g), T_3 (2.53 g) and T_7 (2.55 g) which were on par with each other.

4.1.2.9 Seed yield ha^{-1}

The results pertaining to the grain yield of fenugreek as influenced by the organic treatments are presented in table-19. A perusal of data revealed that different organic sources and their combinations significantly influenced the seed yield in fenugreek during first season (2008-09). Seed yield ranged from 7.30 q ha^{-1} to 12.56 q ha^{-1}. Among different treatments, T_{12}: 100 % RDF with 12.56 q ha^{-1} of seed yield was significantly superior to other treatments followed by T_8 (9.41 q ha^{-1}) and T_6 (9.35 q ha^{-1}). Significantly lower values for seed yield was registered by T_4 (7.05 q ha^{-1}) followed by T_9 (7.30 q ha^{-1}) which were on par with each other.

During the second season (2009-10) of study, significantly higher yield of 11.46 q ha^{-1}was obtained in T_{12}: 100 % RDF when compared to other treatments followed by T_8: FYM + PM and T_6: VC + PM recording 9.78 q ha^{-1} and 9.76 q ha^{-1} respectively. Further T_{11} (50 % RDF) was also significantly superior in yield (9.28 q ha^{-1}) over other treatments *viz*., T_1, T_2, T_3, T_4, T5, T_7, T_9, T_{10}. Similarly, T_4 (NC) treatment was significantly inferior to other treatments and it was on par with T_9.

In pooled data, the yield ranged from 7.20 q ha^{-1} to 12.01q ha^{-1} and among different treatments, T_{12}: 100 % RDF recorded significantly the highest yield of 12.01 q ha^{-1} over other treatments followed by T_8 (9.60 q ha^{-1}) and T_6 (9.55 q ha^{-1}).

Among organic treatments, T_8: FYM + PM and T_6: VC + PM recorded significantly higher yield of 9.60 q ha^{-1}and 9.55 q ha^{-1} respectively over other treatments. The treatments; T_8 and T_6 recorded 4.58 % and 4.00 % increase respectively over T_{11}: 50 % RDF. Significantly lower yield of 7.2 q ha^{-1} was recorded

Table 18: Effect of organic manures on seed yield plant^{-1} in fenugreek

Treatments	Seed yield (g) plant^{-1}		
	2008-09	2009-10	Pooled mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	2.93	3.03	2.98
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	2.60	2.70	2.65
T_3 : Poultry manure (PM) @7.0t ha^{-1}	2.48	2.58	2.53
T_4 : Neem cake (NC) @5.0 t ha^{-1}	2.71	2.81	2.76
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	2.75	2.85	2.80
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	3.13	3.23	3.18
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	2.50	2.60	2.55
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	2.60	3.13	2.86
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	2.71	2.81	2.76
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	2.91	2.93	2.92
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	2.41	2.51	2.46
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	3.85	3.95	3.90
Mean	2.79	2.92	2.86
Sem±	0.05	0.06	0.05
CD (P=0.05)	0.14	0.18	0.15

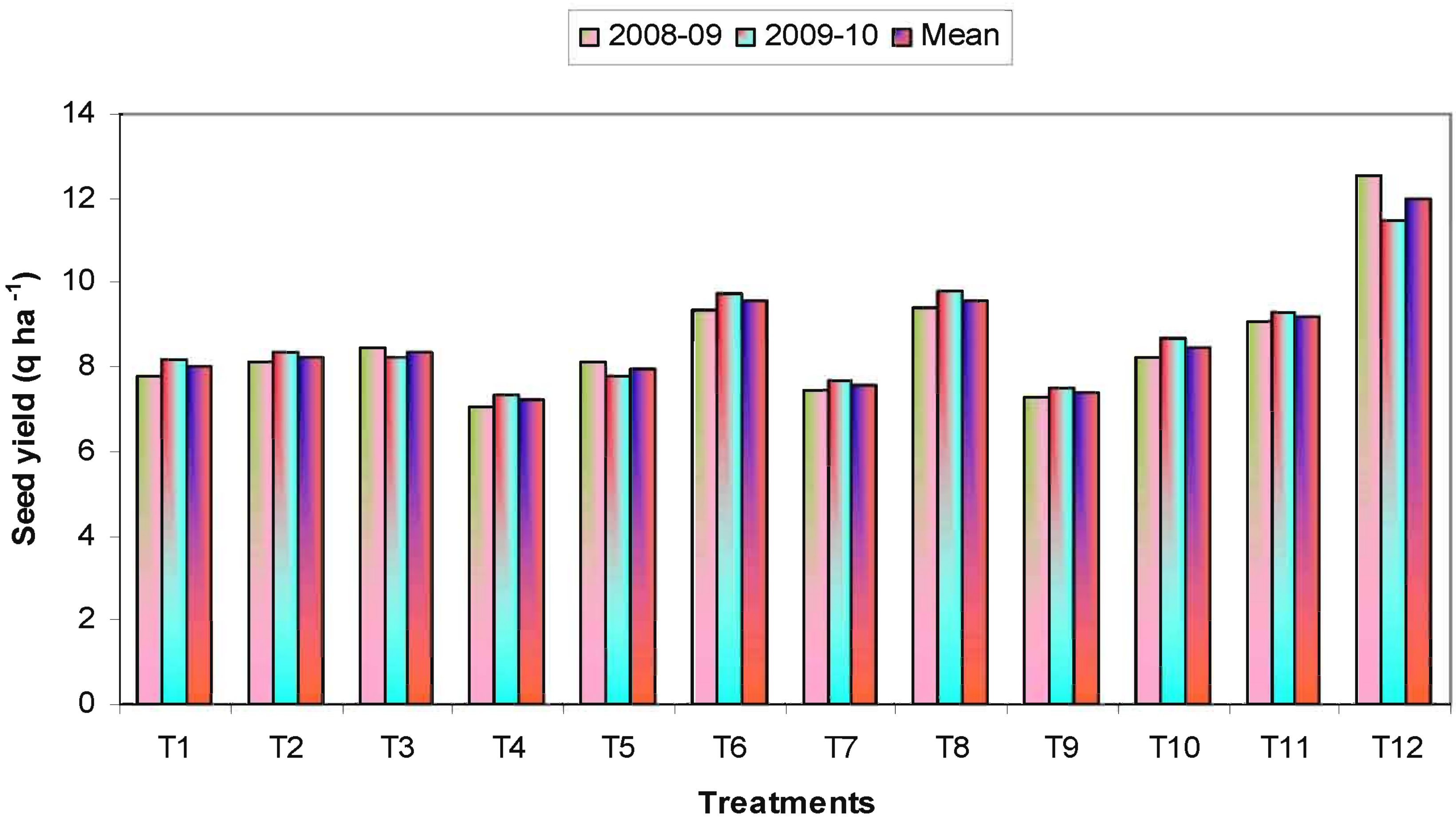


Fig.7: Effect of organic manures on seed yield ha^{-1} in fenugreek

by T_4: NC as compared to other treatments and it was on par with T_9: FYM + NC.

4.1.2.10 Biological yield ha^{-1}

Data in relation to biological yield (q ha^{-1}) are presented in table-20. The data revealed significant differences among treatments during first season (2008-09). Highest biological yield of 55.00 q ha^{-1}was obtained in plots receiving 100 % RDF (T_{12}) which was significantly superior over other treatments followed by T_8 (42.40 q ha^{-1}) and T_6 (41.50 q ha^{-1}) and T_{11} (40.90 q ha^{-1}). Significantly lower values for biological yield was recorded by T_4 (30.90 q ha^{-1}) as compared to other treatments and it was on par with T_9 (31.90 q ha^{-1}).

During the second season (2009-10) also, T_{12}: 100 % RDF with values of 49.31 q ha^{-1} biological yield was found to be highly significant over other treatments followed by T_6 (42.25 q ha^{-1}), T_8 (41.34 q ha^{-1}) and T_{11} (40.83 q ha^{-1}). It was evident from the pooled data that T_{12}: 100 % RDF (52.17 q ha^{-1}) recorded the highest biological yield and was significantly superior over other treatments followed by T_6: VC + PM, T_8: FYM + PM and T_{11}: 50 % RDF. Significantly lower biological yield was recorded by T_4 (31.57 q ha$^{-1)}$) followed by T_9 (33.36 q ha^{-1}).

4.1.2.11 Straw yield ha^{-1}

Data relating to straw yield are presented in table-21. The application of manures through different sources, their combination and RDF had significantly influenced the straw yield in both the seasons. A perusal of data of first season revealed that T_{12}: 100 % RDF recorded highest yield of 42.46 q ha^{-1} and was significantly superior over other treatments followed by T_8: FYM + PM, T_6: VC + PM and T_{11}: 50 % RDF. T_4 (23.87 q ha^{-1}) recorded significantly lowest values for

Table 20: Effect of organic manures on biological yield in fenugreek

Treatments	Biological yield (q ha^{-1})		
	2008-09	**2009-10**	**Pooled mean**
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	35.00	36.43	35.73
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	35.40	36.62	36.02
T_3 : Poultry manure (PM) @7.0t ha^{-1}	37.40	36.72	37.06
T_4 : Neem cake (NC) @5.0 t ha^{-1}	30.90	32.23	31.57
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	35.60	33.81	34.74
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	41.50	42.25	41.91
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	33.70	35.00	34.40
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	42.40	41.34	41.91
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	31.90	34.82	33.36
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	36.80	38.08	37.48
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	40.90	40.83	40.89
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	55.00	49.31	52.17
Mean	38.04	38.12	38.11
Sem±	0.63	0.58	0.61
CD (P=0.05)	1.87	1.70	1.69

Table 21: Effect of organic manures on straw yield in fenugreek

Treatments	Straw yield (q ha^{-1})		
	2008-09	**2009-10**	**Pooled mean**
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	27.20	28.24	27.72
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	27.30	28.27	27.78
T_3 : Poultry manure (PM) @7.0t ha^{-1}	28.92	28.49	28.70
T_4 : Neem cake (NC) @5.0 t ha^{-1}	23.87	24.88	24.37
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	27.54	26.00	26.77
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	32.21	32.49	32.35
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	26.36	27.30	26.83
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	33.08	31.50	32.31
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	24.60	27.28	25.94
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	28.61	29.41	29.01
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	31.90	31.55	31.72
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	42.46	37.85	40.15
Mean	29.50	29.43	29.47
Sem±	0.59	0.53	0.55
CD (P=0.05)	1.74	1.57	1.64

straw yield and it was on par with T_9 (24.60 q ha^{-1}).

During 2009-10 also, T_{12}: 100 % RDF maintained superiority over other treatments with straw yield of 37.85 q ha^{-1} followed by T_6, T_{11} and T_8. The lowest straw yield was recorded by T_4 (24.88 q ha^{-1}) and it was on par with T_5 (26.00 q ha^{-1}).

In pooled data, the straw yield ranged from 24.37 to 40.15 q ha^{-1} and T_{12} (40.15 q ha^{-1}) was significantly superior to other treatments in respect of straw yield followed by T_6, T_8 and T_{11}. The lowest value for straw yield was recorded in T_4 (24.37 q ha^{-1}) and it was on par with T_9 (25.94 q ha^{-1}).

4.1.2.12 Harvest index

Results on harvest index as influenced by different treatments are presented in table-22. The data revealed that application of organic manures and their combinations did not exert any significant influence on harvest index during 2008-09. However, during 2009-10 the treatment, T_8: FYM + PM recorded significantly higher harvest index (23.66 %) over rest of the treatments except T_{12}, T_5 and T_6.

In pooled values, significantly highest harvest index (23.02 %) was recorded by T_{12}: 100 % RDF over T_7 and it was on par with rest of the treatments except T_7 which recorded the lowest harvest index.

4.1.3 Nutrient content in seed and straw

4.1.3.1 Nitrogen content in seed

Data relating to nitrogen content (%) in seed are presented in table-23. It was observed from data that the application of organic manures, their combinations and RDF could not exert any significant influence on nitrogen content in seed during 2009-10. However, during 2008-09 significantly highest nitrogen % was observed in

Table 22: Effect of organic manures on harvest index in fenugreek

Treatments	Harvest index (%)		
	2008-09	2009-10	Pooled Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	22.26	22.48	22.37
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	22.95	22.80	22.87
T_3 : Poultry manure (PM) @7.0t ha^{-1}	22.71	22.41	22.56
T_4 : Neem cake (NC) @5.0 t ha^{-1}	22.80	22.80	22.80
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	22.76	23.06	22.91
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	22.50	23.11	22.80
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	22.00	22.00	22.00
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	22.10	23.66	22.88
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	22.80	21.66	22.23
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	22.40	22.76	22.58
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	22.10	22.73	22.41
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	22.80	23.25	23.02
Mean	22.51	22.72	22.61
Sem±	0.31	0.27	0.29
CD (P=0.05)	NS	0.81	0.80

Table 23: Effect of organic manures on nitrogen, phosphorus and potassium content in seed of fenugreek

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	2.500	2.500	2.500	0.350	0.330	0.340	1.040	1.060	1.050
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	2.400	2.450	2.425	0.350	0.350	0.350	1.080	1.000	1.040
T_3 : Poultry manure (PM) @7.0t ha^{-1}	2.480	2.460	2.470	0.350	0.350	0.350	1.080	1.000	1.040
T_4 : Neem cake (NC) @5.0 t ha^{-1}	2.510	2.510	2.510	0.360	0.350	0.355	1.000	1.010	1.005
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	2.580	2.530	2.555	0.350	0.340	0.345	1.000	0.930	0.965
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	2.560	2.610	2.585	0.310	0.320	0.315	1.060	1.000	1.030
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	2.510	2.550	2.530	0.340	0.350	0.345	1.070	1.070	1.070
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	2.510	2.560	2.535	0.350	0.330	0.340	1.100	1.100	1.100
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	2.430	2.480	2.455	0.330	0.320	0.325	1.200	1.030	1.020
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	2.430	2.480	2.455	0.330	0.310	0.320	1.000	1.000	1.000
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	2.480	2.530	2.505	0.360	0.310	0.335	1.000	0.870	0.935
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	2.600	2.710	2.655	0.340	0.330	0.335	1.100	1.100	1.100
Mean	2.500	2.530	2.515	0.343	0.332	0.337	1.061	1.014	1.037
Sem±	0.030	0.050	0.044	0.008	0.015	0.009	0.020	0.020	0.020
CD (P=0.05)	0.100	NS	0.120	0.023	NS	0.025	0.070	0.060	0.060

T_{12}: 100 % RDF (2.60 %) and it was at par with T_5, T_6, T_7, T_8, T_4 and T_1. Further, the lower nitrogen % in seed was observed in T_2 (2.40 %), T_9 (2.43 %) and T_{10} (2.43 %).

In pooled values, the nitrogen % in seed ranged from 2.425 to 2.655 and significantly highest value for nitrogen % in seed was recorded in T_{12}: 100 % RDF (2.655 %) and it was on par with T_6: VC + PM, T_5: VC + FYM and T_8: FYM + PM. The treatments; T_2 (2.425 %), T_9 (2.455 %) and T_{10} (2. 455 %) recorded lower values.

4.1.3.2 Phosphorus content in seed

The data pertaining to phosphorus % in seed as influenced by different treatments are presented in table-23. During 2008-09, the treatment, T_{11}: 50 % RDF (0.360 %) recorded highest phosphorus % in seed and it was on par with T_4, T_1, T_2, T_3, T_5, T_8, T_7 and T_{12}. The lowest phosphorus % was observed in T_6 (0.310 %), T_9 (0.330 %) and T_{10} (0.330 %).

Further, it could be observed from the data that no significant difference in phosphorus contents of seed was observed among treatments during 2009-10. However, in case of pooled data significantly higher phosphorus % in seed was observed in T_4: NC (0.355 %) and it was at par with rest of the treatments except T_6, T_{10} and T_9 which recorded lower values of 0.315 %, 0.320 % and 0.325 % respectively.

4.1.3.3 Potassium content in seed

Data on potassium content (%) in seed as influenced by various treatments are presented in table-23. It was observed from the data that during 2008-09 significantly higher potassium % in seed was registered by T_9: FYM + NC (1.20 %). Further, the treatments *viz.*, T_8, T_{12}, T_2, T_3, T_7, T_6, T_1 were on par with each other in respect of potassium % in seed. The lowest value for potassium content in seed was observed in T_4, T_5, T_{10}, T_{11} (1. 00 % in each case).

The treatments *viz.*, T_8: FYM + PM (1.10 %), T_{12}: 100 % RDF (1.10 %), T_1: VC (1.06 %) T_7: VC + NC (1.07 %) recorded higher potassium % in seed during 2009-10. The above treatments were on par with each other. On the other hand T_{11} (0.87 %) and T_5 (0.93 %) registered lower potassium % in seed.

In pooled data, the potassium % in seed was highest in T_8: FYM + PM (1.10 %) and lowest in T_{11}: 50 % RDF (0.93 %). The treatments, T_8 and T_{12} recorded higher potassium % in seed and these treatments were on par with T_1, T_2, T_3 and T_7. The lowest potassium % was recorded in T_{11} (0.93 %) followed by T_5 (0.96 %).

4.1.3.4 Nitrogen content in straw

The data relating to nitrogen (%) in straw is presented in tabl-24. It could be observed from data that the application of organic manures and RDF had significantly influenced the nitrogen content of the straw.

During 2008-09, significantly highest nitrogen % in straw was observed in T_4: NC (0.85 %) as compared to other treatments followed by T_8: FYM + PM (0.8 %). The treatments, T_{12}: 100 % RDF (0.72 %), and T_6: VC + PM (0.71 %) and T_3: PM (0.65 %) was on par with each other. The lowest nitrogen % in straw was recorded in T_2 (0.55 %) and T_{11} (0.56 %).

Similarly, during 2009-10 also T_4: NC (0.8 %) recorded highest nitrogen % in straw as compared to other treatments followed by T_8: FYM + PM (0.78 %) and T_{12}: 100 % RDF (0.78 %). The treatments, T_8 and T_{12} were on par with T_4. The lowest

Table 24: Effect of organic manures on nitrogen, phosphorus and potassium content in straw of fenugreek

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	0.580	0.630	0.605	0.137	0.123	0.130	0.430	0.420	0.425
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	0.550	0.550	0.550	0.130	0.127	0.128	0.500	0.500	0.500
T_3 : Poultry manure (PM) @7.0t ha^{-1}	0.650	0.600	0.625	0.127	0.110	0.118	0.500	0.500	0.500
T_4 : Neem cake (NC) @5.0 t ha^{-1}	0.850	0.800	0.825	0.143	0.113	0.128	0.500	0.500	0.500
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	0.610	0.620	0.615	0.127	0.120	0.123	0.470	0.450	0.460
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	0.710	0.710	0.710	0.140	0.120	0.130	0.490	0.490	0.490
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	0.560	0.620	0.590	0.143	0.103	0.123	0.500	0.500	0.500
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	0.800	0.780	0.790	0.140	0.127	0.133	0.450	0.480	0.465
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	0.580	0.600	0.590	0.143	0.120	0.132	0.470	0.460	0.465
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	0.580	0.630	0.605	0.150	0.130	0.140	0.500	0.500	0.500
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	0.560	0.560	0.560	0.140	0.120	0.130	0.500	0.510	0.505
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	0.720	0.780	0.750	0.140	0.110	0.125	0.500	0.530	0.515
Mean	0.640	0.660	0.650	0.138	0.118	0.128	0.484	0.486	0.485
Sem±	0.030	0.020	0.028	0.004	0.004	0.005	0.011	0.018	0.015
CD (P=0.05)	0.090	0.060	0.071	0.014	0.015	0.013	0.034	0.055	0.050

value was recorded in T_2 (0.55 %).

In pooled data, the nitrogen % in straw ranged from 0.550 to 0.825. The highest nitrogen % in straw was observed in T_4: NC (0.825 %) as compared to other treatments and it was on par with T8: FYM + PM (0.79 %). The treatment, T_{12}: 100 % RDF (0.75 %) also recorded significantly higher values for nitrogen % in straw over other treatments except T_4 and T_8. The lowest value was recorded by T_2: FYM (0.55 %) followed by T_{11} (0.56 %).

4.1.3.5 Phosphorus content in straw

Data pertaining to phosphorus % in straw are presented in table-24. During 2008-09, highest phosphorus % in straw was recorded by T_{10}: PM + NC (0.150 %) and it was on par with rest of the treatments except T_2, T_3 and T_5.

In 2009-10 also, the treatment, T_{10}: PM + NC (0.130 %) recorded the highest phosphorus % in straw. However, the above treatment was at par with rest of the treatments except T_4, T_{12}, T_3 and T_7. The lower phosphorus in straw was recorded in T_7 (0.103 %), T_3 (0.110 %) and T_{12} (0.110 %).

It was evident from pooled data that higher phosphorus % in straw was recorded in T_{10} (0.140 %). However, it was on par with rest of the treatments except T_3, T_5, T_7 and T_{12} which recorded lower phosphorus of 0.118 %, 0.123 %, 0.123 % and 0.125 % respectively.

4.1.3.6 Potassium content in straw

Data pertaining to potassium % in straw as influenced by various treatments are presented in table-24. It was observed from the data that during 2008-09 the treatments *viz*., T_2, T_3, T_4, T_7, T_{10}, T_{11}, T_{12} recorded significantly higher value of potassium % in straw (0.5%) over T_8 and T_1. The treatments *viz*., T_6, T_5, T_9 were on par with T_2, T_3, T_4, T_7, T_{10}, T_{11}, T_{12}. The lowest value for potassium % in straw was recorded in T_1 (0.43 %) followed by T_8 (0.45 %).

During 2009-10, the treatment, T_{12}: 100 % RDF recorded higher potassium % (0.53 %) in straw. The above treatment was at par with rest of the treatments except T_1, T_5 and T_9. The lower value for potassium % in straw was recorded in T_1 (0.425 %) followed by T_5 (0.460 %).

It was evident from pooled data that potassium % in straw ranged from 0.425 to 0.515. The treatment, T_{12} recorded significantly higher value for potassium % in straw (0.515 %) over T_1 and T_5 and it was on par with T_2, T_3, T_4, T_6, T_7, T_8, T_9, T_{10} and T_{11}. The lowest value for potassium content was recorded by T_1 (0.420 %) followed by T_5 (0.450 %).

4.1.4 Nutrient uptake

4.1.4.1 Nitrogen uptake

It was evident from the data (table-25) that during 2008-09 significantly higher nitrogen uptake was recorded by T_{12}: 100 % RDF (63.53 kg ha^{-1}) followed by T_8: FYM + PM (50.17 kg ha^{-1}) and T_6: VC + PM (47.13 kg ha^{-1}). The treatments, T_8 and T_6 were on par with each other. The lower nitrogen uptake was recorded by T_9 (32.15 kg ha^{-1}) and T_7 (33.67 kg ha^{-1}).

During 2009-10 also similar trend as that of 2008-09 was exhibited by the treatments, T_{12}, T_8 and T_6. Further, T_9 and T_5 recorded lower nitrogen uptake.

In pooled data also, higher nitrogen uptake was recorded by T_{12}: 100 % RDF

Table 25: Effect of organic manures on nitrogen, phosphorus and potassium uptake in fenugreek

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	35.39	38.36	36.87	6.47	6.24	6.35	19.83	16.77	18.30
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	34.56	36.02	35.29	6.42	6.53	6.48	22.46	22.48	22.47
T_3 : Poultry manure (PM) @7.0t ha^{-1}	39.80	39.78	39.79	6.65	6.02	6.33	22.62	22.47	23.04
T_4 : Neem cake (NC) @5.0 t ha^{-1}	38.25	38.38	38.32	5.99	5.44	5.72	18.98	19.89	19.43
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	37.97	35.97	36.97	6.33	5.82	6.08	21.06	19.15	20.11
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	47.13	48.85	47.99	7.47	7.06	7.26	25.75	25.78	25.77
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	33.67	36.66	35.16	6.33	5.54	5.94	21.15	21.91	21.53
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	50.17	49.79	49.98	7.92	7.29	7.60	25.47	25.90	25.69
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	32.15	34.95	33.55	5.93	5.73	5.83	19.21	17.84	18.52
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	36.84	40.19	38.51	7.08	6.52	6.80	22.57	23.37	22.97
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	40.55	41.38	40.96	7.73	6.94	7.33	25.00	24.46	24.73
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	63.53	57.06	60.29	10.30	7.98	9.14	35.13	32.88	34.00
Mean	40.83	41.45	41.14	7.051	6.42	6.74	23.27	22.74	23.05
Sem±	1.17	1.30	1.23	0.19	0.18	0.19	0.55	1.22	0.95
CD (P=0.05)	3.44	3.82	3.43	0.56	0.55	0.53	1.62	3.57	2.62

(60.29 kg ha^{-1}) followed by T_8: FYM + PM (49.98 kg ha^{-1}) and T_6: VC + PM (47.99 kg ha^{-1}). The treatments, T_8 and T_6 were on par with each other. The lower nitrogen uptake was recorded by T_9 (33.55 kg ha^{-1}) and T_2 (35.29 kg ha^{-1}).

4.1.4.2 Phosphorus uptake

It was evident from the data (table-25) that during 2008-09 significantly higher phosphorus uptake was recorded by T_{12}: 100 % RDF (10.30 kg ha^{-1}) followed by T_8: FYM + PM (7.92 kg ha^{-1}), T_{11}: 50 % RDF (7.73 kg ha^{-1}) and T_6: VC + PM (7.47 kg ha^{-1}). The treatments, T_8 T_{11} and T_6 were on par with each other. The lower phosphorus uptake was recorded by T_9 (5.93 kg ha^{-1}) followed by T_4 (5.99 kg ha^{-1}).

During 2009-10 also similar trend as that of 2008-09 was exhibited by the treatments, T_{12}, T_8, T_6 and T_{11}. Further, T_4 and T_7 recorded lower phosphorus uptake.

In pooled data also, higher phosphorus uptake was recorded by T_{12}: 100 % RDF (9.14 kg ha^{-1}) followed by T_8: FYM + PM (7.60 kg ha^{-1}), T_{11}: 50 % RDF (7.33 kg ha^{-1}) and T_6: VC + PM (7.26 kg ha^{-1}). The treatments, T_8, T_{11} and T_6 were on par with each other. The lower phosphorus uptake was recorded by T_4 (5.72 kg ha^{-1}) and T_9 (5.83 kg ha^{-1}).

4.1.4.3 Potassium uptake

It was evident from the data (table-25) that during 2008-09 significantly higher potassium uptake was recorded by T_{12}: 100 % RDF (35.13 kg ha^{-1}) and it was closely followed by T_6: VC + PM (25.75 kg ha^{-1}), T_8: FYM + PM (25.47 kg ha^{-1}) and T_{11}: 50 % RDF (25 kg ha^{-1}). The treatments, T_6, T_8 and T_{11} were on par with each other. The lower potassium uptake was recorded by T_4 (18.98 kg ha^{-1}) followed by T_9

(19.21 kg ha^{-1}).

During 2009-10 also similar trend as that of 2008-09 was exhibited by T_{12} and the treatments *viz.*, T_8, T_6, T_{11}, T_{10}, T_2, T_3 were on par with each other, Further, T_1 and T_9 recorded lower potassium uptake.

It was evident from the pooled data that significantly higher potassium uptake was recorded by T_{12}: 100 % RDF (34.00 kg ha^{-1}) and it was followed by T_6: VC + PM (25.77 kg ha^{-1}), T_8: FYM + PM (25.69 kg ha^{-1}) and T_{11}: 50 % RDF (24.73 kg ha^{-1}). The treatments, T_6, T_8 and T_{11} were on par with each other. The lower potassium uptake was recorded by T_1 (18.30 kg ha^{-1}) followed by T_9 (18.52 kg ha^{-1}).

4.1.5 Available nitrogen, phosphorus and potassium in soil after harvest of fenugreek

A perusal of data (table-26) on soil analysis for nutrients revealed that no significant differences were observed in available nitrogen and potassium in soil after harvest of fenugreek with application of organic manures and their combinations. But, with regards to available phosphorus in soil significant differences were observed among treatments.

During 2008-09, application of T_6: VC + PM (23.50 kg ha^{-1}) and T_8: FYM + PM (23.07 kg ha^{-1}) resulted in higher phosphorus in the soil followed by T_3: PM, T_9: FYM + NC and T_2: FYM. The above treatments were on par with each other. Similar trend was observed by T_6 and T_8 during 2009-10 and also in pooled values. Lower values for available phosphorus in soil were recorded by T_{11} and T_{12}.

4.1.6 Quality parameters

4.1.6.1 Crude protein content in seed

Data pertaining to crude protein content (%) in seed are presented in table-27. The highest crude protein % was recorded during 2008-09 by T_{12} (16.25 %) and it was on par with T_5, T_6, T_4, T_7, T_8 and T_1. The lowest value was recorded by T_2 (14.99 %) followed by T_9 (15.20 %) and T_{10} (15.20 %).

During 2009-10, no significant differences were noticed among treatments with respect to crude protein % in seed.

However, it could be seen from pooled data that the crude protein content (%) in seed ranged from 15.15 % to 16.61 %. Significantly highest crude protein content (%) was recorded by T_{12} (16.61 %) as compared to other treatments and it was on par with T_6, T_5, and T_8. The lowest crude protein of 15.15 % in seed was recorded by T_2 followed by T_{10} (15.35 %) and T_9 (15.36 %).

4.1.6.2 Crude fibre content in seed

It was evident from the data (table-28) that no significant differences were noticed among treatments with respect to crude fibre content in seed during 2008-09. However, in 2009-10 the treatment, T_9: FYM + NC (7.800 %) recorded significantly higher crude fibre content in seed as compared to other treatments. The above treatment was at par with T_8: FYM + PM (7.733 %) and T_{12}: 100 % RDF (7.767 %). The lowest crude fibre content in seed was registered by T_2: FYM (7.447 %) followed by T_{11}: 50 % RDF (7.483 %).

A perusal of pooled data revealed that T_9: FYM + NC (7.750 %) was significantly superior in respect of crude fibre content as compared to other treatments and it was at par with T_{12}: 100 % RDF (7.724 %) and T_8: FYM + PM (7.692 %). T_2 (7.477 %) and T_{11} (7.492 %) recorded lower value for crude fibre content in seed.

Table 26: Effect of organic manures on available nitrogen, phosphorus and potassium in soil after harvest of fenugreek

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	188.67	189.00	188.84	21.60	21.33	21.465	283.00	281.07	282.03
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	187.50	188.00	187.75	21.80	21.73	21.765	283.50	283.17	283.33
T_3 : Poultry manure (PM) @7.0t ha^{-1}	191.00	190.00	190.50	22.50	22.37	22.435	284.20	283.90	284.05
T_4 : Neem cake (NC) @5.0 t ha^{-1}	191.33	190.83	191.08	21.20	21.03	21.115	285.00	284.90	284.95
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	188.83	189.17	189.00	20.80	20.67	20.735	284.80	285.00	284.9
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	191.10	190.33	190.72	23.50	23.43	23.465	284.00	283.43	283.71
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	185.00	184.83	184.92	21.00	20.83	20.915	283.00	283.10	283.05
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	190.67	191.00	190.84	23.07	22.90	22.985	283.33	282.17	282.75
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	187.50	187.00	187.25	22.50	22.40	22.45	282.70	282.83	282.76
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	190.83	190.00	190.42	21.00	20.70	20.85	282.00	281.83	281.91
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	188.17	187.83	188.00	19.50	19.47	19.485	281.83	282.20	282.01
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	191.33	191.33	191.33	20.00	19.73	19.865	282.33	283.20	282.76
Mean	189.32	189.11	189.22	21.53	22.38	21.95	283.30	283.06	283.18
Sem±	1.38	1.31	1.35	0.28	0.26	0.27	0.81	0.97	0.89
CD (P=0.05)	NS	NS	NS	0.83	0.76	0.76	NS	NS	NS

Table 27: Effect of organic manures on crude protein in seed of fenugreek

Treatments	Crude Protein (%)		
	2008-09	**2009-10**	**Mean**
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	15.62	15.62	15.62
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	14.99	15.31	15.15
T_3 : Poultry manure (PM) @7.0t ha^{-1}	15.51	15.41	15.46
T_4 : Neem cake (NC) @5.0 t ha^{-1}	15.93	15.72	15.82
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	16.14	15.82	15.98
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	16.04	16.35	16.19
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	15.72	15.93	15.82
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	15.72	16.03	15.87
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	15.20	15.52	15.36
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	15.20	15.51	15.35
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	15.51	15.82	15.66
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	16.25	16.97	16.61
Mean	15.65	15.83	15.74
Sem±	0.23	0.31	0.27
CD (P=0.05)	0.68	NS	0.77

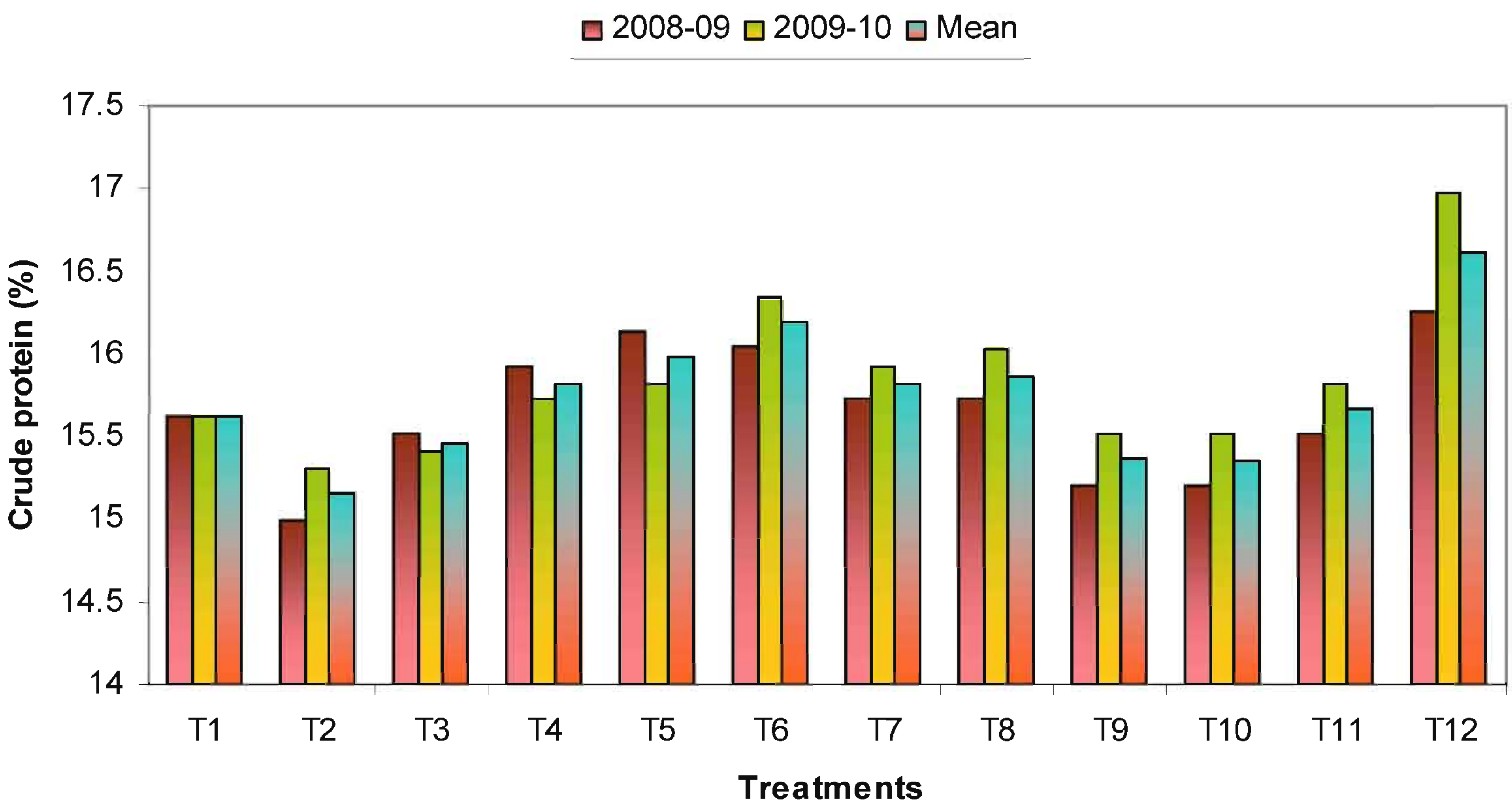


Fig.8: Effect of Organic manures on crude protein in seed of fenugreek

4.1.6.3 Diosgenin content in seed

It was evident from the data (table-29) that various treatments did not exert any significant influence on diosgenin content in seed. However, in pooled data it ranged from 0.216 % to 0.229 %.

4.1.7 Economics

The cost of production, gross returns, net returns and benefit cost ratio were worked out for different organic manures and their combinations in fenugreek during 2008-09 and 2009-10.

4.1.7.1 Cost of production

During 2008-09 and 2009-10 (table-30), the highest cost of production was recorded by T_1: VC (Rs.25,000/- and Rs. 25,500/- ha^{-1} respectively) followed by T_7: VC + NC (Rs. 23,500/- and Rs. 24,100/- ha^{-1} respectively), while the lowest was recorded by T_2: FYM (Rs. 15,280/- and Rs. 15,600/- ha^{-1} respectively) in both the years. In general the treatments with vermicompost as a nutrient source were observed to record higher cost of production than the other treatments.

4.1.7.2 Gross returns

Gross returns (table-30) obtained with 100 % RDF were the highest during 2008-09 (Rs. 41,448/- ha^{-1}) and 2009-10 (Rs. 37,818/- ha^{-1}) followed by T_8: FYM + PM and T_6: VC + PM in both the years, while they were lowest with T_9: FYM + NC in both the years (Rs. 24,090/- and 24,849/- ha^{-1} respectively).

4.1.7.3 Net returns

During 2008-09 and 2009-10 (31), maximum net returns were realised with

Table 28: Effect of organic manures on crude fibre in seed of fenugreek

Treatments	Crude fibre (%)		
	2008-09	2009-10	Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	7.497	7.500	7.498
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	7.507	7.447	7.477
T_3 : Poultry manure (PM) @7.0t ha^{-1}	7.617	7.600	7.608
T_4 : Neem cake (NC) @5.0 t ha^{-1}	7.583	7.543	7.563
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	7.573	7.573	7.573
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	7.590	7.590	7.590
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	7.483	7.540	7.512
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	7.650	7.733	7.692
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	7.700	7.800	7.750
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	7.540	7.593	7.567
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	7.500	7.483	7.492
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	7.680	7.767	7.724
Mean	7.576	7.597	7.587
Sem±	0.056	0.042	0.048
CD (P=0.05)	NS	0.125	0.134

Table 29: Effect of organic manures on Diosgenin content in seed of fenugreek

Treatments	Diosgenin (%)		
	2008-09	2009-10	Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	0.213	0.224	0.219
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	0.217	0.218	0.218
T_3 : Poultry manure (PM) @7.0t ha^{-1}	0.220	0.230	0.225
T_4 : Neem cake (NC) @5.0 t ha^{-1}	0.224	0.226	0.225
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	0.233	0.224	0.229
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	0.225	0.224	0.225
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	0.217	0.218	0.218
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	0.215	0.223	0.219
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	0.212	0.219	0.216
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	0.214	0.220	0.217
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	0.222	0.217	0.219
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	0.218	0.222	0.220
Mean	0.219	0.222	0.221
Sem±	0.004	0.003	0.003
CD (P=0.05)	NS	NS	NS

T_{12}: 100 % RDF (Rs. 25,448/- and 21,518/- ha^{-1} respectively) followed by T_8: FYM + PM (Rs. 15,203/- and 16,724/- ha^{-1} respectively) in both the years. The lowest net returns were realised with T_4: NC during 2008-09 (Rs. 265 ha^{-1}). However, during 2009-10 the lowest (Rs. 1,310/- ha^{-1}) was recorded by T_7: VC + NC.

4.1.7.4 Benefit : cost ratio (BCR)

In this study, it was observed that (table-31) the highest B : C ratio (1.46) was recorded with the application of inorganic fertilizers (T_{12}) followed by application of T_8: FYM + PM: (1.02 B:C ratio) and T_{11}: 50 % RDF: (0.98 B:C ratio). B : C ratios were lower in case of T_1 (VC) and T_7 (VC + NC).

4.1.8 Correlations

From the correlation matrix (Table-32) it was observed that the yield component which was the most important character was positively and significantly correlated with plant height, number of leaves, dry matter content, number of pods $plant^{-1}$, pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield $plant^{-1}$.

The character, plant height was positively and significantly correlated with number of leaves, dry matter content, number of pods $plant^{-1}$, pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield $plant^{-1}$.

Significant and positive correlation was observed for number of leaves with dry matter content, number of pods $plant^{-1}$, pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield $plant^{-1}$.

Table 30: Effect of organic manures on cost of production and gross returns (Rs ha-1) in fenugreek

Treatments	Cost of production			Gross returns		
	2008-09	2009-10	Mean	2008-09	2009-10	Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	25,000	25,500	25,250	25,740	27,027	26,383
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	15,280	15,600	15,440	26,829	27,555	27,192
T_3 : Poultry manure (PM) @7.0t ha^{-1}	16,500	15,900	16,200	27,984	27,159	27,571
T_4 : Neem cake (NC) @5.0 t ha^{-1}	23,000	22,600	22,800	23,265	24,255	23,760
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	20,700	20,950	20,825	26,763	25,740	26,251
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	21,250	21,550	21,400	30,855	32,208	31,531
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	23,500	24,100	23,800	24,585	25,410	24,997
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	15,850	15,550	15,700	31,053	32,274	31,663
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	19,120	19,300	19,210	24,090	24,849	24,469
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	19,750	19,250	19,500	27,258	28,578	27,918
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	15,000	15,500	15,250	29,865	30,624	30,244
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	16,000	16,300	16,150	41,448	37,818	39,633

Table 31: Effect of organic manures on net returns (Rs. ha-1) and benefit cost ratio

Treatments	Net returns			Benefit cost ratio		
	2008-09	2009-10	Mean	2008-09	2009-10	Mean
T_1 : Vermicompost (VC) @6.6 t ha^{-1}	740	1,527	1,133	0.03	0.06	0.04
T_2 : Farm yard manure (FYM) @5.7 t ha^{-1}	11,549	11,955	11,752	0.76	0.77	0.76
T_3 : Poultry manure (PM) @7.0t ha^{-1}	11,484	11,259	11,371	0.70	0.71	0.70
T_4 : Neem cake (NC) @5.0 t ha^{-1}	265	1,655	960	0.01	0.07	0.04
T_5 : VC @3.3 t ha^{-1}+ FYM @2.8 t ha^{-1}	6,063	4,790	5,426	0.29	0.23	0.26
T_6 : VC @3.3 t ha^{-1} + PM @ 3.5 t ha^{-1}	9,605	10,658	10,131	0.45	0.50	0.47
T_7 : VC @3.3 t ha^{-1} + NC @ 2.5 t ha^{-1}	1,085	1,310	1,197	0.05	0.05	0.05
T_8 : FYM @2.8 t ha^{-1} + PM @ 3.5 t ha^{-1}	15,203	16,724	15,963	0.96	1.08	1.02
T_9 : FYM@2.8 t ha^{-1} + NC @2.5 t ha^{-1}	4,970	5,549	5,259	0.26	0.29	0.27
T_{10} : PM @ 3.5 t ha^{-1} + NC @2.5 t ha^{-1}	7,508	9,328	8,418	0.38	0.48	0.43
T_{11} : 50% RDF (30-25-25 NPK kg ha^{-1})	14,865	15,124	14,994	0.99	0.98	0.98
T_{12} : 100% RDF (60-50-50 NPK kg ha^{-1})	25,448	21,518	23,483	1.59	1.32	1.46

Table 32: Correlation matrix combined over two seasons of fenugreek as influenced by organic manures.

Characters	Plant height	No.of leaves/pl	No.of branches/pl	Dry matter content	No. of pods/pl	Pod length	Seeds/pod	Test weight	N uptake	P uptake	K uptake	Crude protein	Seed yield $plant^{-1}$	Seed yield / ha
Plant height	1.000	0.509***	-0.047	0.402 ***	0.345 **	0.232 *	0.313 **	0.321 **	0.544 ***	0.466 ***	0.447 ***	0.311 **	0.402 ***	0.529 ***
No.of leaves		1.000	-0.178	0.712 ***	0.368 **	0.435 ***	0.451***	0.651 ***	0.760 ***	0.732 ***	0.685 ***	0.287 *	0.648 ***	0.784 ***
Branches/pl			1.000	-0.161	-0.025	-0.145	-0.125	-0.352 **	-0.128	-0.180	-0.185	-0.066	-0.135	-0.185
Dry matter/pl				1.000	0.390 ***	0.378 **	0.415 ***	0.653 ***	0.724 ***	0.619 ***	0.668 ***	0.411 ***	0.547 ***	0.774 ***
No. of pods/pl					1.000	0.416 ***	0.311 **	0.437 ***	0.537 ***	0.315 **	0.474 ***	0.374 **	0.549 ***	0.437 ***
Pod length						1.000	0.798 ***	0.290 *	0.380 ***	0.289 *	0.445 ***	0.151	0.326 **	0.348 **
Seeds/ pod							1.000	0.338 **	0.529 ***	0.373 **	0.497 ***	0.339 **	0.333 **	0.444 ***
Test weight								1.000	0.673 ***	0.628 ***	0.646	0.426 ***	0.548 ***	0.663 ***
N uptake									1.000	0.805 ***	0.842 ***	0.565 ***	0.726 ***	0.918 ***
P uptake										1.000	0.830 ***	0.260 *	0.569 ***	0.885 ***
K uptake											1.000	0.389 ***	0.603 ***	0.898 ***
Crude protein												1.000	0.511 ***	0.448 ***
Seed yield/pl													1.000	0.712 ***
Seed yield/ha														1.000

* - Significant at 5 % level, ** - Significant at 1 % level and *** - Significant at 0.1 % level.

Significant and positive correlation was observed for the dry matter content with number of pods plant^{-1}, pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}.

The number of pods plant^{-1} was positively correlated with pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}. The character pod length was positively correlated with seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake and seed yield plant^{-1}. However, it was non significantly and positively correlated with crude protein content in seed.

Significant and positive correlation was observed for seeds pod^{-1} with test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}. Further, the test weight was positively correlated with nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}.

Nitrogen uptake showed significant and positive correlation with phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}. Similarly, phosphorus uptake was significantly and positively correlated with potassium uptake, crude protein in seed and yield plant^{-1}. Significant and positive correlation was observed for potassium uptake with crude protein in seed and yield plant^{-1}. Further, the protein content showed positive and significant correlation with yield plant^{-1}.

4.2 EXPERIMENT- II : EFFECT OF INTIGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND QUALITY OF FENUEGREEK

4.2.1 Growth parameters

4.2.1.1 Plant height

The effects of the various treatments on the plant height are furnished in table-33. In this investigation, it was observed that the application of organic manures, inorganic fertilizers and biofertilizers had significantly influenced the height of the plant at different stages of the crop growth during 2008-09 and 2009-10. However, the differences in the plant height did not attain any significance among the different treatments at 25 DAS (table-33). The plant height increased with the age of the crop in a linear trend reaching maximum at harvest stage. Further, a rapid rate of increase was observed between 25-50 DAS. There after, the plant height increased but slowly upto 75 DAS and marginally between 75DAS-harvest.

The data pertaining to plant height at 50 DAS is presented in table-33. During 2008-09 at 50 DAS, plant height was significantly highest in T_2: 100 % RDF + *Rhizobium* + PSB (36.65 cm) as compared to other treatments and it was on par with T_7: 75 % RDF + PM + *Rhizobium* + PSB (35.78 cm), T_5: 75 % RDF + VC + *Rhizobium* + PSB (35.55 cm). T_1: 100 % RDF (34.45 cm) and T_9: 75 % RDF + NC + *Rhizobium* + PSB (31.30 cm). Significantly lower values for plant height were observed in T_4 (26.75 cm) and it was on par with T_{10}, T_4, T_6, T_8 and T_9.

During 2009-10 at 50 DAS, T_2: 100 % RDF + *Rhizobium* + PSB, T_5: 75 % RDF + VC + *Rhizobium* + PSB and T_7: 75 % RDF + PM + *Rhizobium* + PSB recorded higher plant heights of 37.65 cm, 36.65 cm and 36.45 cm respectively. T_2 recorded significantly higher plant height as compared to other treatments and it was on par with T_5 and T_7. T_4 (27.75 cm) recorded significantly lower plant height and it was on par with T_{10}, T_9, T_3, T_6, T_8 and T_1.

It is evident from the pooled data that application of organic manures,

Table 33: Effect of Integrated nutrient management on plant height at various stages of growth in fenugreek

Treatments	Plant height (cm)											
	25DAS			50DAS			75DAS			at harvest		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	10.86	10.23	10.54	34.45	32.33	33.40	39.35	35.66	37.50	42.75	40.00	41.38
T_2 : 100%RDF+R+PSB	10.81	10.30	10.55	36.65	37.65	37.15	39.70	40.76	40.23	42.66	44.00	43.33
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	8.55	8.80	8.68	29.66	30.66	30.16	32.48	33.58	33.03	35.56	36.91	36.23
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	8.26	9.10	8.68	26.75	27.75	27.25	29.98	31.06	30.52	33.41	34.75	34.08
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	9.51	9.40	9.45	35.55	36.55	36.05	40.61	41.66	41.13	42.83	44.16	43.50
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	8.95	9.00	8.97	30.50	31.60	31.05	34.00	35.08	34.54	37.65	39.00	38.32
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	9.51	9.40	9.45	35.78	36.45	36.12	38.90	40.00	39.45	41.20	42.20	41.70
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	9.73	9.36	9.54	31.00	32.08	31.54	34.20	35.40	34.80	37.50	38.83	38.16
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	9.21	10.16	9.68	31.30	30.33	30.81	35.43	35.66	35.54	38.83	40.16	39.50
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	8.26	9.16	8.71	27.66	28.66	28.16	30.66	31.80	31.23	33.25	34.58	33.91
Mean	9.37	9.49	9.43	31.93	32.41	32.17	35.53	36.07	35.80	38.56	39.46	39.01
SEm±	0.85	0.34	0.65	1.83	1.68	1.75	1.97	1.65	1.69	1.23	1.21	1.22
CD (P=0.05)	NS	NS	NS	5.38	4.93	5.02	5.79	4.86	4.83	3.62	3.55	3.50

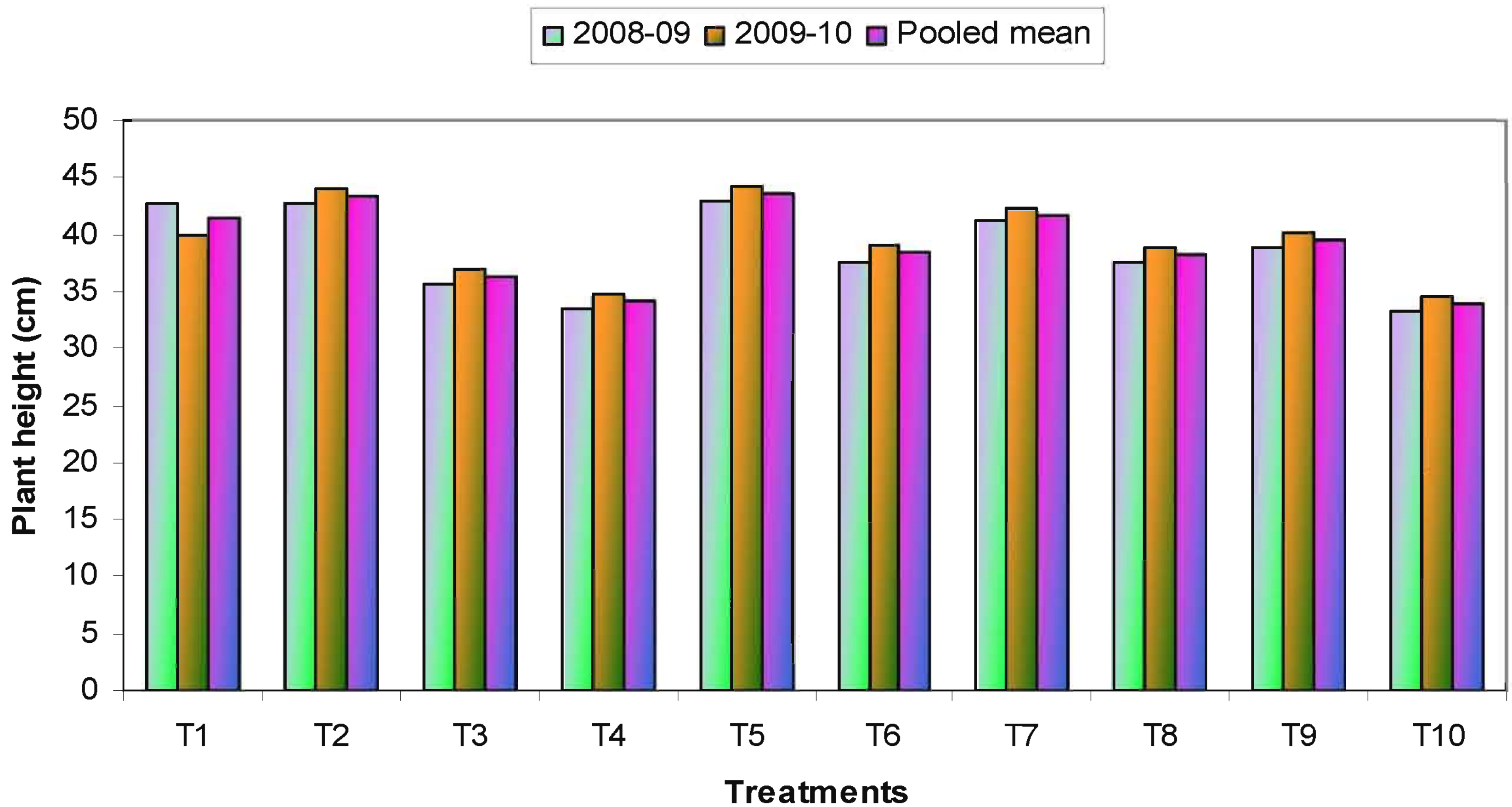


Fig.9: Effect of integrated nutrient management on plant height at harvest stage in fenugreek

inorganic fertilizers and *biofertilizers* in an INM combination significantly influenced the plant height in T_2: 100 % RDF + *Rhizobium* + PSB, T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_5: 75 % RDF + VC + *Rhizobium* + PSB and T_1: 100 % RDF treatments recording greater plant height of 37.15 cm, 36.12 cm, 36.05 cm and 33.40 cm respectively. Significantly lower plant height was recorded with T_4 (27.25 cm) and it was on par with T_{10}, T_3, T_6, T_8 and T_9. The plant height ranged from 27.25 cm to 37.15 cm.

During 2008-09, significantly higher value for plant height at 75 DAS was recorded by T_5: 75 % RDF + VC + *Rhizobium* + PSB and it was on par with T_2: 100 % RDF + *Rhizobium* + PSB, T_1: 100 % RDF, T_7: 75 % RDF + PM + *Rhizobium* +PSB and T_9: 75 % RDF + NC + *Rhizobium* + PSB. A similar trend was also observed in second crop (2009-10). T_5: 75 % RDF + VC + *Rhizobium* + PSB (41.66 cm) recorded significantly higher plant height over other treatments and it was on par with T_2: 100 % RDF + *Rhizobium* + PSB (40.76 cm) and T_7: 75 % RDF + PM + *Rhizobium* + PSB (40 cm). The lowest plant height was recorded with T_4 (31.06 cm).

It was observed from the pooled over data that significantly higher plant height was recorded over other treatments by T_5 with 75 % RDF + VC + *Rhizobium* + PSB and it was on par with T_2: 100 % RDF + *Rhizobium* + PSB, T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_1: 100 % RDF. Similarly, the treatments *viz*., T_9, T_8, T_6, T_3, T_{10} were on par with each other. The lowest plant height was observed in T_4 (30.52 cm) followed by T_{10} (31.23 cm).

At harvest during 2008-09 plant height (table-33) differed significantly and higher values were recorded in T_5: 75 % RDF + VC + *Rhizobium* + PSB as compared to other treatments and it was on par with T_1: 100 % RDF, T_2: 100 % RDF +

Rhizobium + PSB and T_7: 75 % RDF + PM + *Rhizobium* + PSB. Significantly lowest plant height was recorded in T_{10} (33.25 cm) and it was on par with T_4 and T_3.

During 2009-10, T_5: 75 % RDF + VC + *Rhizobium* + PSB (44.16 cm) recorded significantly higher plant height as compared to other treatments but it was on par with T_2: 100 % RDF + *Rhizobium* + PSB (44 cm) and T_7: 75 % RDF + PM + *Rhizobium* + PSB (42.20 cm). The lowest values for plant height were recorded in T_{10}, T_4 and T_3 which were on par with each other.

From the pooled data it was observed that significantly higher plant height was recorded in T_5: 75 % RDF + VC + *Rhizobium* + PSB (43.50 cm) over other treatments and it was on par with T_2: 100 % RDF + *Rhizobium* + PSB (43.33 cm), T_7: 75 % RDF + PM + *Rhizobium* + PSB (41.7 cm) and T_1: 100 % RDF (41.38 cm). Further T_9 was significantly superior over T_4 and T_{10} and it was on par with T_6, T_8 and T_3. The lowest values for plant height were observed in T_{10} (33.91 cm) and it was on par with T_4 and T_3.

4.2.1.2 Absolute growth rate (AGR) for plant height

The data pertaining to AGR for plant height is presented in table-34. The AGR for plant height increased rapidly between 25-50 DAS and thereafter decreased between 50-75 DAS.

During 2008-09, AGR for plant height at 25-50 DAS was not influenced by various treatments and hence the results were non significant. However, during 2009-10 the highest AGR for plant height was recorded by T_2 and it was on par with T_5, T_7, T_8 and T_6. The lowest AGR for plant height was observed in T_4 and T_{10}.

AGR for plant height at 25-50 DAS ranged from 0.743 to 1.066 cm day^{-1}. It is evident from the pooled data that the treatments *viz.*, T_7: 75 % RDF + PM +

Table 34: Effect of integrated nutrient management on Absolute growth rate for plant height at different growth stages in fenugreek

Treatments	AGR AT 25-50 DAS (cm day^{-1})			AGR AT 50-75 DAS (cm day^{-1})		
	2008-09	**2009-10**	**Pooled mean**	**2008-09**	**2009-10**	**Pooled mean**
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	0.943	0.884	0.914	0.196	0.147	0.171
T_2 : 100%RDF+R+PSB	1.034	1.097	1.065	0.293	0.295	0.294
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.845	0.875	0.860	0.113	0.117	0.115
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.739	0.746	0.743	0.183	0.186	0.184
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	1.041	1.086	1.064	0.203	0.205	0.204
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	0.862	0.900	0.881	0.140	0.143	0.142
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	1.051	1.082	1.066	0.125	0.142	0.133
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	0.847	0.909	0.878	0.139	0.133	0.136
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	0.883	0.807	0.845	0.165	0.213	0.189
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	0.776	0.780	0.778	0.120	0.125	0.123
Mean	0.902	0.916	0.909	0.167	0.170	0.169
Sem±	0.082	0.068	0.070	0.058	0.057	0.061
CD (P=0.05)	NS	0.200	0.215	NS	NS	NS

Rhizobium + PSB, T_2: 100 % RDF + *Rhizobium* + PSB, T_5: 75 % RDF + VC + *Rhizobium* + PSB recorded higher values of AGR for plant height but were on par with T_1, T_3, T_6 and T_8. The treatments, T_4 and T_{10} recorded lower values for AGR for plant height.

AGR for plant height at 50-75 DAS was not influenced by various treatments and hence the results were non significant. However, in pooled values the highest and the lowest AGR for plant height were recorded by T_2 (0.294 cm day^{-1}) and T_3 (0.115 cm day^{-1}) respectively.

4.2.1.3 Number of leaves

Data pertaining to the effect of the various treatments on number of leaves are presented in table- 35. Organic manures, inorganic fertilizers and bio fertilizers did not influence the number of leaves at 25 DAS.

During 2008-09 at 50 DAS, significantly higher number of leaves per plant was observed in the plant treated with T_2: 100 % RDF + *Rhizobium* + PSB (97.00 cm) as compared to other treatments and it was on par with T_5: 75 % RDF + VC + *Rhizobium* + PSB (92.00). T_8 (72.16) contained lower number of leaves and it was on par with other treatments except T_2 and T_5.

During 2009-10, significantly higher values for number of leaves were observed in T_2: 100 % RDF + *Rhizobium* + PSB (97.75) and it was at par with T_5: 75 % RDF + VC + *Rhizobium* + PSB, T_3: 75 % RDF + FYM + *Rhizobium* + PSB and T_7: 75 % RDF + PM + *Rhizobium* + PSB. The treatments *viz*., T_8, T_1, T_4, T_6, T_9, T_{10} recorded lower no of leaves and these treatments were on par with each other.

In pooled over data, number of leaves ranged from 72.53 to 97.37. The highest number of leaves were observed in T_2: 100 % RDF + *Rhizobium* + PSB (97.37) which was significantly superior over other treatments and it was on par with T_5: 75 % RDF

Table 35: Effect of Integrated nutrient management on number of leaves plant $^{-1}$ at various stages of growth in fenugreek

Treatments	Number of leaves plant^{-1}								
	25 DAS			50 DAS			75 DAS		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	3.93	4.03	3.98	81.75	76.41	79.08	92.00	98.66	95.33
T_2 : 100%RDF+R+PSB	4.06	3.96	4.01	97.00	97.75	97.37	110.23	114.40	112.31
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	3.63	3.66	3.66	81.41	86.08	83.74	98.16	101.16	99.66
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	3.86	3.83	3.84	80.16	80.91	80.53	95.00	99.00	97.00
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	3.71	3.75	3.73	92.00	94.00	93.00	101.50	104.16	102.83
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	3.83	3.80	3.81	73.16	73.91	73.53	94.00	96.00	95.00
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	3.66	3.70	3.68	83.16	86.00	84.58	104.50	107.16	105.83
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	3.95	3.91	3.93	72.16	72.91	72.53	93.00	95.83	94.41
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	3.90	4.00	3.95	81.00	80.16	80.58	98.26	101.26	99.76
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	3.95	3.85	3.90	73.00	73.75	73.37	95.00	98.00	96.5
Mean	3.89	3.85	3.86	81.48	82.19	81.83	98.16	101.56	99.86
SEm±	0.09	1.04	0.12	5.12	4.01	4.60	3.37	3.51	3.44
CD (P=0.05)	NS	NS	NS	15.03	11.78	13.15	9.89	10.31	9.84

T_1 (Control)

T_7 (75% RDF+PM+R+PSB)

Plate: 4: Number of leaves at 75 DAS in fenugreek as influenced by treatments (Expt 2)

+ VC + *Rhizobium* + PSB and T_7: 75 % RDF + PM + *Rhizobium* + PSB. T_8 recorded the lowest number of leaves and it was on par with rest of the treatments except T_2 and T_5. Further it was observed that T_2, T_5 and T_7 recorded 18.78 %, 14.96 % and 6.5 % increase over control (T_1) respectively.

At 75 DAS (table-35), significantly higher values for number of leaves were reported in T_2 with 100 % RDF + *Rhizobium* + PSB, as compared to rest of the treatments and it was on par with T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_5: 75 % RDF + VC + *Rhizobium* + PSB during 2008-09 and 2009-10. The lowest number of leaves were observed in T_1 (control) and T_8 during 2008-09 and 2009-10 respectively.

A similar trend was also observed in pooled values and the number of leaves ranged from 94.41 to 112.31. Further it was observed that T_2, T_7 and T_5 recorded 15.11 %, 9.92 % and 7.29 % increase over control (T_1) respectively in number of leaves plant^{-1}.

4.2.1.4 Leaf area

Data pertaining to leaf area as influenced by various treatments is furnished in table-36. During 2008-09, the highest leaf area plant^{-1} was recorded by T_2 (330.70 cm^2) which was significantly superior over rest of the treatments and it was on par with T_7 (313.55 cm^2) and T_5 (304.50 cm^2). The treatments, T_1 and T_8 recorded lower leaf area plant^{-1}.

During 2009-10 also, similar trend was exhibited by T_2 (361.50 cm^2), T_7 (348.12 cm^2) and T_5 (332.85 cm^2). However, the lowest leaf area plant^{-1} was registered by T_4 (298.00 cm^2) and T_8 (302.83 cm^2).

In pooled values also, the treatments T_2, T_7 and T5 exhibited similar trend

Table 36: Effect of Integrated nutrient management on leaf area at 75 DAS in fenugreek

Treatments	Leaf area(cm^2)		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	276.00	311.78	293.89
T_2 : 100%RDF+R+PSB	330.70	361.50	346.10
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	294.50	319.68	307.093
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	285.00	298.00	291.50
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	304.50	332.85	318.67
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	282.00	303.36	292.68
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	313.55	348.12	330.83
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	279.00	302.83	290.91
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	294.80	320.00	307.40
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	285.00	309.68	297.34
Mean	294.50	320.78	307.64
SEm±	10.12	11.15	10.80
CD (P=0.05)	29.68	32.71	32.44

recording 346.10, 330.83 and 318.67 cm^2 of leaf area $plant^{-1}$ respectively. T_2 was significantly superior over rest of the treatments and it was on par with T_7 and T_5. The remaining treatments were on par with each other except T_2, T_7 and T_5. The treatments, T_8 (290.91 cm^2) and T_4 (291.50 cm^2) recorded lower leaf area $plant^{-1}$.

4.2.1.5 Leaf area index (LAI)

The results of leaf area index as influenced by various treatments are presented in table-37. During 2008-09, significantly higher LAI was recorded by T_2 (1.102) as compared to other treatments and it was on par with T_7 (1.045) and T_5 (1.015). The treatments, T_1 and T_8 recorded lower leaf area index.

During 2009-10 also, similar trend was exhibited by T_2 (1.205), T_7 (1.160) and T_5 (1.109). However, the lowest LAI was registered by T_4 (0.993) and T_8 (1.009).

In pooled values also, the treatments T_2, T_7 and T_5 exhibited similar trend recording 1.153, 1.102 and 1.062 of LAI respectively. T_2 was significantly superior over rest of the treatments and it was on par with T_7 and T_5. The remaining treatments were on par with each other. The treatments, T_8 (0.969) and T_4 (0.971) recorded lower LAI.

4.2.1.6 Number of branches $plant^{-1}$

The results in respect of the effect of the treatments on branch number $plant^{-1}$ are furnished in table-38. It was observed that integrated nutrient management had exerted significant influence on number of branches $plant^{-1}$ among treatments. The rate of increase of branches was rapid up to 50 DAS and thereafter the increase was marginal from 50 DAS-75 DAS.

Table 37: Effect of Integrated nutrient management on leaf area index in fenugreek

Treatments	Leaf area index		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	0.920	1.039	0.979
T_2 : 100%RDF+R+PSB	1.102	1.205	1.153
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.982	1.065	1.023
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.950	0.993	0.971
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	1.015	1.109	1.062
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	0.940	1.011	0.975
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	1.045	1.160	1.102
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	0.930	1.009	0.969
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	0.983	1.066	1.024
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	0.950	1.032	0.991
Mean	0.981	1.068	1.025
SEm±	0.033	0.037	0.035
CD (P=0.05)	0.098	0.109	0.104

Table 38: Effect of integrated nutrient management on number of branches plant-1 at various stages of growth in fenugreek

Treatments	Number of branches plant^{-1}					
	50DAS			75DAS		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	5.76	6.06	5.91	6.76	7.06	6.91
T_2 : 100%RDF+R+PSB	6.48	6.33	6.40	7.56	7.00	7.28
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	4.60	6.00	5.30	6.50	6.60	6.55
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	5.11	5.32	5.21	6.60	6.90	6.75
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	6.95	6.50	6.73	7.23	7.53	7.38
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	4.91	5.12	5.01	6.20	6.50	6.35
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	6.60	6.33	6.47	7.33	7.63	7.48
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	4.53	5.83	5.18	6.20	6.50	6.35
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	5.30	5.42	5.36	6.00	7.00	6.50
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	5.06	5.18	5.12	6.23	6.53	6.38
Mean	5.53	5.81	5.67	6.66	6.92	6.79
SEm±	0.16	0.13	0.15	0.16	0.14	0.15
CD (P=0.05)	0.48	0.40	0.43	0.47	0.42	0.43

During 2008-09 and 2009-10 at 50 DAS, greater number of branches $plant^{-1}$ were registered by T_5: 75 % RDF + VC + *Rhizobium* + PSB (6.95, 6.50) as compared to other treatments and the treatments, T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_2: 100 % RDF + *Rhizobium* + PSB were on par with the T_5. The lowest number of branches were recorded in T_8 (4.53) and T_6 (5.12) during 2008-09 and 2009-10 respectively.

In pooled figures also, the above treatments, T_5, T_7 and T_2 significantly recorded higher values and followed similar trend over other treatments. Further, the treatment, T_1 reported significantly higher number of branches over T_3, T_4, T_6, T_8, T_9 and T_{10}. The lowest number of branches was noticed in T_6 (5.01) followed by T_{10} (5.12).

The data revealed that during 2008-09 significantly higher number of branches $plant^{-1}$ at 75 DAS were recorded by T_2: 100 % RDF + *Rhizobium* + PSB (7.56) as compared to other treatments and it was on par with T_7 : 75 % RDF + PM + *Rhizobium* + PSB and T_5 : 75 % RDF + VC + *Rhizobium* + PSB. Significantly lowest number of branches was reported in T_9 (6.00) and it was on par with T_{10}, T_8 and T_6.

Similarly during 2009-10, treatments; T_7 (7.63) and T_5 (7.53) recorded significantly higher values over other treatments.

However, in pooled over data significantly higher number of branches $plant^{-1}$ was recorded by T_7: 75 % RDF + PM + *Rhizobium* + PSB (7.48) followed by T_5: 75 % RDF + VC + *Rhizobium* + PSB (7.38) and T_2: 100 % RDF + *Rhizobium* + PSB (7.28) which were on par with T_7. The lowest number of branches was observed in case of T_8 (6.35) and T_6 (6.35) followed by T_{10} (6.38).

4.2.1.7 Dry matter production $plant^{-1}$

Table 39: Effect of Integrated nutrient management on dry matter production plant^{-1} in fenugreek

Treatments	Dry matter (g) plant^{-1}											
	25DAS			50DAS			75DAS			at harvest		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	0.46	0.51	0.48	3.64	3.71	3.67	8.96	7.82	8.39	12.00	12.55	12.27
T_2 : 100%RDF+R+PSB	0.46	0.51	0.48	3.66	3.59	3.62	9.36	9.86	9.61	14.93	15.63	15.28
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.36	0.41	0.38	2.96	3.50	3.23	7.66	8.16	7.91	12.45	13.15	12.80
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.35	0.40	0.37	2.67	2.87	2.77	7.19	7.69	7.44	11.69	12.39	12.04
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	0.40	0.45	0.42	3.55	3.65	3.60	9.58	9.84	9.71	14.11	14.48	14.29
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	0.38	0.36	0.37	3.05	3.96	3.50	8.02	7.82	7.92	14.05	13.85	13.95
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	0.40	0.38	0.39	3.57	3.47	3.52	9.17	9.00	9.09	14.41	14.21	14.31
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	0.42	0.40	0.41	3.29	3.20	3.24	8.07	7.90	8.00	13.12	12.91	13.01
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	0.40	0.38	0.39	3.42	3.32	3.37	8.35	8.19	8.27	13.38	13.18	13.28
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	0.35	0.33	0.34	2.76	3.00	2.88	7.23	7.03	7.13	11.63	10.62	11.12
Mean	0.39	0.41	0.40	3.25	3.42	3.34	8.35	8.33	8.34	13.17	13.29	13.23
SEm±	0.03	0.03	0.03	0.16	0.26	0.19	0.44	0.46	0.44	0.57	0.59	0.58
CD (P=0.05)	NS	0.10	0.10	0.48	NS	0.57	1.3	1.37	1.28	1.68	1.75	1.68

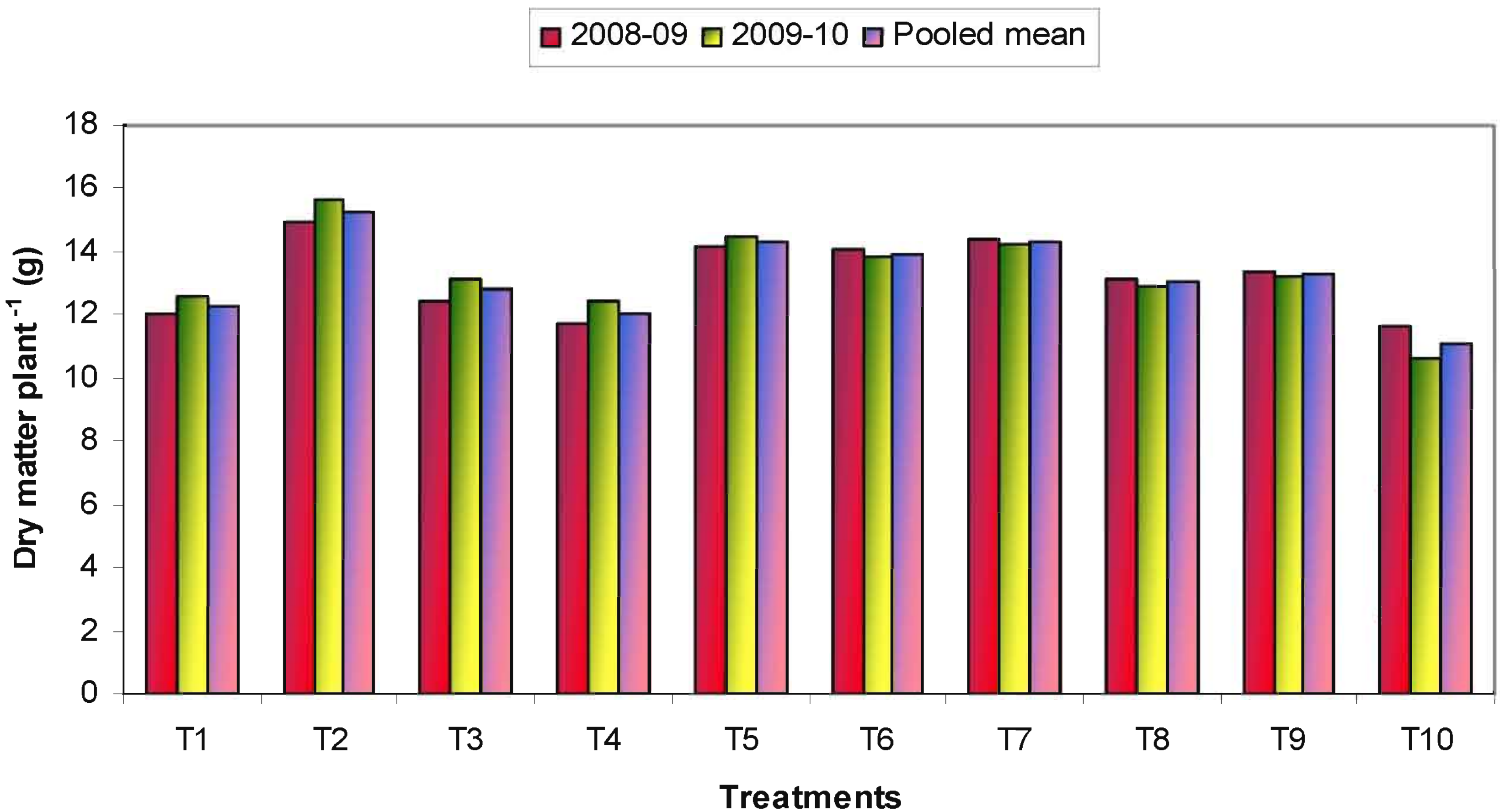


Fig.10: Effect of integrated nutrient management on dry matter production plant^{-1} at harvest stage in fenugreek

Data pertaining to dry matter production plant^{-1} as influenced by various treatments are furnished in tables-39. It was found that dry matter production plant^{-1} was influenced by integrated nutrient management treatments at different stages of crop growth. It was noticed that the dry matter content increased with age of the crop registering the highest values at harvest. The rate of dry matter accumulation was slow upto 50 DAS and thereafter, it increased markedly.

During 2008-09 at 25DAS, no significant differences could be observed among the treatments in respect of dry matter production. During 2009-10 on the other hand significantly higher values for dry matter accumulation were noticed by T_2: 100 % RDF + *Rhizobium* + PSB (0.51 g), T_1: 100 % RDF (0.51 g) and were on par with T_5: 75 % RDF + VC + *Rhizobium* + PSB and T_3: 75 % RDF + FYM + *Rhizobium* + PSB. The treatments *viz.*, T_{10}, T_6, T_7, T_9, T_8, T_4 recorded significantly lower values for dry matter production when compared to control (T_1) and T_2.

In pooled values, it could be observed that T_1 (control) (0.48 g) and T_2 (0.48 g) recorded significantly higher values as compared to T_4, T_6 and T_{10} but T_1 and T_2 were on par with T_3, T_5, T_7, T_8, and T_9. The lowest values were recorded in T_{10}, T_4 and T_6.

During 2008-09 at 50 DAS, the dry matter production was significantly higher in T_2, T_1, T_7 and T_5 when compared to rest of the treatments and these treatments were at par with T_9 and T_8. The lowest dry matter production was reported in T_4 and it was on par with T_{10}, $T_3$and T_6. However, during 2009-10 the results were non significant.

It was observed from pooled data that differences among treatments in dry matter content were significant. The treatments *viz.*, T_1, T_2, T_5, T_7, T_6 were significantly superior over T_4 and T_{10}. Further T_9, T_8 and T_3 were on par with T_1, T_2, T_5, T_7 and T_6.

During 2008-09 at 75 DAS higher dry matter content plant^{-1} was obtained in treatment, T_5:75 % RDF +VC+ *Rhizobium* + PSB (9.58 g plant^{-1}) and the treatments *viz*., T_2, T_7, T_1 and T_9 were on par with T_5 in respect of dry matter production. Lowest values were recorded by T_4 and $T_{10.}$

During 2009-10, significantly higher dry matter production was recorded by T_2: 100 % RDF + *Rhizobium* +PSB (9.86g) and T_5: 75 % RDF + VC + *Rhizobium* + PSB (9.84 g) over other treatments and were on par with T_7.

It was evident from pooled data that the crop which received T_5: 75 % RDF + VC + *Rhizobium* + PSB (9.71 g) was significantly superior over other treatments. The treatments, T_2 and T_7 were on par with T_5. Further, it was found that dry matter production was lower in the crop that received T_{10}: 50 % RDF + NC + *Rhizobium* + PSB. The crop that received T5: 100 % RDF +VC + *Rhizobium* + PSB recorded 13.6 % increase over control (T_1).

The results pertaining to dry matter production are presented in Table-39. At harvest stage the values for dry matter production recorded significant difference and during 2008-09, the treatment T_2 (14.93 g) was found to be superior and it was on par with the treatments *viz*., T_7, T_5, T_6, T_9. The lower value for dry matter production was observed in T_{10} followed by T_4.

During 2009-10, highest dry matter production was reported in T_2: 100 % RDF + *Rhizobium* + PSB followed by T_5: 75 % RDF + VC + *Rhizobium* + PSB and T_7: 75 % RDF + PM + *Rhizobium* + PSB which were on par with T_2. The lowest dry matter production was registered by T_{10}.

In pooled data, it was observed that T_2 was significantly superior over other treatments recording 15.28 g of dry matter plant^{-1}. However, it was on par with T_7, T_5 and T_6. The lowest dry matter production was observed in T_{10} followed by T_4.

Further, it was observed that T_2 recorded 19.7 % increase in dry matter production over control (T_1).

4.2.1.8 Crop growth rate for dry matter production

Data relating to CGR for dry matter production are presented in table-40. The crop growth rate, an indicator for dry matter production per unit time increased with age of crop recording a maximum between 50-75 DAS. However, no significant differences in CGR for dry matter production at 25-50 DAS and 50-75 DAS among various treatments were observed during both the years of study.

4.2.2 Yield and yield attributing parameters

4.2.2.1 Days to 50 % flowering

Results pertaining to days to 50 % flowering are presented in table-41. It was observed that significant differences in days to 50 % flowering among treatments were noticed due to integrated use of organic manures, inorganic fertilizers and biofertilizers. However, during 2008-09 the differences among the treatments did not attain significance.

On the other hand during 2009-10, significantly early flowering with lowest number of days was noticed in T_8: 50 % RDF + PM + *Rhizobium* + PSB (37.16 days) and treatments *viz*., T_1, T_2, T_7 were also on par with T_8 tending to record early flowering. Flowering was significantly delayed in T_3: 75 % RDF + FYM + *Rhizobium* + PSB when compared with rest of the treatments except T_6, T_9 and T_{10}.

It was also observed from pooled data that significantly early flowering was noticed in T_2: 100 % RDF + *Rhizobium* + PSB (37.41 days) and it was on par with rest of the treatments except T_6, T_3 and T_9 in which flowering was delayed.

4.2.2.2 Number of pods plant^{-1}

Table 40: Effect of integrated nutrient management on Crop Growth Rate for dry matter at different growth stages in fenugreek

Treatments	CGR AT 25-50 DAS (g m^{-2} day^{-1})			CGR AT 50-75 DAS (g m^{-2} day^{-1})		
	2008-09	2009-10	Pooled mean	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	4.236	4.258	4.247	7.098	5.489	6.293
T_2 : 100%RDF+R+PSB	4.267	4.102	4.184	7.600	8.364	7.982
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	3.471	4.111	3.791	6.258	6.218	6.238
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	3.542	3.298	3.420	5.587	6.431	6.009
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	4.196	4.262	4.229	8.036	8.258	8.147
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	3.556	3.471 -	3.513	6.627	6.471	6.549
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	4.227	4.120	4.173	7.4 67	7.364	7.416
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	3.827	3.738	3.782	6.378	6.271	6.324
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	4.036	3.484	3.760	6.573	6.929	6.751
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	3.218	3.556	3.387	5.9 60	5.382	5.671
Mean	3.857	3.840	3.848	6.758	6.710	6.740
Sem±	0.267	0.292	0.280	0.667	0.840	0.725
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 41: Effect of integrated nutrient management on days taken to 50% flowering in fenugreek

Treatments	Days to 50%flowering		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	37.10	37.93	37.51
T_2 : 100%RDF+R+PSB	37.58	37.25	37.41
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	38.25	41.83	40.04
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	39.16	39.50	39.33
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	38.33	39.50	38.91
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	40.50	41.00	40.75
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	38.25	37.41	37.83
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	40.16	37.16	38.66
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	39.41	40.58	39.99
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	39.25	39.91	39.58
Mean	38.80	39.20	39.00
SEm±	0.78	0.77	0.78
CD (P=0.05)	NS	2.26	2.22

Table 42: Effect of integrated nutrient management on number of pods plant^{-1} in fenugreek

Treatments	Pods plant^{-1}		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	38.00	38.50	38.25
T_2 : 100%RDF+R+PSB	42.91	41.91	42.41
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	38.16	38.83	38.49
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	37.83	36.83	37.33
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	40.50	43.00	41.75
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	37.50	36.50	37.00
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	42.50	44.50	43.50
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	34.50	34.50	34.50
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	37.91	38.91	38.41
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	37.60	35.43	36.51
Mean	38.74	38.89	38.81
SEm±	1.46	1.30	1.38
CD (P=0.05)	4.30	3.81	3.96

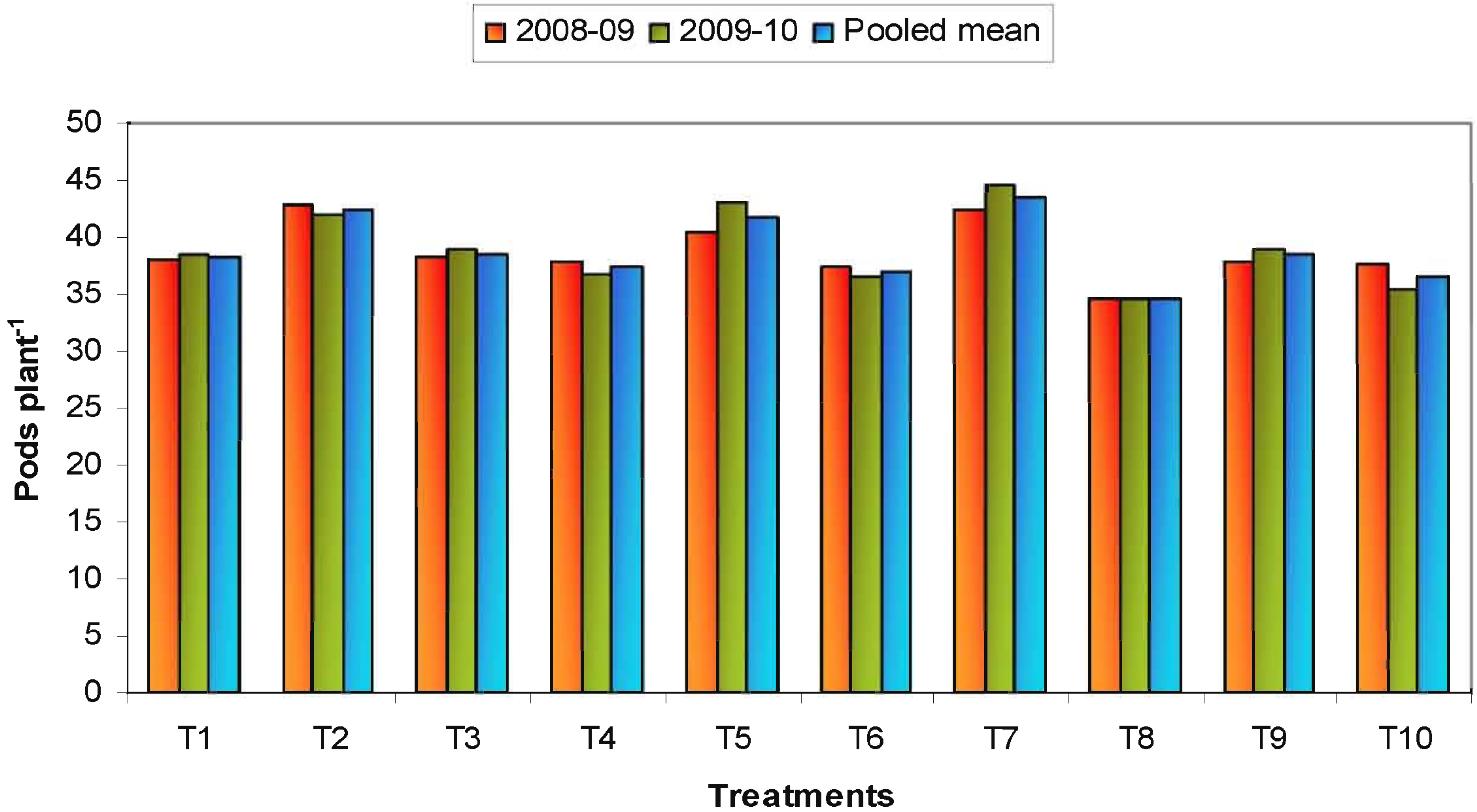
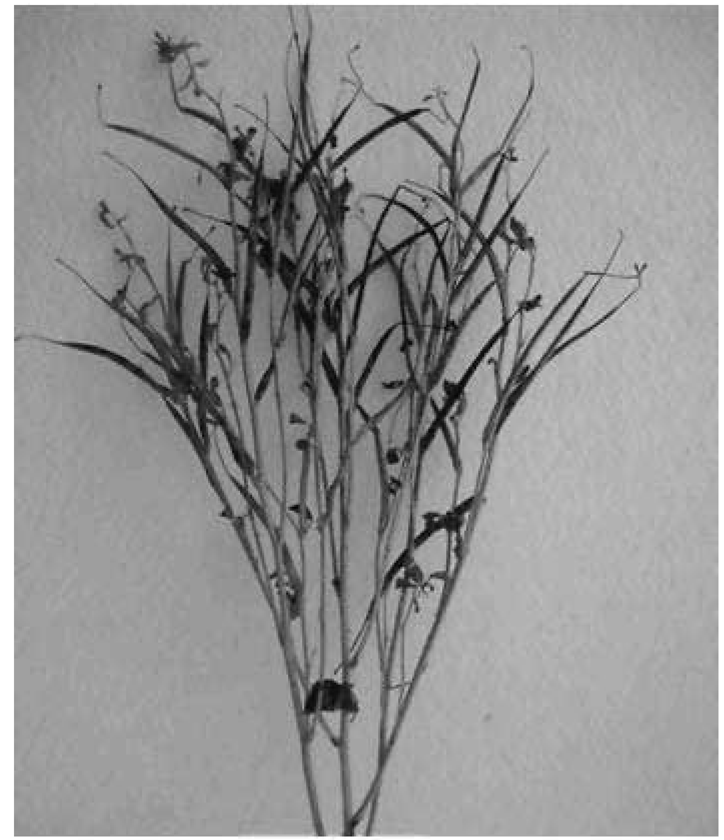


Fig.11: Effect of integrated nutrient management on number of pods plant^{-1} in fenugreek

T_7 (75 % RDF + PM + R + PSB)



T_8 (50 % RDF + PM + R + PSB)

Plate : 5 : Variation in pod number in fenugreek as influenced by INM treatments

Data relating to number of pods plant^{-1} are furnished in table-42. In general it was observed from the data that significant differences were observed with respect to number of pods plant^{-1} due to INM treatments. In the first season crop, number of pods plant^{-1} was found to be significantly higher in T_2: 100 % RDF + *Rhizobium* + PSB (42.91 pods) and treatments, T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_5: 75 % RDF + VC + *Rhizobium* + PSB were on par with T_2. Further, among other treatments *viz*., T_3, T_1, T_4, T_6, T_8, T_9, and T_{10} no significant difference was observed. Lowest pod number was recorded by T_8 (34.50 pods).

In the second season crop, the results revealed that T_7 was significantly superior and produced highest pod number as compared to other treatments and it was on par with T_5 and T_2.The lowest pods were recorded in T_8 while it was on par with T_4, T_6 and T_{10}.

It was evident from pooled data that pod number was highest in the crop that received T_7: 75 % RDF + PM + *Rhizobium* + PSB while it was lowest in the crop that received T_8: 50 % RDF + PM + *Rhizobium* + PSB. T_7 was significantly superior over other treatments with 43.5 pods plant^{-1} and it was on par with T_2 and T_5. Further, it was observed that the treatment that received 75 % RDF + PM + *Rhizobium* + PSB: T_7 recorded 12 % increase in pod number over control (T_1).

4.2.2.3 Pod length

Results on the effect of various INM treatments on pod length are presented in the table-43. It was observed from the data that pod length was significantly influenced due to the various INM treatments. In both the seasons , T_5: 75 % RDF + VC + *Rhizobium* + PSB recorded significantly higher pod length followed by T_2 and T_7 in 2008-09 and T_7 and T_2 in 2009-10 and the treatments *viz*., T_2 and T_7 were on

Table 43: Effect of Integrated nutrient management on pod length in fenugreek

Treatments	Pod length (cm)		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	8.33	8.63	8.48
T_2 : 100%RDF+R+PSB	11.5	10.93	11.21
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	9.18	9.48	9.33
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	10.08	9.98	10.03
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	12.00	12.03	12.02
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	9.00	8.90	8.95
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	11.33	11.63	11.48
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	9.33	9.23	9.28
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	8.50	8.80	8.65
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	9.30	9.20	9.25
Mean	9.85	9.88	9.86
SEm±	0.47	0.46	0.47
CD (P=0.05)	1.40	1.35	1.34

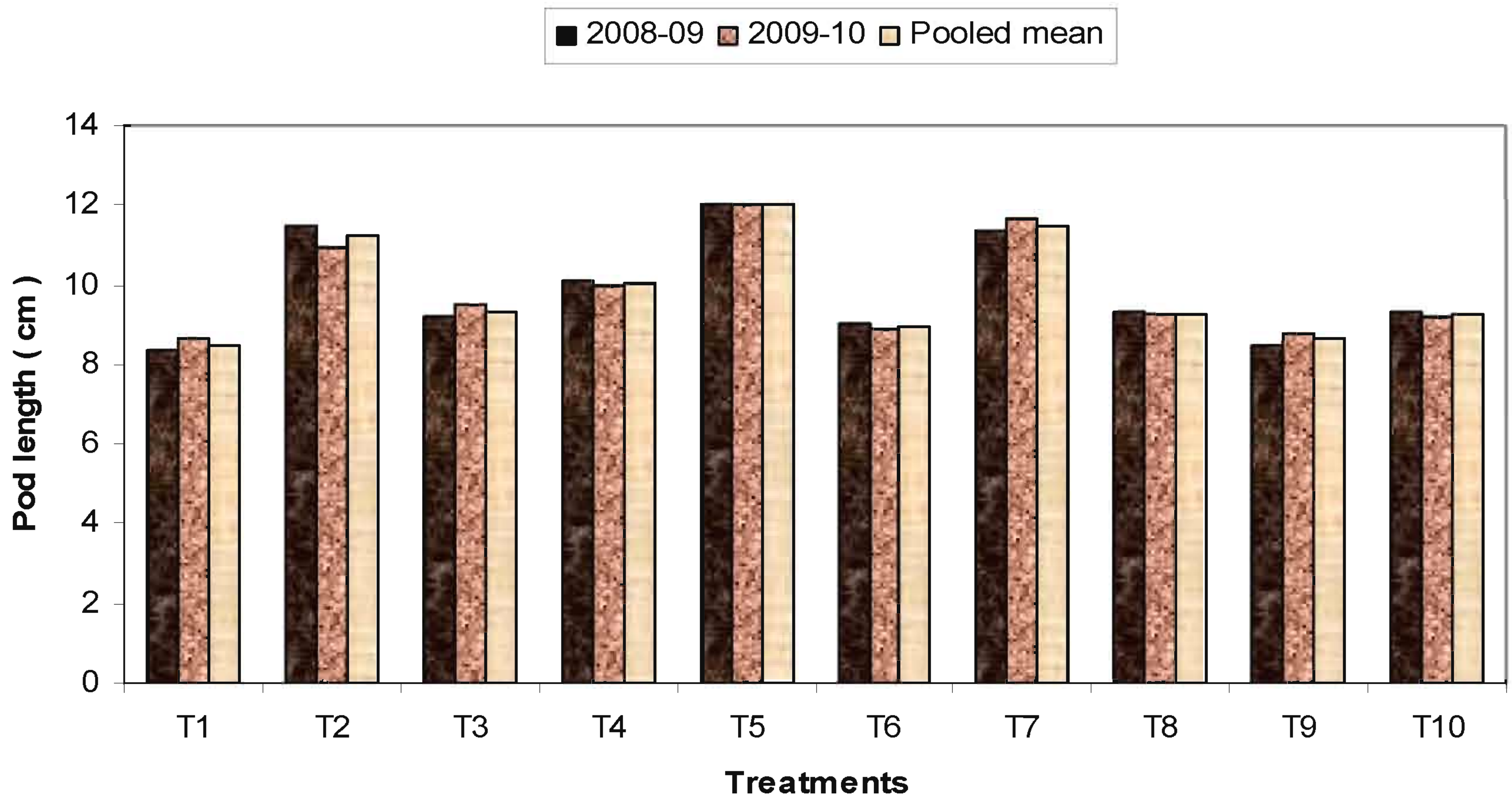


Fig.12: Effect of Integrated nutrient management on pod length in fenugreek

par with T_5. The lowest pod length was recorded by T_1 (control).

It is clear from the pooled data that the treatment, T_5 significantly recorded higher pod length and it was on par with T_7 and T_2. It was also observed that the T_4 recorded significantly higher pod length compared to T_1 and T_9 and it was on par with T_3, T_6, T_8 and T_{10}. The lowest pod length was observed in T_1 followed by T_9. Further it was inferred that the crop that received 75 % RDF + VC + *Rhizobium* + PSB (T_5) recorded 29.3 % increase in pod length over control (T_1).

4.2.2.4 Number of seeds pod^{-1}

The data in respect of number of seeds pod^{-1} (table-44) revealed significant differences among the various INM treatments. It could be observed that in both the seasons, the number of seeds pod^{-1} were found to be significantly higher in treatment T_2: 100 % RDF + *Rhizobium* + PSB (12.50, 12.16 seeds pod^{-1}) as compared to other treatments and it was on par with T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_5: 75 % RDF +VC+ *Rhizobium* + PSB. The lowest number of seeds pod^{-1} was observed in T_8.

It is evident from the pooled data that the number of seeds pod^{-1} ranged from 9.38 to 12.33. Significantly higher number of seeds pod^{-1} was observed in T_2 as compared to other treatments and it was on par with T_7 and T_5. The rest of the treatments were on par with each other and the lowest number of seeds pod^{-1} was observed in T_8 followed by T_{10}. Further it was observed that T_2, T_7 and T_5 recorded 18.9 %, 17.2 % and 15.25 % increase in seeds over control (T_1) respectively.

4.2.2.5 Grain filling percentage

It was observed from the data (table-45) that the differences in grain filling

Table 44: Effect of Integrated nutrient management on number of seeds pod^{-1} in fenugreek

Treatments	Number of seeds pod^{-1}		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	10.33	9.66	10.00
T_2 : 100%RDF+R+PSB	12.50	12.16	12.33
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	10.33	10.23	10.28
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	9.80	9.66	9.73
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	11.78	11.83	11.80
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	10.25	10.18	10.21
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	12.16	12.00	12.08
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	9.20	9.03	9.11
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	9.51	9.85	9.68
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	9.50	9.26	9.38
Mean	10.53	10.38	10.46
SEm±	0.66	0.55	0.61
CD (P=0.05)	2.00	1.61	1.74

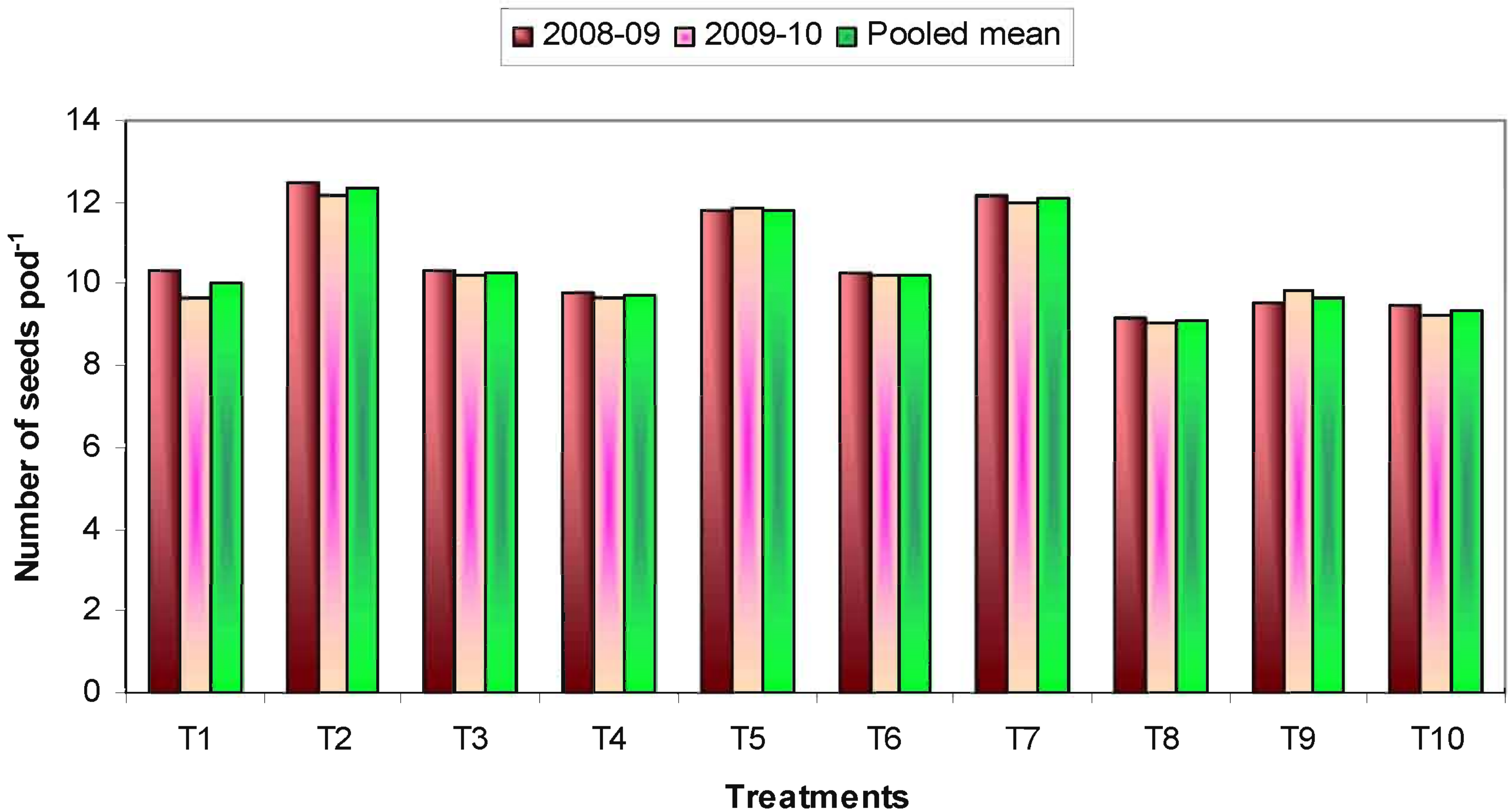


Fig.13: Effect of Integrated nutrient management on number of seeds pod^{-1} in fenugreek

Table 45: Effect of Integrated nutrient management on grain filling percentage in fenugreek

Treatments	Grain filling (%)		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	90.75	91.08	90.91
T_2 : 100%RDF+R+PSB	92.83	93.16	93.00
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	90.16	93.83	91.99
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	87.50	87.83	87.66
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	92.50	92.83	92.66
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	89.83	90.16	90.00
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	92.78	93.11	92.94
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	87.33	87.66	87.49
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	90.83	91.16	91.00
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	87.00	87.33	87.16
Mean	90.15	90.81	90.48
SEm±	1.70	1.90	1.70
CD (P=0.05)	NS	NS	NS

were not found to be significant due to INM treatments. However, during 2008-09, a tendency for the highest grain filling was observed in T_2: 100 % RDF + R + PSB while it was lowest in T_{10}: 50 % RDF + NC + *Rhizobium* + PSB. Similarly during 2009-10, T_3 recorded highest grain filling percentage.

In pooled data also, a tendency for highest grain filling was observed in T_2: 100 % RDF + *Rhizobium* + PSB. However, various INM treatments could not exert any significant influence on grain filling.

4.2.2.6 Grain shelling percentage

Results in respect of the effect of the treatments on grain shelling are furnished in table-46. It was observed from the data that significant difference was noticed in grain shelling among treatments. During 2008-09, T_2: 100 % RDF + *Rhizobium* + PSB (42.16 %) and T_7: 75 % RDF + PM + *Rhizobium* + PSB (41.83 %) recorded significantly higher values for grain shelling % as compared to other treatments while it was highest in T_7: 75 % RDF + PM + *Rhizobium* + PSB during 2009-10. It was closely followed by treatments *viz*., T_5, T_2, T_9, T_3, T_1.

In pooled data, it was observed that T_7: 75 % RDF + PM + *Rhizobium* + PSB (42.58 %) registered higher shelling % over other treatments and it was on par withT_2: 100 % RDF + *Rhizobium* + PSB. The lowest shelling % was observed in T_8 and T_6 treatments. Further, it was observed that T_7 and T_2 recorded 7.44 % and 5.40 % increased over control (T_1) respectively.

4.2.2.7 Test weight

Results on the effect of INM treatments on test weight are furnished in table-47. The results revealed that T_5: 75 % RDF + VC + *Rhizobium* + PSB recorded significantly higher values for test weight as compared to other treatments during both

Table 46: Effect of Integrated nutrient management on grain shelling percentage in fenugreek

Treatments	Grain shelling (%)		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	38.66	40.16	39.41
T_2 : 100%RDF+R+PSB	42.16	41.16	41.66
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	38.83	40.33	39.58
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	39.83	38.83	39.33
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	39.83	41.33	40.58
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	37.83	36.83	37.33
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	41.83	43.33	42.58
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	37.78	36.78	37.28
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	39.28	40.78	40.03
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	37.95	36.95	37.45
Mean	39.40	39.64	39.52
SEm±	0.66	0.66	0.66
CD (P=0.05)	1.93	1.93	1.88

Table 47: Effect of Integrated nutrient management on Test weight in fenugreek

Treatments	Test weight (g)		
	2008-09	**2009-10**	**Pooled mean**
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	10.66	10.40	10.53
T_2 : 100%RDF+R+PSB	11.75	11.65	11.70
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	10.41	10.51	10.46
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	9.33	9.24	9.28
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	12.83	12.93	12.88
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	10.46	10.36	10.41
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	12.41	12.45	12.43
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	9.30	9.26	9.28
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	10.25	10.28	10.26
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	9.25	9.23	9.24
Mean	10.66	10.63	10.64
SEm±	0.42	0.44	0.43
CD (P=0.05)	1.24	1.29	1.67

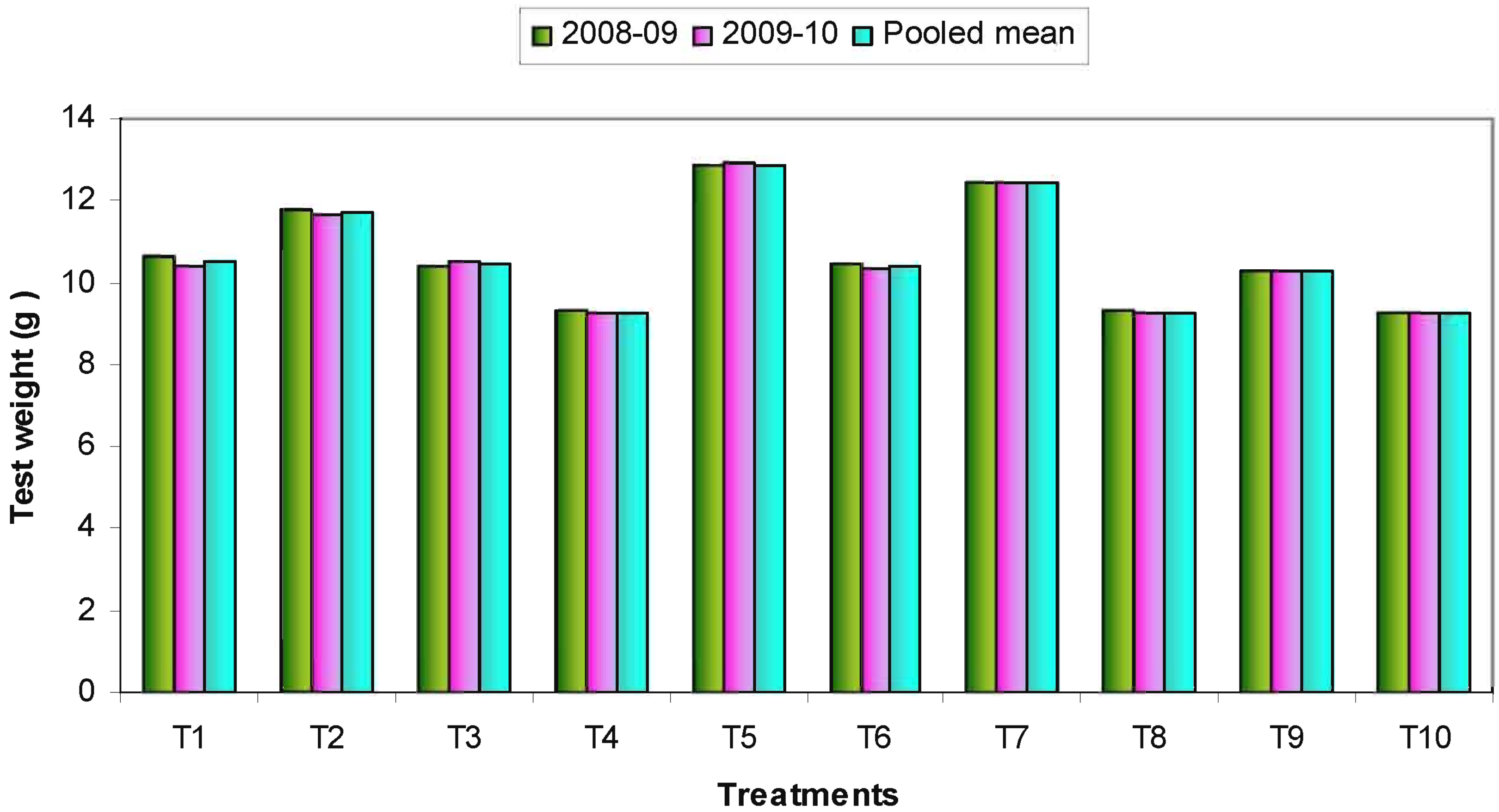


Fig.14: Effect of Integrated nutrient management on Test weight in fenugreek

the seasons under study and it was on par with T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_2.

Similarly in pooled data also, it was noticed that the above three treatments; T_5, T_7 and T_2 registered higher values of 12.88 g, 12.43 g and 11.70 g respectively. Further it was found that the treatments; T_1, T_3, T_6 and T_9 were on par with each other. The lowest test weight was observed in T_{10} followed by T_8 and T_4 treatments. Further, it was observed that T_5 recorded 18.20 % increase in test weight over control (T_1).

4.2.2.8 Seed yield plant^{-1}

The results in respect of seed yield plant^{-1} as influenced by INM treatments are furnished in table-48. It was observed from the data that significant differences in seed yield plant^{-1} among various INM treatments could be noticed during both the years of study. In both the years, consecutively the highest seed yield plant^{-1} was recorded in T_5: 75 % RDF + VC + *Rhizobium* + PSB as compared to rest of the treatments and the treatments, T_2 and T_7 were on par with T_5. The lower values for seed yield plant^{-1} were recorded in T_{10}.

In pooled data, seed yield plant^{-1} was observed to be higher and lower in the crop which received T5: 75 % RDF + VC + *Rhizobium* + PSB (4.13 g) and T_{10}: 50 % RDF + NC + R + PSB (2.73 g) respectively. Significantly higher seed yield plant^{-1} was recorded by T_5: 75 % RDF + VC + *Rhizobium* + PSB (4.13 g) as compared to other treatments and it was on par with T_2: 100 % RDF + R + PSB (4.11 g) and T_7: 75 % RDF + PM + *Rhizobium* + PSB (4.05 g). The treatment, T_6: 50 % RDF + VC + *Rhizobium* + PSB (3.32 g) recorded significantly higher seed yield plant^{-1} over T_{10}: 50 % RDF + NC + *Rhizobium* + PSB and it was on par with T_1, T_8, T_3, T_9 and T_4. Further it was observed that T_5, T_2 and T_7 recorded 19.85 %, 19.26 % and 18.27 % increase in seed yield plant^{-1} respectively over control (T_1).

4.2.2.9 Seed yield ha^{-1}

The effect of various INM treatments on grain yield is furnished in table-49. A perusal of data revealed that different organic manures, inorganic fertilizers and biofertilizers in INM combinations significantly influenced the grain yield in fenugreek during both the years of study. During 2008-09, T_2: 100 % RDF + *Rhizobium* + PSB recorded significantly highest grain yield (12.50 q ha^{-1}) compared to other treatments and it was at par with T_5: 75 % RDF + VC + *Rhizobium* + PSB (11.75q ha^{-1}), T_1: 100 % RDF (11.00 q ha^{-1}) and T_7: 75 % RDF + PM + *Rhizobium* + PSB (10.83 q ha^{-1}). The lowest values for grain yield were recorded by the treatments, T_{10}, T_6 and T_4. Further the treatments, T_3, T_8, T_9, T_4, T_6 and T_{10} were on par with each other. T_2 and T_5 recorded 12.55 % and 6.38 % increase in grain yield ha^{-1} respectively over control (T_1). Further it was observed that though the treatment, T_7 was on par with T_2 and T_5 in respect of grain yield but it recorded 1.56 % decrease in yield over control (T_1).

During 2009-10, significantly highest grain yield of 12.41q ha^{-1} was obtained in T_2: 100 % RDF + *Rhizobium* + PSB and it was at par with T_5 (11.91q ha^{-1}) and T_7 (11.00q ha^{-1}). Further, it could also be observed that there was no significant difference among the treatments viz., T_3, T_1, T_9, T_8, T_4, T_{10} and T_6. The lowest grain yield was observed in T_6 (8.33 q ha^{-1}) and T_{10} (8.41 q ha^{-1}). Further, it was observed that T_2, T_5 and T_7 recorded 20.7 %, 17.4% and 10.6 % increase in grain yield respectively over control (T_1).

If pooled data for both the years are considered, it was observed that highest yield of 12.50 q ha^{-1} was recorded by T_2: 100 % RDF + R + PSB followed by T_5, T_7

Table 48: Effect of Integrated nutrient management on seed yield plant^{-1} in fenugreek

Treatments	Seed yield (g) plant^{-1}		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	3.36	3.26	3.31
T_2 : 100%RDF+R+PSB	4.05	4.16	4.11
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	3.00	3.16	3.08
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	2.83	2.95	2.89
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	4.10	4.16	4.13
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	3.26	3.38	3.32
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	4.00	4.10	4.05
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	3.05	3.18	3.12
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	2.88	3.00	2.94
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	2.68	2.78	2.73
Mean	3.32	3.41	3.37
SEm±	0.17	0.19	0.17
CD (P=0.05)	0.52	0.56	0.51

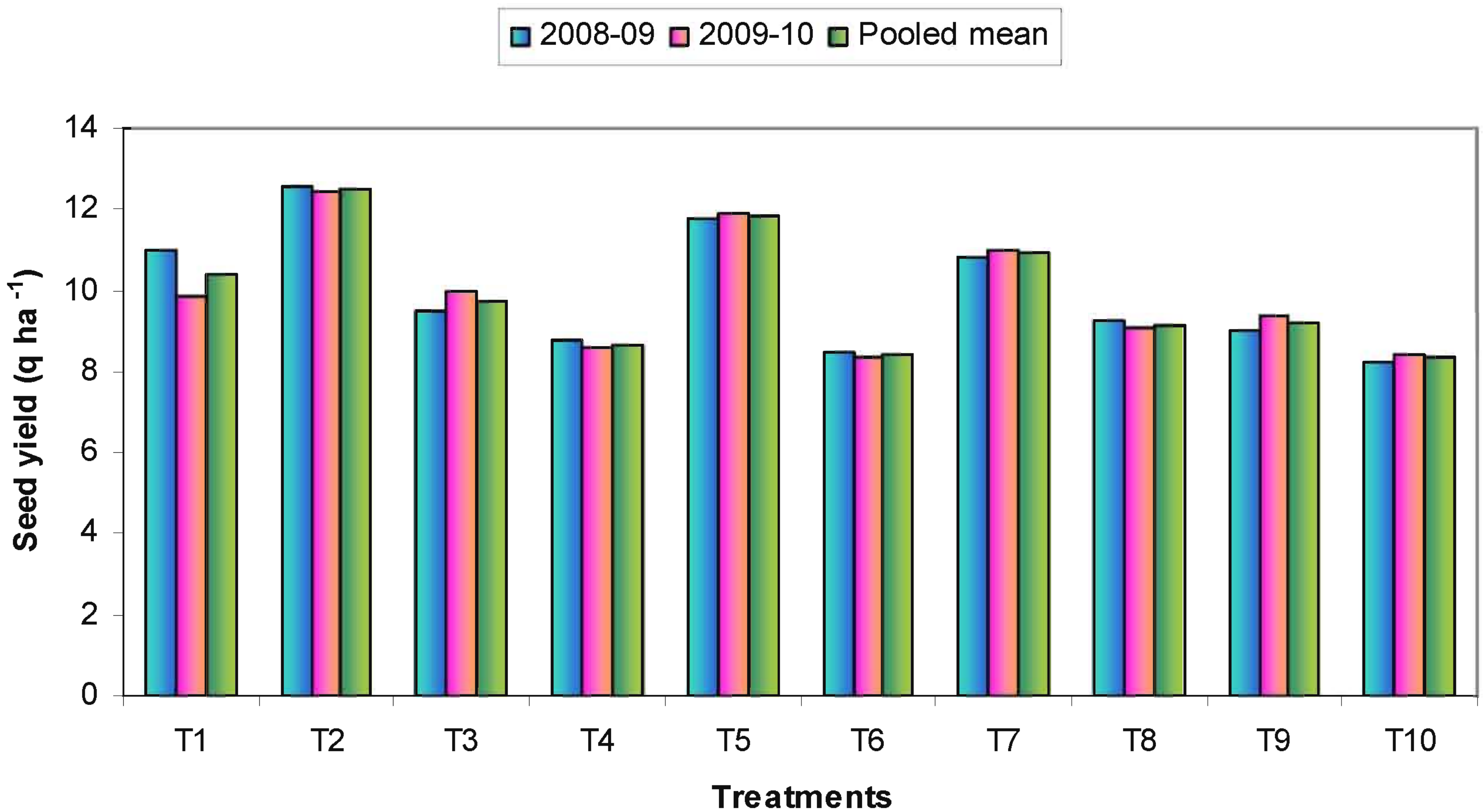


Fig.15: Effect of Integrated nutrient management on seed yield in fenugreek

Table 49: Effect of Integrated nutrient management on seed yield in fenugreek

Treatments	Seed yield (q ha^{-1})		
	2008-09	**2009-10**	**Pooled mean**
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	11.00	9.83	10.41
T_2 : 100%RDF+R+PSB	12.58	12.41	12.50
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	9.50	10.00	9.75
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	8.75	8.58	8.66
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	11.75	11.91	11.83
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	8.50	8.33	8.41
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	10.83	11.00	10.91
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	9.25	9.08	9.16
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	9.00	9.35	9.17
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	8.25	8.41	8.33
Mean	9.94	9.89	9.91
SEm±	0.83	0.69	0.82
CD (P=0.05)	2.46	2.04	2.36

and T_1 which were at par with T_2. The lowest yield of 8.33 q ha^{-1} was obtained in the crop receiving T_{10}: 50 % RDF + NC + *Rhizobium* + PSB (8.33 q ha^{-1}) followed by T_6 (8.41q ha^{-1}) and T_4 (8.66 q ha^{-1}). Further, it was observed that the treatments *viz*., T_3, T_8, T_9, T_4, T_6 and T_{10} were on par with each other. The treatments *viz*., T_2, T_5 and T_7 recorded 16.7%, 12.0 %, 4.5 % increase in grain yield respectively over control (T_1).

4.2.2.10 Biological yield

Data in respect of biological yield are furnished in table-50. The data revealed significant differences among the treatments in respect of biological yield. During 2008-09 the highest biological yield of 46.62 q ha^{-1} was obtained by T_2: 100 % RDF + *Rhizobium* + PSB followed by T_5 (43.51q ha^{-1}), T_1 (42.58 q ha^{-1}), T_7 (40.16 q ha^{-1}) and T_3 (37.31q ha^{-1}) which were on par with T_2. The lowest biological yield was recorded by T_{10} (31.61 q ha^{-1}) and T_6 (32.61 q ha^{-1}).

During 2009-10, T_7: 75 % RDF + PM + *Rhizobium* + PSB recorded higher biological yield (44.64 q ha^{-1}) as compared to other treatments. The treatments *viz*., T_2, T_5, T_6, T_3 were on par with T_7. The lowest biological yield was recorded in T_{10} (35.72 q ha^{-1}) and T_8 (35.85 q ha^{-1}).

In respect of pooled data it was observed that the plots receiving T_2: 100 % RDF + *Rhizobium* + PSB (45.06 q ha^{-1}) recorded highest yield followed by T_5 (43.26 q ha^{-1}) and T_2 was at par with other treatments *viz*., T_1, T_3, T_5 and T_7. The lowest biological yield was however recorded in T_{10} (33.66 q ha^{-1}) followed by T_4 (35.48 q ha^{-1}).

4.2.2.11 Straw yield

Results pertaining to the effect of INM treatments on straw yield are pertained in table-51. Application of organic manures, inorganic fertilizers and biofertilizers in an INM combination did not exert any influence on straw yield.

4.2.2.12 Harvest index

Data in respect of harvest index as influenced by INM treatments are presented in table-52. The data presented in table-52 revealed that during 2008-09, the treatments, T_7: 75 % RDF + PM + *Rhizobium* + PSB (27.08) and T_5: 75 % RDF + VC + *Rhizobium* + PSB (27.00) recorded significantly higher values for harvest index compared to other treatments and these treatments were at par with T_2, T_6, T_9 and T_{10}. Lowest values for harvest index were recorded by T_8 (25.33) and T_3 (25.35).

On the other hand, during 2009-10 highest values for harvest index were recorded by T_2 (27.96) followed by T_5 (27.5) while these were at par with T_1 and T_7.

In pooled data, it was observed that T_2, T_5, T_7, T_9 andT_1 were on par with each other and highest value for harvest index was noticed in T_2; 100 % RDF + *Rhizobium* + PSB (27.46) followed by T_5 (27.25). The lowest harvest index was recorded by T_8 (25.24) followed by T_3 (25.85).

4.2.3 Nutrient content in seed and straw

4.2.3.1 Nitrogen content in seed

Data pertaining to nitrogen % in seed as influenced by various INM treatments are presented in table-53. It is evident from data that during 2008-09, T_2 and T_7 recorded significantly higher nitrogen % (2.81 %) as compared to other treatments and these treatments were at par with T_3 (2.8 %) and T_5 (2.8 %). The lowest nitrogen content was recorded by T_{10} (2.38 %) followed by T_8 (2.45 %).

Table 50: Effect of Integrated nutrient management on biological yield in fenugreek

Treatments	Biological yield (q ha^{-1})		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	42.58	35.95	39.26
T_2 : 100%RDF+R+PSB	46.62	43.50	45.06
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	37.31	38.84	38.07
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	34.38	36.58	35.48
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	43.51	43.00	43.25
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	32.61	39.63	36.12
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	40.16	44.64	42.40
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	36.51	35.85	36.18
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	34.09	37.74	35.91
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	31.61	35.72	33.66
Mean	37.94	39.14	38.54
SEm±	3.26	2.19	2.78
CD (P=0.05)	9.58	6.43	7.95

Table 51: Effect of Integrated nutrient management on straw yield in fenugreek

Treatments	Straw yield (q ha^{-1})		
	2008-09	**2009-10**	**Pooled mean**
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	31.57	25.03	28.30
T_2 : 100%RDF+R+PSB	34.03	31.08	32.55
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	27.81	28.84	28.32
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	25.63	28.00	26.81
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	31.76	31.09	31.42
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	24.11	31.29	27.70
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	29.33	33.64	31.48
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	27.26	26.77	27.01
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	25.09	28.49	26.79
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	23.36	27.3	25.33
Mean	27.99	29.15	28.57
SEm±	2.44	2.33	2.26
CD (P=0.05)	NS	NS	NS

Table 52: Effect of Integrated nutrient management on harvest index in fenugreek

Treatments	Harvest index		
	2008-09	2009-10	Pooled mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	25.90	26.90	26.40
T_2 : 100%RDF+R+PSB	26.96	27.96	27.46
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	25.35	26.35	25.85
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	25.41	26.41	25.91
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	27.00	27.50	27.25
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	26.08	25.75	25.91
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	27.08	26.91	27.00
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	25.33	25.16	25.24
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	26.41	26.16	26.29
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	26.08	25.91	25.99
Mean	26.16	26.50	26.33
SEm±	0.38	0.43	0.41
CD (P=0.05)	1.12	1.27	1.17

Table 53: Effect of Integrated nutrient management on nitrogen, phosphorus and potassium content in seed of fenugreek

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	2.630	2.700	2.665	0.500	0.490	0.495	1.000	1.000	1.000
T_2 : 100%RDF+R+PSB	2.810	2.850	2.830	0.510	0.520	0.515	1.040	1.000	1.020
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	2.800	2.780	2.790	0.520	0.510	0.515	1.000	1.000	1.000
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	2.700	2.680	2.690	0.390	0.420	0.405	0.950	0.960	0.955
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	2.800	2.800	2.800	0.560	0.560	0.56	0.960	0.970	0.965
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	2.580	2.600	2.590	0.410	0.410	0.41	0.930	0.890	0.910
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	2.810	2.830	2.820	0.560	0.560	0.56	0.940	0.980	0.960
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	2.450	2.480	2.465	0.380	0.380	0.38	0.890	0.890	0.890
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	2.650	2.660	2.655	0.560	0.560	0.56	0.960	0.990	0.975
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	2.380	2.430	2.405	0.380	0.370	0.375	0.900	0.920	0.910
Mean	2.661	2.681	2.671	0.477	0.478	0.477	0.957	0.960	0.959
SEm±	0.032	0.030	0.030	0.021	0.020	0.020	0.007	0.012	0.010
CD (P=0.05)	0.095	0.100	0.104	0.062	0.060	0.052	0.020	0.036	0.028

During 2009-10, T_2 recorded significantly highest value for nitrogen content (2.85 %) over other treatments and it was at par with T_7 (2.83 %), T_5 (2.8 %) and T_3 (2.78 %). The lowest nitrogen content was recorded by T_{10} (2.43 %) and T_8 (2.48 %).

The nitrogen content in seed ranged from 2.405 % to 2.830 %. From pooled data it was noticed that the nitrogen % in seed ranged from 2.405 % to 2.830 %. T_2 recorded the highest nitrogen content in seed and was found to be superior over other treatments recording 2.83 % nitrogen in seed and it was at par with T_7 (2.82 %), T_5 (2.8 %) and T_3 (2.79 %). The lowest nitrogen content in seed was recorded by T_{10} (2.405 %) followed by T_8 (2.465 %).

4.2.3.2 Phosphorus content in seed

During both the years of study, it was evident from data (table-53) that the treatments *viz.*, T_5, T_7, T_9 recorded significantly higher Phosphorus content in seed (0.56 %) over other treatments.

It was observed from pooled data that phosphorus % in seed ranged from 0.38 % to 0.56 %. The treatments, T_5, T_7, and T_9 were on par with T_3 and T_2. The lowest value was recorded by T_{10} (0.375 %) followed by T_8 (0.380 %).

4.2.3.3 Potassium content in seed

Data pertaining to potassium % in seed are presented in table-53. It could be seen from data during 2008-09 that T_2 recorded significantly higher potassium in seed (1.04 %) as compared to rest of the treatments followed by T_3 and T_1 (1.00 %). The lowest value for potassium content in seed was recorded by T_8 (0.89 %).

During 2009-10 the treatments *viz.*, T_1, T_2, T_3 were found to be superior over rest of the treatments recording highest potassium values. These treatments were on par with T_9, T_7, and T_5. The lowest value was recorded by T_8 (0.890 %) and T_6 (0.890 %).

A consideration of pooled data revealed that potassium % in seed ranged from

Table 54: Effect of Integrated nutrient management on nitrogen, phosphorus and potassium content in straw of fenugreek

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	0.750	0.750	0.750	0.140	0.140	0.140	0.490	0.500	0.495
T_2 : 100%RDF+R+PSB	0.780	0.780	0.780	0.150	0.140	0.145	0.610	0.660	0.635
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.730	0.720	0.725	0.150	0.140	0.145	0.640	0.640	0.640
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.670	0.660	0.665	0.110	0.120	0.115	0.490	0.490	0.490
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	0.680	0.710	0.695	0.150	0.150	0.150	0.650	0.660	0.655
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	0.670	0.680	0.675	0.120	0.120	0.120	0.460	0.490	0.475
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	0.710	0.740	0.725	0.140	0.140	0.140	0.660	0.667	0.663
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	0.630	0.610	0.620	0.120	0.120	0.120	0.470	0.470	0.470
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	0.710	0.710	0.710	0.140	0.140	0.140	0.690	0.700	0.695
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	0.620	0.590	0.605	0.120	0.120	0.120	0.500	0.500	0.500
Mean	0.695	0.695	0.695	0.134	0.133	0.133	0.566	0.577	0.572
SEm±	0.020	0.017	0.020	0.004	0.004	0.003	0.011	0.011	0.011
CD (P=0.05)	0.060	0.050	0.052	0.010	0.011	0.010	0.035	0.033	0.034

0.91 % to 1.02 %. T_2 recorded significantly higher potassium % in seed (1.02 %) as compared to other treatments and it was at par with T_3 and T_1. The lowest potassium % in seed was recorded by T_8 (0.890 %) followed by T_{10} (0.910 %) and T_6 (0.910 %).

4.2.3.4 Nitrogen content in straw

Data relating to nitrogen content in the straw is reported in table-54. During 2008-09, T_2 recorded the highest nitrogen content and was found to be superior over rest of the treatments recording 0.78 % nitrogen and it was at par with T_1 (0.75 %) and T_3 (0.73 %). The lowest nitrogen value was recorded in T_{10} (0.62 %) followed by T_8 (0.630 %).

A similar trend was noticed in 2009-10 also and highest nitrogen % in straw was recorded in T_2 (0.78 %) and it was at par with the treatments, T_1 (0.75 %) and T_7 (0.74 %). The lowest value was recorded in T_{10} (0.59%).

It was observed from the pooled data that T_2 was found to be superior over other treatments recording the highest nitrogen content in straw (0.780 %) and it was at par with T_1 (0.750 %). The treatments, T_7 (0.725 %) and T_3 (0.725 %) were on par with T_9 (0.71 %) and T_6 (0.675 %). The lowest value was recorded by T_{10} (0.605 %) followed by T_8 (0.620 %).

4.2.3.5 Phosphorus content in straw

It was observed from the data (table-54) that during 2008-09 the treatments *viz*., T_5, T_3, T_2 were significantly superior over rest of the treatments recording 0.150 % phosphorous in straw and it was at par with T_1, T_7, and T_9 (0.140 %).

During 2009-10 and also in case of pooled values, highest phosphorous content in straw (0.150 %) was recorded by T_5 and it was at par with T_1, T_2, T_3, T_7, and T_9. However, the lowest values of phosphorous were recorded in T_4 (0.115 %).

4.2.3.6 Potassium content in straw

It was observed from the data (table-54) that T_9 recorded highest values and was found to be superior over rest of the treatments recording 0.69 % and 0.70 % potassium in straw during 2008-09 and 2009-10 respectively and it was on par with T_7. The lowest potassium % was recorded in T_6 (0.46 %) and T_8 (0.47 %) during 2008-09 and 2009-10 respectively.

From the pooled data it was observed that the potassium in straw ranged from 0.470 % to 0.695 % and it was significantly highest in T_9 (0.695 %) as compared to rest of the treatments and it was on par with T_7 (0.660 %). Similarly, no significant difference was observed among treatments, T_7, T_2, T_3 and T_5. The lowest potassium content in straw was observed in T_8 (0.470 %) and T_6 (0.475 %).

4.2.4 Nutrient uptake

4.2.4.1 Nitrogen uptake

Data in respect of total nitrogen uptake by the plant are presented in table-55. During 2008-09, the treatment T_2 was found to be superior recording 62.13 kg ha^{-1} nitrogen uptake as compared to other treatments. The above treatment was at par with T_5 (54.47 kg ha^{-1}), T_1 (52.68 kg ha^{-1}) and T_7 (51.48 kg ha^{-1}). The treatments *viz*., T_3, T_9, T_4, T_8, T_6 were on par with each other. The lowest nitrogen uptake was registered by T_{10}.

During 2009-10, significantly higher nitrogen uptake was reported in T_2 (59.67 kg ha^{-1}) over other treatments and it was on par with T_7 (56.17 kg ha^{-1}) and T_5 (55.70 kg ha^{-1}). The treatments *viz*., T_3, T_1, T_9, T_6 were on par with each other. T_{10} and T_8 recorded lower nitrogen uptake.

Table 55: Effect of Integrated nutrient management on nitrogen, phosphorus and potassium uptake in fenugreek

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	52.68	48.39	50.54	10.00	8.84	9.42	26.50	23.43	24.97
T_2 : 100%RDF+R+PSB	62.13	59.67	60.90	11.63	11.57	11.60	34.00	33.11	33.55
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	47.05	48.81	47.93	9.04	9.28	9.16	27.19	28.51	27.85
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	41.00	41.69	41.35	6.26	7.03	6.65	20.86	21.96	21.41
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	54.47	55.70	55.08	11.45	11.62	11.53	31.93	32.45	32.19
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	38.19	43.02	40.61	6.44	7.24	6.84	19.17	22.84	21.00
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	51.48	56.17	53.82	10.44	11.19	10.82	29.82	33.08	31.45
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	39.92	39.09	39.50	6.91	6.80	6.85	21.24	20.89	21.07
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	41.70	45.14	43.42	8.72	9.36	9.04	26.07	29.10	27.59
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	33.52	36.66	35.09	5.99	6.61	6.30	19.29	21.47	20.38
Mean	46.21	47.43	46.81	8.69	8.95	8.82	25.60	26.68	26.14
SEm±	4.12	2.27	3.30	0.77	0.58	0.68	2.21	1.47	1.96
CD (P=0.05)	12.09	6.67	9.51	2.27	1.70	1.95	6.47	4.30	6.01

It is evident from pooled data that similar trend as that of 2009-10 was exhibited by T_2 (60.90 kg ha^{-1}), T_5 (55.08 kg ha^{-1}) and T_7 (53.82 kg ha^{-1}). However, the treatment T_5 recorded higher nitrogen uptake than T_7. Further, no significant difference was observed among the treatments viz., T_3, T_1, T_9, T_4. T_{10} and T_8 recorded lower nitrogen uptake.

4.2.4.2 Phosphorous uptake

Data pertaining to total phosphorous uptake by the plant are presented in table-55. During 2008-09, the treatment T_2 was found to be superior recording 11.63 kg ha^{-1} phosphorous uptake as compared to other treatments. The above treatment was at par with T_5 (11.45 kg ha^{-1}), T_7 (10.44 kg ha^{-1}) and T_1 (10.00 kg ha^{-1}). The treatments *viz*., T_3, T_9, T_8 were on par with each other. The lowest phosphorous uptake was registered by T_{10} and T_4.

During 2009-10, significantly higher phosphorous uptake was reported in T_5 (11.62 kg ha^{-1}) over other treatments and it was on par with T_2 (11.57 kg ha^{-1}) and T_7 (11.19 kg ha^{-1}). The treatments *viz*., T_9, T_3, T_1 were on par with each other. T_{10} and T_8 recorded lower phosphorous uptake.

It is evident from pooled data that T_2 was found to be significantly superior over other treatments recording 11.60 kg ha^{-1} phosphorous uptake followed by T_5 (11.53 kg ha^{-1}) and T_7 (10.82 kg ha^{-1}). The above treatments were on par with T_2. Further, no significant difference was observed among the treatments *viz*., T_1, T_3, T_9. T_{10} and T_4 recorded lower phosphorous uptake.

4.2.4.3 Potassium uptake

Results of total potassium uptake by the plant as influenced by various treatments are presented in table-55. During 2008-09, the treatment T_2 was found to be superior recording 34.00 kg ha^{-1} potassium uptake as compared to other treatments. The above treatment was at par with T_5 (31.93 kg ha^{-1}), and T_7 (29.82 kg ha^{-1}). The treatments *viz.*, T_3, T_1, T_9, T_8, T_4 were on par with each other. The lowest potassium uptake was registered by T_6 and T_{10}. During 2009-10, significantly higher potassium uptake was reported in T_2 (33.11 kg ha^{-1}) over other treatments and it was on par with T_7 (33.08 kg ha^{-1}), T_5 (32.45 kg ha^{-1}) and T_9 (29.10 kg ha^{-1}). The treatment, T_3 was also recorded higher value for potassium uptake over rest of the treatments except T_2, T_7, T_5 and T_9. T_8 and T_{10} recorded lower potassium uptake.

It is evident from pooled data that T_2 recorded higher potassium uptake of 33.55 kg ha^{-1} as compared to other treatments and it was on par with T_5 (32.19 kg ha^{-1}), T_7 (31.45 kg ha^{-1}) T_3 (27.85 kg ha^{-1}) and T_9 (27.59 kg ha^{-1}). The rest of the treatments were on par with each other. T_{10}, T_6 and T_8 recorded lower potassium uptake.

4.2.5 Available nitrogen, phosphorus and potassium in soil after harvest of fenugreek

A consideration of results (table-56) on soil analysis for nutrients revealed that significant differences among treatments were recorded in available nitrogen and phosphorus whereas, no significant differences were reported with respect to available potassium in the soil.

During 2008-09, significantly higher available nitrogen (195.40 kg ha^{-1}) was recorded with application of 75 % RDF + PM + *Rhizobium* + PSB (T_7) as compared to other treatments except T_9, T_5 and T_3. The above treatments were on par with each other. The treatment, T_1 recorded the lowest available nitrogen in soil.

During 2009-10 the treatment, T_7 recorded significantly higher available nitrogen in the soil as compared to rest of the treatments. Next to T_7, the treatment T_6

Table 56: Effect of Integrated nutrient management on nitrogen, phosphorus and potassium content in soil after harvest of fenugreek

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potasssium (kg ha^{-1})		
	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean	2008-09	2009-10	Pooled Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	189.73	186.73	188.23	21.90	21.07	21.48	286.16	283.33	284.74
T_2 : 100%RDF+R+PSB	193.17	191.00	192.08	22.50	22.57	22.53	286.50	284.00	285.25
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	194.40	192.17	193.28	23.17	22.07	22.62	288.10	285.60	286.85
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	193.40	191.40	192.40	22.77	21.77	22.27	286.16	284.16	285.16
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	194.73	192.33	193.53	23.27	22.37	22.82	288.16	285.33	286.74
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	193.33	194.00	193.66	23.90	23.60	23.75	286.17	284.16	285.16
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	195.40	196.00	195.70	26.17	25.50	25.83	287.67	285.00	286.33
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	193.67	192.00	192.83	24.00	23.33	23.66	286.17	284.50	285.33
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	195.00	193.17	194.08	22.83	22.70	22.76	286.73	285.33	286.03
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	193.27	191.40	192.33	22.00	21.60	21.80	286.00	284.00	285.00
Mean	193.61	192.02	192.81	23.25	22.65	22.95	286.78	284.55	285.66
SEm±	0.44	0.47	0.45	0.30	0.36	0.33	0.56	0.56	0.57
CD (P=0.05)	1.30	1.36	1.30	0.87	1.05	0.95	NS	NS	NS

Table 57: Effect of Integrated nutrient management on crude protein in seed of fenugreek

Treatments	Crude protein (%)		
	2008-09	2009-10	Pooled Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	16.450	16.870	16.660
T_2 : 100%RDF+R+PSB	17.610	17.810	17.710
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	17.490	17.390	17.440
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	16.870	16.760	16.815
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	17.490	17.490	17.490
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	16.140	16.240	16.190
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	17.600	17.700	17.650
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	15.310	15.510	15.410
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	16.560	16.660	16.610
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	14.890	15.200	15.045
Mean	16.641	16.763	16.702
SEm±	0.200	0.220	0.210
CD (P=0.05)	0.590	0.660	0.610

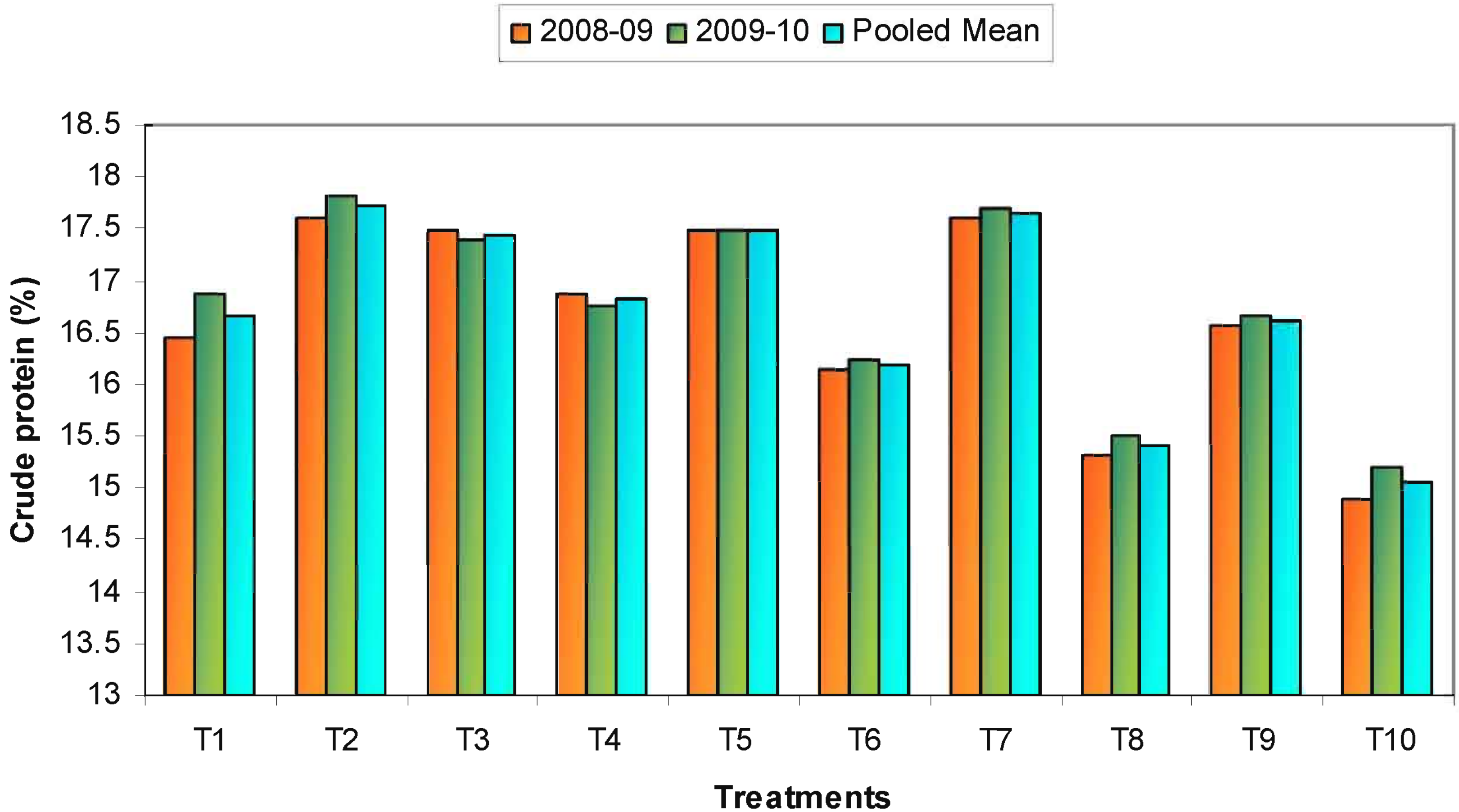


Fig.16: Effect of Integrated nutrient management on crude protein content in seed of fenugreek

also recorded significantly higher value for nitrogen.

A perusal of pooled data revealed that significantly higher available nitrogen in the soil (195.70 kg ha^{-1}) was recorded by T_7 as compared to rest of the treatments. The treatments *viz*., T_9, T_6, T_5, T_3 and T_8 were at par with each other. T_1 (188.23 kg ha^{-1}) and T_2 (192.08 kg ha^{-1}) recorded lower available nitrogen in the soil.

During 2008-09, significantly higher available phosphorus (26.17 kg ha^{-1}) was recorded by T_7: 75 % RDF + PM + *Rhizobium* + PSB over rest of the treatments. The treatments *viz*., T_8, T_6, T_5, T_3 were on par with each other. T_1 (21.90 kg ha^{-1}) and T_{10} (22.00 kg ha^{-1}) recorded lower available phosphorous in soil.

Similar trend as that of 2008-09 was exhibited by the treatment, T_7 (25.50 kg ha^{-1}) during 2009-10. Next to T_7 the treatment, T_8 (23.33 kg ha^{-1}) recorded higher available phosphorus in the soil and it was on par with T_9 and T_2. Lower available phosphorus was recorded in T_1 (21.07 kg ha^{-1}) and T_{10} (21.60 kg ha^{-1}) treatments.

In pooled values also similar trend was exhibited by T_7 (25.83 kg ha^{-1}) followed by T_6 (23.75 kg ha^{-1}), T_8 (23.66 kg ha^{-1}) and T_5 (22.82 kg ha^{-1}) which were on par with each other. The treatments, T_1 (21.48 kg ha^{-1}) and T_{10} (21.80 kg ha^{-1}) recorded lower values for available phosphorus in the soil.

4.2.6 Quality parameters

4.2.6.1 Crude protein content in seed

Data in respect of crude protein content in seed of fenugreek are presented in table-57. It is evident from the data that T_2 recorded 17.61 % and 17.81 % crude protein in seed during 2008-09 and 2009-10 respectively. The above treatment was found to be superior over rest of the treatments. The treatments *viz*., T_7, T_5, T_3 were at par with T_2. The lowest crude protein was recorded in T_{10} (14.89 %, 15.20 %)

during both the years of study.

From pooled data it could be observed that the highest crude protein (17.710 %) and the lowest crude protein was recorded by T_2 and T_{10} respectively. The treatment, T_2 was found to be significantly superior over rest of the treatments with highest crude protein of 17.710 % and it was at par with T_7, T_5 and T_3. T_4 also recorded higher crude protein (16.81 %) over rest of the treatments except T_2, T_7, T_5 and T_3 but was at par with T_1 and T_9. The lowest value for crude protein was observed in T_{10} (15.045 %) followed by T_8 (15.410 %).

4.2.6.2 Crude fibre content in seed

Data in respect of crude fibre content in seed as influenced by various treatments are presented in table-58. During 2008-09, significantly higher crude fibre in seed was reported in T_5 (7.667 %) as compared to other treatments and it was on par with T_9 (7.650 %) and T_{10} (7.623 %). T_6 and T_7 recorded lower crude fibre content of 7.400 % in seed.

During 2009-10, the treatment, T_9 was found to be significantly superior recording 7.677 % crude fibre in seed as compared to rest of the treatments except T_5 and T_{10}. The treatment, T_9 was at par with T_5 and T_{10}. The lower values for crude fibre were observed in T_4 (7.373 %) and T_6 (7.383 %).

A consideration of pooled data revealed that crude fibre in seed was found to be significantly higher in T_9 (7.663 %) over rest of the treatments and it was comparable with T_5 (7.657 %) and T_{10} (7.612 %). Further, T_2 was significantly superior over rest of the treatments except T_9, T_5 and T_{10}. T_4 (7.378 %) and T_6 (7.392 %) recorded lower crude fibre in seed.

4.2.6.3 Diosgenin content in seed

Results pertaining to the effect of INM treatments on diosgenin content in seed are pertained in table-59. Application of organic manures, inorganic fertilizers and biofertilizers in an INM combination did not exert any influence on diosgenin content in seed and hence the results were non significant during both the years of study. However, in pooled values the treatments, T_4 (0.219 %) and T6 (0.219 %) recorded higher diosgenin content in seed whereas, the lowest diosgenin content was recorded in T_{10} (0.207 %).

4.2.7 Economics

The cost of production, gross returns, net returns and benefit : cost ratio were worked out for different doses of inorganic fertilizers, organic manures, biofertilizers and their combinations in fenugreek during 2008-09 and 2009-10.

4.2.7.1 Cost of Production

During 2008-09 (table-60), the highest cost of production was recorded by T_5: 75 % RDF + VC + *Rhizobium* + PSB (Rs.21,600/- ha^{-1}) followed by T_6: 50 % RDF + VC + *Rhizobium* + PSB (Rs. 21,100/- ha^{-1}). Similarly, T_6 recorded higher (21,500/- ha^{-1}) cost of production during 2009-10 followed by T_5. While the lowest was recorded by T_1: 100 % RDF (Rs. 15,500/- ha^{-1}) and T_4: 50 % RDF + FYM + *Rhizobium* + PSB (Rs. 15,100/- ha^{-1}) during 2008-09 and 2009-10 respectively. In general the treatments with vermicompost as a nutrient source were observed to record higher cost of production than the other treatments.

4.2.7.2 Gross Returns

Gross returns (table-60) obtained with 100 % RDF + *Rhizobium* + PSB (T_2) were the highest during 2008-09 (Rs. 41,514/- ha^{-1}) and 2009-10 (Rs. 40,953/- ha^{-1})

Table 58: Effect of Integrated nutrient management on crude fibre in seed

Treatments	Crude fibre (%)		
	2008-09	2009-10	Pooled Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	7.410	7.397	7.403
T_2 : 100%RDF+R+PSB	7.500	7.500	7.500
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	7.455	7.467	7.461
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	7.383	7.373	7.378
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	7.667	7.647	7.657
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	7.400	7.383	7.392
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	7.400	7.433	7.417
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	7.417	7.403	7.410
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	7.650	7.677	7.663
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	7.623	7.600	7.612
Mean	7.490	7.488	7.489
SEm±	0.024	0.026	0.018
CD (P=0.05)	0.071	0.077	0.073

Table 59: Effect of Integrated nutrient management on Diosgenin in seed

Treatments	Diosgenin (%)		
	2008-09	2009-10	Pooled Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	0.220	0.207	0.213
T_2 : 100%RDF+R+PSB	0.218	0.200	0.209
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.225	0.205	0.215
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	0.225	0.212	0.219
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	0.217	0.214	0.215
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	0.222	0.217	0.219
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	0.215	0.215	0.215
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	0.222	0.212	0.217
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	0.212	0.205	0.208
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	0.214	0.200	0.207
Mean	0.219	0.208	0.213
SEm±	0.004	0.004	0.003
CD (P=0.05)	NS	NS	NS

followed by T_5: 75 % RDF + VC + *Rhizobium* + PSB, while the lowest was recorded by T_{10}: 50 % RDF + NC + *Rhizobium* + PSB during 2008-09 and T_6: 50 % RDF + VC + *Rhizobium* + PSB during 2009-10.

4.2.7.3 Net returns

During 2008-09 (table-61), maximum net returns were realised with T_2: 100 % RDF + *Rhizobium* + PSB (Rs. 25,514/- ha^{-1}) followed by T_1: 100 % RDF (Rs. 20,800/- ha^{-1}). Similarly, during 2009-10 also T_2 (Rs. 24,503/- ha^{-1}) recorded highest net returns followed by T_7 (Rs. 19,050/- ha^{-1}). The lowest net returns were realised with T_6: 50 % RDF + VC + *Rhizobium* + PSB during both the years.

4.2.7.4 Benefit : cost ratio (BCR)

It was observed (table-61) that highest B : C ratio (1.54) was recorded by application of 100 % RDF + *Rhizobium* + PSB (T_2) followed by 100 % RDF: T_1 (1.19 B : C ratio) and 75 % RDF + PM + *Rhizobium* + PSB : T_7 (1.12 B : C ratio). Though, the application of 75 % RDF + VC + *Rhizobium* + PSB (T_5) recorded higher grain yield than 75 % RDF + PM + *Rhizobium* + PSB (T_7), the B : C ratio was found to be lower due to high cost of vermicompost. Similarly, the lowest B : C ratio was observed in T_6.

4.2.8 Correlations

From the correlation matrix (Table-62) it was observed that the yield component which was the most important character was positively and significantly correlated with plant height, number of branches, number of leaves, dry matter content, number of pods $plant^{-1}$, pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield $plant^{-1}$.

The character, plant height was positively correlated with number of leaves,

Table 60: Effect of Integrated nutrient management on cost of production and gross returns (Rs. ha-1) in fenugreek

Treatments	Cost of production			Gross returns		
	2008-09	2009-10	Mean	2008-09	2009-10	Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	15,500	15,900	15,700	36,300	32,439	34,369
T_2 : 100%RDF+R+PSB	16,000	16,450	16,225	41,514	40,953	41,233
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	16,120	16,300	16,210	31,350	33,000	32,175
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	15,620	15,100	15,360	28,875	28,314	28,594
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	21,600	21,200	21,400	38,775	39,303	39,039
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	21,100	21,500	21,300	28,050	27,489	27,769
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	16,750	17,250	17,000	35,739	36,300	36,019
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	16,250	16,600	16,425	30,525	29,964	30,244
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	19,000	19,300	19,150	29,700	30,855	30,277
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	18,500	18,250	18,375	27,225	27,753	27,489

Table 61: Effect of Integrated nutrient management on net retuns and benefit cost ratio in fenugreek

Treatments	Net retuns (Rs. ha^{-1})			Benefit Cost Ratio		
	2008-09	2009-10	Mean	2008-09	2009-10	Mean
T_1 : 100% RDF (60-50-50 NPK ha^{-1})	20,800	16,539	18,669	1.34	1.04	**1.19**
T_2 : 100%RDF+R+PSB	25,514	24,503	25,008	1.59	1.49	**1.54**
T_3 : 75% RDF +FYM-2.8 t ha^{-1}+R+PSB	15,230	16,700	15,965	0.94	1.02	0.98
T_4 : 50% RDF +FYM-2.8 t ha^{-1}+R+PSB	13,255	13,214	13,234	0.85	0.88	0.86
T_5 : 75% RDF +VC-3.3t ha^{-1}+R+PSB	17,175	18,103	17,639	0.80	0.85	0.82
T_6: 50% RDF +VC-3.3t ha^{-1}+R+PSB	6,950	5,989	6,469	0.33	0.28	0.30
T_7 : 75% RDF +PM-3.5 t ha^{-1}+R+PSB	18,989	19,050	19,019	1.13	1.10	1.12
T_8 : 50% RDF + PM-3.5 t ha^{-1}+R+PSB	14,275	13,364	13,819	0.88	0.81	0.84
T_9 : 75% RDF +NC-2.5 t ha^{-1}+R+PSB	10,700	11,555	11,127	0.56	0.60	0.58
T_{10}: 50% RDF + NC-2.5 t ha^{-1} +R+PSB	8,725	9,503	9,114	0.47	0.52	0.50

Table 62: Correlation matrix combined over two seasons of fenugreek as influenced by integrated nutrient managemen

Characters	Plant height	No.of leaves/ pl	No.of branches /pl	Dry matter content	No. of pods/pl	Pod length	Seeds/ pod	Test weight	N uptake	P uptake	K uptake	Crude protein	Seed yield/pl
Plant height	1.000	0.299 *	0.577***	0.731***	0.441***	0.326 *	0.618 ***	0.581***	0.672***	0.688***	0.612 ***	0.553 ***	0.639 ***
No.of leaves		1.000	0.508***	0.309 *	0.561***	0.526 ***	0.408 **	0.488 ***	0.468***	0.517***	0.574 ***	0.444 ***	0.607 ***
Branches/pl			1.000	0.392 **	0.583***	0.661 ***	0.568 ***	0.685 ***	0.592***	0.573***	0.602 ***	0.586 ***	0.686 ***
Dry matter/pl				1.000	0.454***	0.418 ***	0.590 ***	0.483***	0.516***	0.513***	0.461***	0.537 ***	0.524 ***
No. of pods/pl					1.000	0.458 ***	0.557 ***	0.587 ***	0.523***	0.571***	0.508 ***	0.592 ***	0.520 ***
Pod length						1.000	0.580 ***	0.732***	0.591***	0.614***	0.594 ***	0.484 ***	0.715 ***
Seeds/ pod							1.000	0.658 ***	0.680***	0.664***	0.669 ***	0.616 ***	0.653 ***
Test weight								1.000	0.596***	0.696***	0.608 ***	0.620 ***	0.769 ***
N uptake									1.000	0.928***	0.877 ***	0.708 ***	0.725 ***
P uptake										1.000	0.902 ***	0.679 ***	0.754 ***
K uptake											1.000	0.656 ***	0.651 ***
Crude protein												1.000	0.561***
Seed yield/pl													1.000
Seed yield/ ha													

* - Significant at 5 % level, ** - Significant at 1 % level and *** Significant at 0.1 % level.

number of branches, dry matter content, number of pods plant^{-1}, pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}. Significant and positive correlation was observed for number of leaves with number of branches, dry matter content, number of pods plant^{-1}, pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}.

The character number of branches was positively correlated with dry matter content, number of pods plant^{-1}, pod length, seeds pod^{-1}, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}.

A positive correlation was observed for the dry matter content with number of pods plant^{-1}, pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}.

The number of pods plant^{-1} was positively correlated with pod length, seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}.

The character pod length was positively correlated with seeds pod^{-1}, test weight, nitrogen uptake, phosphorus uptake, potassium uptake and seed yield plant^{-1}.

A positive correlation was observed for seeds pod^{-1} with test weight, nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}. Further, the test weight was positively correlated with nitrogen uptake, phosphorus uptake, potassium uptake, crude protein (%) in seed and seed yield plant^{-1}.

Nitrogen uptake showed a positive correlation with phosphorus uptake, potassium uptake, crude protein content in seed and seed yield plant^{-1}. Similarly, phosphorus uptake was significantly and positively correlated with potassium uptake, crude protein content in seed and yield plant^{-1}. A positive correlation was observed for potassium uptake with crude protein content in seed and yield plant^{-1}. Further, the protein content showed positive and significant correlation with yield plant^{-1}.

Chapter V

DISCUSSION

CHAPTER-V

DISCUSSION

Fenugreek (*Trigonella foenum graecum* L.) occupies prime position among seed spices grown in India. It is a multipurpose spice crop whose parts are utilized as leafy vegetable, fodder and condiment (Khiriya *et al.*, 2003). It has aromatic, carminative, tonic and galactagogue properties. Therefore, the quality of the grain is very important, as it is also used as adjuvant in pharmaceutical preparations. In general, the grain yield and quality of fenugreek are influenced by different factors such as nutrition, cultural practices etc. Among these, nutrition is most important factor which has great influence on vegetative growth and grain yield (Sharma *et al.*, 2006) and the crop is known to respond well to applied nutrients.

To maintain and sustain a higher level of soil fertility and crop productivity, usage of organic manures assumes importance in the present day system of crop production. The conjunctive use of organic manures will not only improve the soil health but also helps to increase seed yield and quality of fenugreek. The increasing cost of nitrogenous inorganic fertilizers and non-availability of NPK fertilizers in recent years can emphasize the need for full exploitation of organic manures in crop production.

Though the response of crops to inorganic fertilizers is immediate, the role of organic manures in increasing the yield can not be underestimated. It must be realised that only soil along with formal components constitute the living soil. Under these circumstances organic manures have become time tested material for improving soil fertility and productivity as well. In the recent past, several positive responses to organic manures in spices and condiments were well documented. Application of FYM recorded higher yield in onion and fenugreek as reported by Chattopadhyay and

Chakravarthy (1990). Estrada *et al.* (1997) reported that application of sheep manure increased the yield in capsicum. Similarly, application of poultry manure @ 10 t ha^{-1} improved the yield in chillies (Kumar *et al.*, 2006). In fennel also, increase in yield was observed with application of FYM @ 10 t ha^{-1} (Anonymous, 2006).

'Organic manure' is a very broad term. It covers manure made from cattle dung, excreta of other animals, rural and urban compost, other animal waste, crop residues and green manures. Further, application of organic manures in huge quantities for compensating the entire crop nutrition requirements may not be feasible as they contain low nutrient (N, P_2O_5 and K_2O) levels.

5.1 EXPERIMENT- I

A field trial was carried out during *rabi* season of 2008-2009 and 2009-2010 to study the effects of different organic sources on growth, yield, quality and nutrient uptake in fenugreek with locally available organic manures *viz.*, vermicompost(VC), farmyard manure (FYM), poultry manure (PM) and neem cake (NC) and their combinations *viz.*, VC + FYM, VC + PM, VC + NC, FYM + PM, FYM + NC and PM + NC in comparison with 50% and 100% recommended dose of inorganic fertilizers (RDF). The investigation was conducted for two *rabi* seasons for confirmation of results. The treatments were formulated based on N equivalent basis. The experiment entitled **"The effect of different organic sources on growth, yield and quality of fenugreek"** was carried out with the following treatments as detailed below:

T_1 : Vermicompost @6.6 t ha^{-1}

T_2 : Farm yard manure @5.7 t ha^{-1}

T_3 : Poultry manure @7.0t ha^{-1}

T_4 : Neem cake @5.0 t ha^{-1}

T_5 : Vermicompost @3.3 t ha^{-1} + Farm yard manure @2.8 t ha^{-1}

T_6 : Vermicompost @3.3 t ha^{-1} + Poultry manure @ 3.5 t ha^{-1}

T_7 : Vermicompost @3.3 t ha^{-1} + Neem cake @ 2.5 t ha^{-1}

T_8 : Farm yard manure @2.8 t ha^{-1} + Poultry manure @ 3.5 t ha^{-1}

T_9 : Farm yard manure @2.8 t ha^{-1} + Neem cake @2.5 t ha^{-1}

T_{10} : Poultry manure @ 3.5 t ha^{-1} + Neem cake @2.5 t ha^{-1}

T_{11} : 50 % RDF (30 – 25 – 25 NPK kg ha^{-1})

T_{12} : 100 % RDF (60 – 50 – 50 NPK kg ha^{-1})

5.1.1 Effect of treatments during 2008-09 and 2009-10

From the data, it was observed that during both the years of study the treatments *viz.*, T_{12}, T_8, T_6 consistently performed well as compared to other treatments in terms of number of leaves plant^{-1} (75 DAS) and dry matter production plant^{-1}. Similarly, with respect to days to 50 % flowering the treatments, T_{12} and T_{11} were found to be superior over other treatments as flowering was advanced in both the years of study. Further, T_{12} and T_6 recorded higher plant height at harvest stage during 2008-09, whereas T_3, T_6 and T_{12} recorded higher plant height (harvest stage) during 2009-10. However, in pooled values similar trend as that of 2008-09 was exhibited by T_{12} and T_6 recording higher plant height at harvest stage.

Similarly, significant differences were noticed among various treatments with respect to yield and yield attributing characters. The number of pods plant^{-1} was reported to be higher in T_{12}, T_7 and T_8. However, during 2009-10, only T_{12} and T_8 performed well recording higher number of pods plant^{-1}. Further, it was observed that T_{10}, T_{12} and T_8 for pod length; T_{12} and T_8 for seeds pod^{-1}; T_{12} and T_6 for test weight consistently recorded higher values. In case of seed yield plant^{-1}, T_{12} performed well followed by T_6. The treatments, T_{12}, T_8, and T_6 recorded higher values for seed yield, biological yield and straw yield and consistency was maintained by above treatments during both the years of the study.

Further, it was observed that in parameters like dry matter production (25 DAS and 50 DAS), nitrogen content in seed, phosphorus content in seed, crude protein content in seed and CGR for dry matter (25-50 DAS), the treatments could influence only in first year and as such the results were significant in first year and non significant in second year of study whereas, in harvest index, crude fibre content in seed and AGR for plant height (25-50 DAS) the treatmental effects were non significant in first year and significant in second year.

These differential responses of the treatments between the two seasons as observed above may be attributed to the variation in the seasons and meteorological conditions.

In this context, to avoid seasonal variations, the results were discussed at length based on the pooled values as detailed below.

5.1.2 Growth

Growth is an irreversible increase in size and shape of the plant and it is affected by the complex interaction between environmental factors and physiological processes which are influenced by the external inputs like water and nutrients. It can be observed that in the present field experiment, application of different organic sources of manures and their combinations and recommended dose of fertilizer at different levels exerted a significant influence on vegetative growth of the crop in terms of plant height, number of leaves (50 DAS and 75 DAS), leaf area, dry matter production and days to 50 % flowering.

In this experiment, the plant height increased with the age of the crop reaching a maximum at harvest stage. Further, a rapid rate of increase in plant height was observed between 25-50 DAS. Thereafter, the plant height had slowed down up to 75 DAS and increased marginally between 75 DAS to harvest. The rate of dry matter accumulation was found to be at a slower pace upto 50 DAS and thereafter, it increased markedly.

In the present study, it can be observed that the vegetative growth in terms of plant height (harvest stage), number of leaves (75 DAS), and dry matter production at harvest stage (table- 3,5 and 9) was found to be significantly increased with application of 100 % RDF: T_{12} and it was at par with T_8: FYM + PM and T_6: VC + PM. Further, application of poultry manure (T_3) alone also recorded comparable plant height which was on par with T_{12}: 100 % RDF, T_8: FYM + PM and T_6: VC + FYM. Similarly, leaf area and leaf area index were also found to be higher with application of 100 % RDF: T_{12} as compared with other treatments and it was at par with T_6: VC + PM. These results are in agreement with Jat *et al.* (2006) who reported an increase in plant height in fenugreek with application of inorganic fertilizers. Similarly, increase in plant height, dry matter production and leaf area index with application of FYM was also reported by Khiriya *et al.* (2001).

Application of 50 % RDF (T_{11}) also recorded better plant height during early stage (25DAS) comparable with 100 % RDF (T_{12}). The plant height in T_7, dry matter production in T_3 and T_4 and leaf area in T_4 and T_7 treatments were lower and the remaining treatments recorded intermediate values. Further, with regards to number of days taken to 50 % flowering (table-11), it was significantly advanced in the crop supplied with 50 % RDF (T_{11}) and 100 % RDF (T_{12}) when compared to all other organic sources where flowering was delayed. The initial vigorous growth in T_{12} and T_{11} treatments of RDF might have advanced the flowering.

A perusal of data revealed that the absolute growth rate (AGR) for plant height increased rapidly between 25-50 DAS and thereafter decreased between 50-75 DAS, whereas the crop growth rate (CGR), an indicator of dry matter production per unit time increased with age of crop recording a maximum between 50-75 DAS. The treatments; T_6 and T_8 recorded higher values for AGR for plant height at 25-50 DAS (table-4) as compared to other treatments and rest of the treatments were at par with each other. However, no significant difference was observed among treatments in case of AGR for plant height at 50-75 DAS. Further, it was observed that the CGR for dry matter production at 25-DAS (table-10) was higher in T_{12} as compared to T_1, T_2, T_3 and T_4 but was at par with rest of the treatments. Similarly, CGR (50-75 DAS) for dry matter production was higher with T_6 and it was comparable with the treatments; T_8, T_{12}, T_2 and T_3. The lower value for AGR for plant height at 25-50 DAS was recorded in T_4 while the treatments, T_1 and T_5 recorded lower values for CGR for dry matter production at 25-50 DAS and 50-75 DAS respectively.

From the above observations made on vegetative characters it can be inferred that application of inorganic fertilizers exerted a profound influence on plant growth even at early stage and boosted the vegetative growth by providing nutrients in assimilable forms and at a very rapid rate. On the contrary, vegetative growth in plants treated with organic manures was found to be rather slow initially and improved gradually. It is reasonable to state that the organic manures might have taken longer time to undergo mineralization process in the soil and to provide the plants with usable nutrient forms (Goswamy and Rattan, 2004). However, the vegetative growth was also promoted by certain organic treatments *viz*., T_6: VC + FYM and T_8: FYM + PM. The increase in the growth parameters such as plant height, number of leaves and dry matter production in T_6: VC + FYM and T_8: FYM + PM may be attributed to improved nutrient availability through organic manures such as vermicompost, poultry manure and farm yard manure applied in a combined form which would have exerted a complimentary effect on growth parameters. Similarly, vermicompost is reported to be a good source of macro and micro elements, growth hormones, vitamins and microflora. Vermicompost also contains plant growth promoters and group 'B' vitamins and their effect on growth was similar to the effect of IAA (Neilson, 1965). Further, other organic manures, especially farm yard manure and poultry manure (Treatments; T_6 and T_8) might have improved the rhizosphere leading to an improvement in nutrient availability to the plants.

5.1.3 Seed yield and yield attributes

Seed yield is the manifestation of morphological, physiological and growth parameters in any crop. Seed yield in fenugreek is the product of several of its yield attributes such as number of pods plant^{-1}, pod length, number of seeds pod^{-1}, test weight, grain shelling percentage, seed yield plant^{-1} and harvest index *etc*., (Anonymous, 2004). In the present investigation, yield and yield attributing characters were found to be significantly influenced by different organic manures and their combinations.

A perusal of the results on seed yield in fenugreek revealed that significantly highest seed yield of 12.00 q ha^{-1} (table-19) was recorded by application of 100 % RDF : T_{12} followed by application of FYM + PM : T_8 and VC + PM: T_6. Among organic sources of treatments, T_8: FYM + PM and T_6: VC + FYM recorded higher grain yield of 9.60 q ha^{-1} and 9.55 q ha^{-1} respectively. The above treatments recorded 4.58 % and 4.00 % increase over T_{11}: 50 % RDF. The increase in yield with application of 100 % RDF (T_{12}) could be due to an increase in the values of growth and yield attributing characters such as plant height, leaf area index, dry matter accumulation, number of pods plant^{-1}, number of seeds pod^{-1}, test weight and seed yield plant $^{-1}$ and increased nutrient uptake. The same was also evident from the positive and significant correlations recorded in this experiment between yield and yield attributing characters such as number of pods plant^{-1}, number of seeds pod^{-1}, test weight and seed yield plant^{-1} (table-32). Similar positive correlations between yield and yield attributing characters were also reported by Sarada *et al.* (2008). The increase in yield with application of 100 % RDF might be due to direct supply of nutrient ions to soil solution through available (fertilizers) form and better assimilation of nutrients in early stages for the production of carbohydrates ultimately resulting in an increase of the vegetative growth and inturn resulting in higher seed yields.

It was observed that next to T_{12}: 100 % RDF, the highest seed yield of 9.60 q ha^{-1} was recorded by T_8 (FYM + PM) followed by T_6 (VC + PM). The increase in yield with application of T_8: FYM + PM could be due to a promotion of yield attributing characters such as pod length, number pods plant^{-1} and number of seeds pod^{-1} (table-13, 12 and 14). Further, increased leaf production, dry matter accumulation, AGR for plant height (25-50 DAS) and CGR for dry matter content (50-75 DAS) also might have positively contributed for initial booster of vigour of the plants resulting in higher yield. This is also evident from the positive correlation registered between yield and pod length, number of pods plant^{-1} and number of seeds pod^{-1} (Table -32). The increase in yield in fenugreek with application of FYM was also reported by Khiriya *et al.* (2003). Chatopadhyay and Chakravarthy (1990) and Subbaiah *et al.* (1983) also reported similar increase in yield with application of FYM in onion and tomato crops respectively and offer support to the above results.

Similarly, application of T_6: VC + PM resulted in higher seed yield of 9.55 q

ha^{-1} (table-19) as compared to rest of the treatments except T_{12} and T_8. The better performance of T_6 comprising of vermicompost and poultry manure could be due to increased vegetative parameters such as plant height (harvest stage), leaf production (75 DAS), dry matter production (harvest stage), leaf area, leaf area index and CGR for dry matter production (50-75 DAS) and yield attributing characters such as test weight, number of pods $plant^{-1}$ and seed yield $plant^{-1}$. This is also supported by the positive and significant correlation recorded between yield and yield attributing characters *viz*., number of leaves, dry matter production, test weight, number of pods $plant^{-1}$ and seed yield $plant^{-1}$ (table-32). The higher seed yield with application of FYM + PM and VC + PM in treatments, T_8 and T_6 might be due to slow and consistent release of nutrients through out the crop period ultimately resulting in better pod set, increased number of pods $plant^{-1}$, increased number of seeds pod^{-1} resulting in higher seed yield. In general, it could be observed that the average seed yield (8.42 q ha^{-1}) with application of organic manures in combination was found to be higher than individual application of organic manures (7.94 q ha^{-1}). Increased plant yields with organic manures have earlier been reported by Kadam *et al.* (1985), Hilman and Suwandi (1991) in tomato with oil cakes, Shanmugavelu (1989) in chillies, Maynard (1991) in capsicum and tomatos with poultry manures. Similarly, Deora and Jitender singh (2008) and Tarun *et al.* (2006) also reported increased grain yield in fenugreek and support these results.

Further, it was observed that significantly lower seed yield of 7.20 q ha^{-1} was obtained with application of NC: T_4 as compared to other treatments and it was at par with FYM + NC: T_9. The lower yield in T_4 and T_9 might be due to poor and slower uptake of phosphorus and potassium resulting in reduced growth and yield attributes. The rest of the treatments recorded intermediate values for seed yield.

In this experiment, the test weight of seed and seed yield $plant^{-1}$ (table-17 and

18) were found to be highest in T_{12} followed by T_6. The increased test weight in these treatments might be attributed to rapid translocation and accumulation of photosynthates to the economic sink. The increased seed yield plant^{-1} might be due to higher initial growth, test weight, number of pods plant^{-1} and pod length in case of T_{12} and better test weight and number of pods plant^{-1} in case of T_6.

In this study with respect to grain filling (table-15), no significant differences were observed among the treatments.

In case of grain shelling percentage (table-16) the treatments; T_8 and T_7 recorded higher values over other treatments which may be attributed to higher test weight recorded and better seed number pod^{-1} leading to higher recovery of grain from pods.

In respect of straw yield of fenugreek, application of 100 % RDF (T_{12}), VC + PM (T_6), FYM + PM (T_8) and 50 % RDF (T_{11}) recorded higher values (table-21). The increased straw yield might be attributed to increased uptake of NPK. The results are in close conformity with findings of Deora and Jitendar Singh (2008)

Similarly, the biological yield (table-20) was also found to be higher with application of 100 % RDF (T_{12}) followed by VC + PM (T_6), FYM + PM (T_8) and 50% RDF (T_{11}). Further, T_{12} recorded significantly higher harvest index over T_7. The increase in harvest index might be attributed to higher initial growth of plant due to improved nutrient uptake leading to rapid translocation and accumulation of photosynthates to economic sink.

A perusal of results revealed that grain yield of fenugreek could be enhanced with the application of organic manures in a combination (VC + PM: T_6 and FYM + PM: T_8) rather than application of organic manures alone or chemical fertilizers alone.

5.1.4 Nutrient content in seed and straw and its uptake

The plant nutrients were applied in the form of mineral fertilizers *viz*., urea, single super phosphate, muriate of potash, organic sources such as farmyard manure, poultry manure, vermicompost and neem cake and their mixups in twelve different forms and combinations. These twelve forms and combinations referred to as T_1 to T_{12}. Thus, chemical fertilizers at recommended rate of application with out any organic source of plant nutrients constituted the treatment, T_{12}, while the same at 50 % rate of application, a treatment has been introduced to elicit additional information on mineral nutrition of the plant fenugreek formed the treatment T_{11}.

The pattern of the content and uptake of the major plant nutrients *viz*., nitrogen, phosphorus and potassium as affected by their rates of application and sources (inorganic or organic) are discussed in brief in the following sections with respect to each nutrient dealt separately.

5.1.4.1 Nitrogen

A perusal of the data (table-25) presented indicates that nitrogen uptake in the plant was found to be highest with the application of 100 % RDF (T_{12}) followed by T_8: FYM + PM and T_6: VC + PM.

The nitrogen % in seed (table-23) also exhibited a similar trend as that of total nitrogen uptake by the plant. However, in addition to T_{12}, T_6 and T_8, the treatment, T_5: VC + FYM also recorded better nitrogen % in seed comparable with above three treatments. Similarly, application of neem cake (T_4) recorded significantly higher nitrogen % in straw (table-24) as compared to rest of the treatments and it was comparable with T_8: FYM + PM.

A significantly higher increase in nitrogen uptake particularly in T_{12} comprising only inorganic fertilizers as noticed here may be attributed to the direct addition of nitrogen in readily available form. Nitrogen was applied in the form of urea which contains the nutrient in amide form. Urea is readily converted to ammonical form by urease catalyzed urea hydrolysis and then promptly oxidized to nitrate form by nitrification. Fenugreek absorbs nitrogen in nitrate and ammonical form and thus could find the nutrients soon after application. This may probably the reason for best performance of the treatment T_{12} in respect of content and uptake of the nutrient. The increase in nitrogen uptake by T_8: FYM + PM and T_6: VC+PM may be attributed to slow and sustained release of nutrient from farmyard manure, poultry manure and vermicompost. These sources contain nitrogen in complex organic form which requires the mineralization process to be executed for bringing nitrogen in available form. This process is essentially a soil microbiological process carried out by the soil heterotrophic microflora and is a slow process. As a result the entire nitrogen becomes available to the plant over an extended period of time. These results are in conformity with the findings of Jat *et al.* (2006) and Khiriya *et al.* (2003) who too reported similar increase in nitrogen uptake with increased dose of FYM in fenugreek.

A point of equal significance in context is that nitrogen supply from organic sources depends upon their chemical nature and nitrogen content too. Further, synchronicity between crop demand and nitrogen supply is also very important for successful nutrient uptake. It can be reasoned that in the above treatments the combination of poultry manure with farm yard manure and vermicompost might have developed good synchronicity between nitrogen supply from organic manures and crop demand preventing higher loss of nitrogen through leaching or de nitrification (Krichman and Bergstrion, 2001). As a result, greater part of the nutrient could be utilized by the plant.

The lowest uptake of nitrogen was noticed in T_2: FYM and T_9: FYM + NC which might be due to slow release of nitrogen from FYM and also in case of neem cake, its transient inhibitory effect on soil nitrifying bacteria. Similarly, T_{11}, T_3, T_{10} and T_4 were intermediary and these treatments were on par with each other.

5.1.4.2 Phosphorus

Results (table-25) on phosphorus uptake revealed that highest phosphorus uptake was recorded with application of 100 % RDF (T_{12}) followed by T_8, T_{11} and T_6.

Phosphorus content in seed (table-23) was higher in T_4 with application of neem cake. However, it was on par with most of the treatments except T_6, T_9 and T_{10}. But similar trend was not exhibited in straw, as T_{10} with PM + NC recorded slightly higher phosphorus content (table-24) and it was at par with remaining treatments except T_3, T_5, T_7 and T_{12}.

The increase in phosphorus uptake with 100 % RDF (T_{12}) may be attributed to the direct addition of phosphorus in the form of chemical fertilizers which provide the nutrient to the soil solution in readily available orthophosphate form. Similarly, increase in the phosphorus uptake in T_8 with FYM + PM and T_6 with VC + PM may be attributed to applied organic matter in the manures which might have led to the formation of coating on the sequioxides, because of which phosphate fixing capacity of the soil might have been reduced in organic manures applied plots. This might have reduced the bounded phosphorous in the soil duly increasing the available nutrient pool of the element in discussion (Reddy and Reddy, 1998). Application of FYM in fenugreek upto 15 t ha^{-1} increased the NPK uptake as reported by Khiriya *et al.* (2003). Similar results were also reported by Deora and Jitender singh (2008) with application of vermicompost in fenugreek and support the above findings.

The lowest uptake was observed in T_4: NC and T_9: FYM + NC which were at par with each other. The rest of the treatments showed intermediate values with respect to phosphorus uptake.

5.1.4.3 Potassium

The data (table-25) relating to the effect of organic manures on potassium uptake by the plant showed significant difference among treatments.

The application of (T_{12}) 100 % RDF registered the highest potassium uptake followed by T_8, T_6, T_{11} and T_3. Further, T_1, T_9 and T_4 recorded lower values for potassium uptake. Similarly, the potassium content in seed (table-23) was found to be slightly higher in T_8: FYM + PM and T_{12}: 100 % RDF and it was at par with T_1: VC, T_2: FYM, T_3: PM and T_7: VC + NC. However, in case of potassium % in straw except T_1 and T_5, the remaining treatments were at par with each other (table-24).

The reason for increased uptake of potassium with T_{12} could be due to supply of this nutrient in a direct fertilizer form. Similarly, the higher uptake of potassium due to application of organic manures may be attributed to the beneficial effect of organic manures on reduction of potassium fixation capacity of the soil and interaction of organic manures with clay micelles to release potassium ions from the nonexchangeable fraction to the available pool (Reddy and Reddy, 1998). The increase in potassium uptake in fenugreek was also reported by Khiriya *et al.* (2003) with application of FYM.

5.1.5 Available nitrogen, phosphorus and potassium in soil after harvest of fenugreek

A perusal of data (table-26) on soil analysis for nutrients revealed that no significant differences were observed in available nitrogen and potassium in soil after harvest of fenugreek with application of organic manures and their combinations. But, with regards to available phosphorus in soil significant differences were observed among treatments.

Application of VC + PM (T_6) and FYM + PM (T_8) resulted in higher phosphorus in the soil followed by T_3: PM, T_9: FYM + NC and T_2: FYM. The above treatments were on par with each other. The build up of available phosphorus in the soil with application of VC + PM and FYM + PM could be due to decomposition and mineralization of organic manures which produced a variety of organic acids. These acids might have dissolved the insoluble inorganic phosphate content of the soils such as tricalcium phosphate leading to an increase in available phosphorus contents of the soil (Khan *et al*., 1994). On contrary, similar increase in available phosphorus in soil was not observed with application of inorganic fertilizers probably because a much greater part of the phosphorus present in them was utilized by the plant and thus there was no phosphorus build up in the soil.

5.1.6 Quality parameters

In this study, the effect of various organic manures on seed quality was assessed in terms of the protein content, crude fibre and diosgenin content in seed.

5.1.6.1 Crude protein content in seed

Proteins are one of the most important biochemical source of aminoacids macro molecules with versatile biochemical functions. Proteins are mostly found in seeds. Seeds with high protein content thus become very nutritious and advantageous for human consumption. Fenugreek is no exception to this basic principle of protein biochemistry. The crude protein content (table-27) was highest in the treatment, T_{12}: 100 % RDF and it was at par with T_6, T_5 and T_8. The lowest value for protein content was recorded by T_2 followed by T_{10} and T_9.

The protein content in seed could be the direct effect of its nitrogen content. The better protein content in organic treatments *viz*., T_6, T_5 and T_8 comparable with inorganic fertilizers (T_{12}) might be attributed to improvement in soil properties due to application of organic manures leading to a higher uptake of nitrogen. According to Nowak (1970) earthworms in vermicompost stimulate the microbial activity which enhances the transformation of soluble nitrogen into protein. In its absence, a larger fraction of soil nitrogen would have been lost by leaching down to the lower horizons of the soil. The beneficial effect of FYM on protein content as observed here may be due to increased nitrogen content in seed. Wang *et al*. (1994) also observed the increase in protein content with the application of FYM and support these findings.

5.1.6.2 Crude fibre content in seed

The crude fibre % in seed (table-28) was found to be significantly highest (7.75 %) with application of FYM + NC: T_9 and it was comparable with 100 % RDF: T_{12} (7.723 %) and FYM + PM: T_8 (7.692 %). The lowest value was reported in T_2: FYM and T_{11}: 50 % RDF. Sridevi and Sumathi (2008) also reported similar results in organically grown tomatoes. However, Premshekar and Rajashree (2009) reported highest crude fibre content in okra with application of inorganic fertilizers. Therefore, further experimentation is required to confirm such divergent results which are found to be rather inconsistent.

5.1.6.3 Diosgenin content in seed

In this study the combination of inorganic fertilizers, organic manures and biofertilizers did not influence the diosgenin content in seed (table-29) of fenugreek. As per the available reports it might be a varietal character and may not be influenced by nutrient application. (Bhavasar *et al.*, 1980).

A perusal of the results in this study indicate that the quality in fenugreek in terms of crude fibre and protein content in seed can be considerably improved by usage of organic manures. However, further research is required to arrive at a definite conclusion.

5.1.7 Benefit : cost ratio (BCR)

In this study (table-31), it is observed that the highest benefit cost ratio (1.46) was recorded with the application of inorganic fertilizers (T_{12}) followed by application of T_8: FYM + PM: (1.02 B:C ratio) and T_{11}: 50 % RDF: (0.98 B:C ratio). B : C ratios were lower in case of T_1 (VC) and T_7 (VC + NC).

The above results indicated that there is ample scope for substitution of inorganic fertilizers with organic manures which can be encouraged among farmers keeping long term advantages such as soil health and environmental safety in view. However, the lesser yields obtained with these organic treatments compared with RDF can be better compensated with higher sale price for the produce under organic agriculture by tapping international markets.

Considering the seed yields as well as benefit : cost ratio and nutritional qualities of seed and straw in view, it can be concluded that application of T_8 : Farm yard manure @ 2.8 t ha^{-1} + Poultry manure @ 3.5 t ha^{-1} was found promising and can be recommended for obtaining higher yield with especially nutritionally improved quality of seed and straw in fenugreek.

Thus, under sustainable agriculture the application of organic manures in long run will ensure positive relationship between soil, plant, water, fauna and soil microflora resulting in healthy soil and result in proper energy flow in soil-crop-water environment system and keep biological life cycle alive resulting in sustainable crop yields.

5.2 EXPERIMENT- II

Fenugreek responds to applied nutrients and mineral nutrition plays an important role in its cultivation (Patel *et al.* 1991). Application of required quantities of chemical fertilizers is expensive as the cost of chemical fertilizers is ever increasing. Small and marginal farmers who represent major portion of farming community in India are thus finding very difficult or getting choked in debit traps in procuring the chemical fertilizers. Besides, continuous application of chemical fertilizers in judicious manner affects the soil health adversely.

The basic concept underlying Integrated Nutrient Management is the maintenance or adjustment of soil fertility and plant nutrient supply above optimum level to get the benefits from all possible sources of plant nutrients in an integrated manner. INM practices were found to be successful in many spices and condiments. Under integrated nutrient management, application of vermicompost and farmyard manure in combination with inorganic fertilizers improved the yield in drumstick (Damodaran *et al.*, 1999). Tarun Adak *et al.* (2006) also reported improvement in soil fertility with application of chemical fertilizers and biofertilizers in fenugreek. Similarly, with an integrated approach quality parameters like crude protein content in fenugreek can also be improved with application of vermicompost and inorganic fertilizers as reported by Deora and Jitender Singh (2008). Integrated nutrient management envisages the exploitation and use of all the locally available organic sources of nutrients such as farmyard manure, vermicompost, green manure, neem cake, poultry manure, sewage sludge, press mud and biofertilizers in a judicious combination with inorganic fertilizers (Subba Rao and Chandrasekhar Rao, 1980).

Use of biofertilizers has become popular in many horticultural crops and also in spices. The biofertilizers not only aid in nitrogen fixation but also produces growth substances like auxins, gibberellins and cytokinins and thereby indirectly regulates the crop growth and would improve crop production.

Fenugreek is a sensitive crop and needs efficient nutrient management practices with an integrated approach of exploring all possible nutrient resources, not only to augment the nutrients to improve yield, but also to improve the quality of produce. Grain quality is very important in case of fenugreek as the grain is utilised in pharmaceutical preparations. Therefore, an integrated approach with specific emphasis on organic manures and biofertilizer components in combination with chemical fertilizers is expected to give good benefits in a leguminous crop like fenugreek.

Considering the foregoing factors an investigation entitled **'Effect of Integrated nutrient management on growth, yield and quality of fenugreek'** was carried out with the following INM treatments:

T_1: 100 % RDF (60 – 50 – 50 NPK kg ha^{-1})-control

T_2: 100 % RDF (60 – 50 – 50 NPK kg ha^{-1}) + *Rhizobium* + PSB

T_3: 75 % RDF+ Farm yard manure @ 2.8 t ha^{-1} + *Rhizobium* + PSB

T_4: 50 % RDF + Farm yard manure @ 2.8 t ha^{-1} + *Rhizobium* + PSB

T_5: 75 % RDF + Vermicompost @ 3.3 t ha^{-1} + *Rhizobium* + PSB)

T_6: 50 % RDF+ Vermicompost @ 3.3 t ha^{-1} + *Rhizobium* + PSB

T_7: 75 % RDF + Poultry manure @ 3.5 t ha^{-1} + *Rhizobium* + PSB

T_8: 50 % RDF + Poultry manure @ 3.5 t ha^{-1} + *Rhizobium* + PSB

T_9: 75 % RDF + Neem cake @ 2.5 t ha^{-1} + *Rhizobium* + PSB

T_{10}: 50 % RDF + Neem cake @ 2.5 t ha^{-1} + *Rhizobium* + PSB

Biofertilizers are also included in the study, since they are inexpensive source of plant nutrients, which are capable of mobilizing nutrient ions from nonusable form to usable form through biological process in the soil (Guar, 1982). Biofertilizers employed in this experiment are: *Rhizobium* for supplementing nitrogen requirements and phosphate solubilizing bacteria (PSB) (*Bacillus megatherium*) for conversion of insoluble phosphates in the soil into soluble forms. Taking these strategies into account, the present experiment was conducted and the results obtained are discussed in this chapter.

5.2.1 Effects of treatments during 2008-09 and 2009-10 (year wise)

The data revealed that higher plant height at harvest stage was recorded by T_5, T_2 and T_7 treatments during both the years of study and similar trend was also exhibited by above treatments in pooled values. However, during 2009-10 the treatment, T_1 also recorded higher plant height next to T_2. Regarding number of branches $plant^{-1}$ at 75 DAS, number of leaves $plant^{-1}$ at 75 DAS and dry matter production $plant^{-1}$ at harvest stage, the treatments *viz*., T_2, T_7, T_5 consecutively recorded higher values as compared to other treatments. But, with respect to number of branches $plant^{-1}$, only T_7 and T_5 performed well recording higher values.

Similarly, in case of number of pods $plant^{-1}$, pod length, seeds pod^{-1}, test weight, seed yield $plant^{-1}$, leaf area and nutrient uptake the treatments *viz*., T_2, T_5, T_7 consistently performed well recording higher values with slight variation in the order of ranking during both the years of study. The above treatments also recorded higher seed yield ha^{-1}. But, during 2008-09 besides, T_2, T_5 and T_7, the treatment T_1 also performed well recording higher seed yield ha^{-1} on par with above treatments.

Further, it could be observed that in parameters like dry matter production (25 DAS), days to 50 % flowering and AGR for plant height (25-50 DAS) the treatments could not influence consistently and as such the results were non significant in first crop, while in dry matter production (50DAS) the treatmental effects were significant in first crop and non significant in second crop. These differential responses of the treatments between the two seasons as observed above may be attributed to the variation in the seasons and meteorological conditions.

In this context, to avoid seasonal variations, the results were discussed at length based on the pooled values as detailed below.

5.2.2 Growth

Growth is also a phenotypic expression of the plant with respect to nutrient status provided all other conditions are favourable. In general it is known that the growth parameters like plant height, number of branches and leaves plant^{-1} in addition to leaf area plant^{-1} and LAI and dry matter accumulation would contribute for economic yield of the crop (Anonymous, 2004). In the present investigation, application of different organic sources of manures and their combinations at different levels and recommended dose of fertilizers (RDF) had exerted a significant influence on plant height, leaves plant^{-1}, leaf area and dry matter production at different stages of the crop growth.

In this study it can be observed that the vegetative growth in terms of plant height, leaf number, dry matter production and LAI in fenugreek was promoted by the treatments *viz.*, T_2: 100 % RDF + *Rhizobium* + PSB, T_5: 75 % RDF + VC + *Rhizobium* + PSB, T_7: 75 % RDF + PM + *Rhizobium* + PSB, while the growth was poor in T_{10}: 50 % RDF + NC + *Rhizobium* + PSB and T_4: 50 % RDF + FYM + *Rhizobium* + PSB.

If pooled values are considered significantly higher values for plant height, dry matter production at harvest stage (table- 33 and 39) and leaf production (75 DAS) was recorded with application of T_2: 100 % RDF + *Rhizobium* + PSB and it was on par with T_5: 75 % RDF + VC + *Rhizobium* + PSB and T_7: 75 % RDF + PM + *Rhizobium* + PSB. It was observed that T_2 recorded 19.7 % increase in dry matter over control (T_1). These results are in agreement with Jat *et al.*, (2006) who reported increase in growth parameters like plant height and dry matter in fenugreek with inorganic fertilizers. Further, the treatment T_1: 100 % RDF recorded higher dry matter production during early stages of crop growth. Similarly, the treatments T_{10}: 50 % RDF + NC + *Rhizobium* + PSB and T_4: 50 % RDF + FYM + *Rhizobium* + PSB recorded lower plant height and dry matter production respectively. The remaining treatments were intermediary.

The number of branches plant^{-1} (75 DAS) (table-38) was also reported to be higher in T_2, T_5 and T_7 treatments. With regards to days taken to 50 % flowering, days to flowering was significantly advanced in the crop supplied with inorganic sources *i.e.*, 100 % RDF + *Rhizobium* + PSB (T_2) when compared to organic sources of treatments; T_3, T_6 and T_9 in which flowering was delayed. Similarly, leaf area and LAI (table-36 and 37) were reported to be higher in the crop treated with T_2: 100 % RDF + *Rhizobium* + PSB and it was on par with T_5: 75 % RDF + VC + *Rhizobium* + PSB and T_7: 75 % RDF + PM + *Rhizobium* + PSB.

From the observations made on vegetative characters, it can be inferred that the higher plant height and number of branches, leaves plant^{-1} and leaf area and dry matter production recorded in inorganic fertilizers application in the present study (T_2) can be attributed to their readily soluble and easily available forms to the plant at root zone and rapid release of nutrients compared to organic manures. The increase in plant height and number of branches, leaves plant^{-1} and LAI could be owing to higher uptake of nutrients by the plant particularly of nitrogen which has a prime role in the promotion of vegetative growth in plants. Rapid cell elongation occurs with adequate availability of nitrogen which favourably influences the plant growth. Nitrogen, being an important constituent of protoplasm increases the synthesis of carbohydrates and amino acids *etc.*, from which the phytohormones such as auxins, gibberellins, cytokinins and ethylene are synthesized resulting in increased plant growth (Maynard *et al.* 1987). The increased plant height could also be attributed to the higher availability of nitrogen, boosting the vegetative growth by enhanced cell division and cell elongation (Pande and Sinha, 1972). The absorbed nitrogen combining with carbohydrates synthesized by leaves through increased photosynthetic activity might have led to the formation of amino acids and proteins resulting in the build-up of new tissues and the consequent increase in growth parameters (Childers, 1966).

Application of vermicompost and poultry manure with 75 % RDF (T_5 and T_7) combined with *Rhizobium* and PSB also promoted the growth and recorded higher vegetative growth and were on par with inorganic treatment, 100 % RDF combined with *Rhizobium* and PSB (T_2). The higher values for vegetative characters recorded in case of T_7 and T_5 could be attributed to an increase in nitrogen availability consistently through organic manures and inorganic fertilizers.

The beneficial effects of organic manures are well documented in several horticultural crops. Application of organic manures have various advantages such as increasing soil physical properties, water holding capacity and organic carbon content apart from supplying good quality of nutrients. The application of organic manures and their mineralization in the soil can release significant amounts of nitrogen in a mineralized and available form and so may satisfy the needs of crops for nitrogen

(Amlinger *et al*., 2003 and Bavec *et al*., 2006). Bhavalkar (1991) also reported that vermicompost is a rich source of macro and micronutrients, vitamins, growth hormones and micro flora. The earthworms in vermicompost stimulate the microbial activity, which enhances the transformation of soluble nitrogen into protein preventing their loss by leaching to the lower horizons of the soil (Nowak, 1970). Vermicompost is also rich in bacteria like *Azotobacter*, *Azotspirillum* besides number of actinomycetes which help in plant growth. This might have favoured the vegetative growth. Similarly, poultry manure in this study might have served as better substrate for PSB and might have favoured higher microbial activity. Increase in vegetative growth may be attributed to increased availability of phosphorous due to PSB.

The growth parameters such as AGR and CGR indicate the development of crop in a logical sequence and elucidate the causes for difference in yield through the events that had occurred earlier in growth (Anonymous, 2004). The absolute growth rate (AGR) (table-34) for plant height increased rapidly between 25-50 DAS and thereafter decreased between 50-75 DAS, whereas the crop growth rate, an indicator of dry matter production per unit time increased with age of crop recording a maximum between 50-75 DAS. The treatments *viz*., T_7: 75 % RDF + PM + *Rhizobium* + PSB, T_2: 100 % RDF + *Rhizobium* + PSB, T_5: 75 % RDF + VC + *Rhizobium* + PSB recorded higher values of AGR for plant height but were on par with T_1, T_3, T_6 and T_8.The increase in AGR for plant height at 25-50 DAS was also reported in fenugreek with application of vermicompost and poultry manure by Srinivas (2004). The increase in the growth parameter such as AGR for plant height in the crop supplied with 75 % RDF + PM + *Rhizobium* + PSB (T_7) and 75 % RDF + VC + *Rhizobium* + PSB (T_5) could be attributed to the higher availability of nitrogen, other nutrients and plant hormones from vermicompost and poultry manure in combination with inorganic fertilizers. However, in this study with respect to CGR no significant differences could be observed among the treatments and CGR remained unaffected.

The lower values for vegetative growth in plant height and dry matter production in treatments, T_4: 50 % RDF + FYM + *Rhizobium* + PSB and T_{10}: 50 % RDF + NC + *Rhizobium* + PSB may be attributed to the shortage/deficiency of nitrogen which might have increased the ABA levels in all parts of the shoot, root and xylem exudates (Krauss,1978) and dropping the gibberellic acid levels of the shoots and decreased in production and export of cytokinins from roots to shoot and leaves ultimately resulting in reduced growth (Krauss and Marchner, 1982). It could also be attributed to inadequate and untimely nitrogen supply that might have also resulted in shorter plants with a concomitant reduction in vegetative growth.

5.2.3 Seed yield and yield attributes

In the present experiment, the seed yield and yield attributes were significantly influenced by the integrated use of organic manures, inorganic fertilizers and biofertilizers in an INM combination.

If per plant yields (table-48) are considered, significantly higher seed yield plant^{-1} was recorded by T_5: 75 % RDF + VC + *Rhizobium* + PSB (4.13 g) as compared to other treatments and it was on par with T_2: 100 % RDF + R + PSB (4.10 g) and T_7: 75 % RDF + PM + *Rhizobium* + PSB (4.05 g). Further it was observed that T_5, T_2 and T_7 recorded 19.85 %, 19.26 % and 18.27 % increase in seed yield plant^{-1} respectively over control (T_1). The seed yield plant^{-1} was lowest in T_{10} followed by T_4.

The results (table-49) of seed yield on per hectare basis revealed that significantly highest seed yield in fenugreek was recorded by the application of T_2:

100 % RDF + *Rhizobium* + PSB followed by T_5: 75 % RDF + VC + *Rhizobium* + PSB, T7: 75 % RDF + PM + *Rhizobiun* + PSB and T_1: 100 % RDF. The treatments *viz.*, T_2, T_5, T_7 recorded grain yield of 12.50, 11.83, 10.91 q ha^{-1} respectively. T_2, T_5, T_7 recorded 16.72 %, 12.00 % and 4.58 % increases in seed yield over control (T_1) respectively.

The increase in the seed yield with application of (T_2) 100 % RDF + *Rhizobium* + PSB could be due to an increase in the values of growth and yield attributing characters such as plant height, branch number, dry matter production and LAI, number of seeds pod^{-1}, harvest index, pod length, test weight, number of pods $plant^{-1}$, seed yield $plant^{-1}$ and shelling %. Increased nutrient uptake resulted in initial vegetative growth of the plant in terms of the plant height (harvest stage), number of leaves, dry matter content, leaf area and leaf area index. The same was also evident from the positive correlation recorded between yield and yield attributing characters such as number of pods $plant^{-1}$, seed yield $plant^{-1}$, pod length and test weight (table-62). Also the higher nutrient availability through inorganic fertilizers and also due to direct role of biofertilizers in nitrogen fixation might have contributed positively for overall improvement in growth and development of the plant.

It was observed that next to T_2, the highest seed yield of 11.83 q ha^{-1} (table-49) was recorded by T_5: 75 % RDF+ VC + *Rhizobium* + PSB followed by T_7 and T_1. T_5 recorded 7.77 % and 12.00 % increase in seed yield over T_7 and T_1 (control) respectively. The increase in the seed yield with application of 75 % RDF along with vermicompost and biofertilizers (*Rhizobium* and PSB) (T_5) could be due to increase in growth characters and yield attributing characters such as pod length, test weight, seed yield $plant^{-1}$ and better pod number, seeds pod^{-1} and harvest index. Further, the higher plant (harvest stage) and better leaf production, dry matter content, AGR and plant height, LA and LAI also positively contributed for initial vegetative growth of the plant. The same was also evident from positive and significant correlation registered between yield and number of leaves, dry matter content, pod number, number of seeds and test weight (table-62). Similar beneficial effect of vermicompost on grain yield of fenugreek was also reported by Kamalesh *et al.* (2006). The increase in yield with application of vermicompost in tomato was also reported by Prabhakaran (2003). Vermicompost is rich source of macro and micronutrients, growth hormones and microflora (Bhawalkar, 1991). The earthworm derived nitrogen could supply 30 % of the total crop requirements as it is potential source of readily available nutrients for plant growth (Curry and Byrne, 1992). The phosphorous content in vermicompost is higher than the phosphorus content in FYM (Shinde *et al.*, 1992). Further, it also contains micronutrients like Fe (178 ppm), Mn (24.6 ppm), Zn (19.2 ppm) and Cu (7.6 ppm).

Similarly, application of (T_7) 75 % RDF along with poultry manure and biofertilizers (*Rhizobium* and PSB) resulted in higher seed yield of 10.91 q ha^{-1} (table-49) as compared to other treatments except T_2 and T_5. The above treatment (T_7) registered 12 %, 17.2 %, 18.27 % and 4.5 % increase in number of pods $plant^{-1}$, number of seeds $plant^{-1}$, test weight and grain yields ha^{-1} respectively over control (100 % RDF). The better performance of T_7: 75 % RDF + PM + *Rhizobium* + PSB could be due to increased vegetative parameters such as AGR for plant height, leaf area, leaf area index, number of leaves and dry matter content and yield attributing characters like number of pods, pod length, number of seeds pod^{-1}, test weight and seed yield $plant^{-1}$. The same is also evident from positive and significant correlation between yield and number of leaves, dry matter content, pod number, number of seeds and test weight (table-62). Significant and positive correlation among yield and yield attributing characters was also reported by Kole and Mishra (2006) and Jat (2004 a). A similar increase in number of pods $plant^{-1}$, number of seeds $plant^{-1}$, test weight and grain yield in fenugreek with application of poultry manure was also reported by earlier authors (Anonymous, 2004).

The higher seed yield associated with application of vermicompost and poultry manure (T_5 and T_7) in combination with nitrogenous fertilizers may be attributed to higher mineralization of various essential elements due to increased microbial activity and organic colloids resulting in better availability and uptake of these elements ultimately resulting in increased photosynthetic activity. The increased photosynthetic activity in turn would have increased assimilation of photosynthates resulting in a higher C : N ratio (Smith, 1950). An increase in the higher C : N ratio might have helped in increasing number of pods, test weight and seed number pod^{-1} ultimately resulting in higher yields. Similar results were also reported by Deora and Jitendar Singh (2008) with application of vermicompost in fenugreek. These results were also found to be in conformity with the findings of Rayar (1986), Vivekananda (1988), Yadav *et al.* (1991), Chawale *et al.* (1993), Christopherlourduraj *et al.* (1996), Asha *et al.* (1995) Deshmukh and Dev (1995), Agasimani (1996) in ground nut and Kamlesh *et al.* (2006) in fenugreek.

In this study, the treatment, T_1 (control) comprising of only 100 % recommended dose of fertilizers recorded seed yield of 10.41 q ha^{-1} and was found to be on par with T_2, T_5 and T_7 (table-49). The increased seed yield in T_1 over other treatments *viz*., T_3, T_4, T_6, T_8, T_9, T_{10} may be attributed to increased initial vegetative growth and yield attributes due to higher nutrient availability through inorganic fertilizers.

In this experiment, the treatments, T_3, T_8 and T_9 recorded intermediate values for seed yield. Similarly, the treatments; T_{10}, T_6 and T_4 recorded lower grain yield of 8.33, 8.41 and 8.66 q ha^{-1} respectively. The reduction of yield in the above treatments may be due to poor initial vegetative growth and dry matter accumulation leading to reduction in yield attributing characters like lower per plant yield, test weight and number of pods particularly in treatments T_{10} and T_4 and lower nutrient uptake Similarly, the decreased yield in T_6 may be due to reduction in leaf area leading to reduction in number of pods.

Further, it was observed that T_7: 75 % RDF + PM + *Rhizobium* + PSB registered higher grain shelling % (42.58 %) over other treatments and it was on par withT_2: 100 % RDF + *Rhizobium* + PSB. The treatments, T_7 and T_2 recorded 7.44 % & 5.40 % increase in grain shelling % over control (T_1) respectively. It was noticed that the treatments; T_5, T_7 and T_2 registered higher values of 12.88 g, 12.43 g and 11.70 g test weight (table-47) respectively. Further it was observed that T_5 recorded 18.20 % increase in test weight over control (T_1). The increased test weight might have lead to higher grain shelling % in T_7 and T_2. The higher test weight in T_5, T_7 and T_2 may be attributed to the accumulation of stored food material in endosperm of seed as influenced by the combination of organic manures and nitrogen application in split doses resulting in better translocation and accumulation of stored food material in the endosperm. The present findings are in accordance with Abusaleha (1992 b) who reported increased seed weight in okra with poultry manure and nitrogen fertiliser combination.

The biological yield (table-50) was found to be significantly highest in T_2 and it was at par with T_1, T_3, T_5 and T_7. There were no significant differences among treatments with respect to straw yield (table-51). Similarly, the highest value for harvest index (HI) was also noticed in T_2: 100 % RDF + *Rhizobium* + PSB (27.46) followed by T_5 (27.25). The efficient partitioning of dry matter to reproductive structures and economic sink might have led to higher test weight resulting in increased harvest index.

5.2.4 Nutrient content in seed and straw and its uptake

5.2.4.1 Nitrogen

The data presented clearly indicate that nitrogen uptake (table-55) in the plant was found to be maximum with application of 100 % RDF + *Rhizobium* + PSB *i.e.*, T_2 followed by 75 % RDF + VC + *Rhizobium* + PSB: T_5 and 75 % RDF + PM + *Rhizobium* + PSB: T_7 and the above treatments were on par with each other. The lowest uptake was registered by T_{10}: 50 % RDF + NC+ *Rhizobium* + PSB: T_{10} followed by T8: 50 % RDF + PM + *Rhizobium* + PSB, while the rest of the treatments recorded intermediate values.

The nitrogen % in seed (table-53) also exhibited similar trend as that of nitrogen uptake by the plant. However, in addition to T_2, T_7, and T5 the combination of FYM and 75 % RDF with biofertilizers (T_3) also recorded better nitrogen % in seed comparable with above treatments. Application of 100 % RDF with biofertilizers (T_2) recorded significantly higher nitrogen % in straw (table-54) as compared to other treatments and it was also comparable with control (100 % RDF).

The availability of higher contents of nitrogen with a concomitant improved growth of plant might have resulted in higher uptake (Nehra *et al.* 2006). The lowest uptake especially with 50 % RDF + NC + *Rhizobium* + PSB (T_{10}) may be attributed to reduced growth of the plant at early stage due to slow release of nitrogen from neem cake.

A higher increase in nitrogen uptake particularly in T_2 noticed here is reasonable and can be attributed to direct addition of nitrogen in the form of fertilizers. Similarly, increase in nitrogen uptake by INM treatments (T_5, T_7) may be attributed to improved availability of nutrients by mineralization through vermicompost and poultry manure (T_5 and T_7) and fixation of atmospheric nitrogen by *Rhizobium* leading to greater availability of nitrogen to the plant. The results are in conformity with the findings of Jat *et al.* (2006) who reported increase in nitrogen uptake with application of farmyard manure along with *Rhizobium* in fenugreek.

5.2.4.2 Phosphorus

The total phosphorus uptake by the plant was found to be highest (table-55) with 100 % RDF + *Rhizobium* + PSB: T_2 followed by T_5 and T_7. On the other hand, lowest uptake was observed in T_{10} which was at par with T_4, T_6 and T_8. The rest of the treatments showed intermediate values.

Phosphorus % in seed (table-53) was also higher in T_5, T_7 and T_9 and these treatments were on par with T_3 and T_2. Similarly, T_5 recorded highest phosphorus % in straw (table-54) and it was on par with T_1, T_2, T_3, T_7 and T_9. T_4 recorded lowest phosphorus % in straw. The increase in phosphorus uptake with application of 100 % RDF + *Rhizobium* + PSB may be attributed to improvement of phosphorous availability due to the action of PSB. It has synergistic effect towards *Rhizobium* which leads to *Rhizobium* proliferation. The effect of *Rhizobium* and PSB by release of growth promoting substances and increased availability which leads to greater root growth which causes greater absorption of nutrients from the soil. These results are in conformity with the findings of Thakare *et al.* (2002). Similarly, Jat (2004) also reported 6 % increase in phosphorus uptake over control with application of *Rhizobium* + PSB in fenugreek.

The increase in phosphorous uptake in INM treatments (T_5 andT_7) may be attributed to applied organic matter which might have led to the formation of coating on the sequioxides, because of which phosphate fixing capacity of the soil might have been reduced in organic manure applied plots (Reddy and Reddy, 1998).

Though higher amount of organic manures were applied in T_{10} and T_4 treatments, the uptake was found to be poor which might be due to slow release of nitrogen from organic manures leading to relatively poor growth of the plant particularly at 50 DAS.

5.2.4.3 Potassium

The data (table-55) relating to the effect of organic manures, inorganic chemicals and biofertilizers on potassium uptake by the plant showed significant variation among treatments. The application of 100 % RDF + *Rhizobium* + PSB: T_2 registered the highest potassium uptake and it was at par with 75 % RDF + VC + *Rhizobium* + PSB: T_5, 75 % RDF + PM + *Rhizobium* + PSB (T_7), 75 % RDF + FYM + *Rhizobium* + PSB (T_3) and 75 % RDF + NC + *Rhizobium* + PSB (T_9). Therefore, it is evident from above data that all treatments with 75 % RDF showed higher values for potassium uptake. Further, application of 50 % RDF + NC and biofertilizers (T_{10}) recorded lowest uptake and it was at par with 100 % RDF (T_1), 50 % RDF + FYM + *Rhizobium* + PSB (T_4), 50 % RDF + VC + *Rhizobium* + PSB (T_6) and 50 % RDF + PM + *Rhizobium* + PSB (T_8).

The potassium content in seed (table-53) was also reported to be higher with 100 % RDF + biofertilizers (T_2) and it was comparable with 75 % RDF + FYM + *Rhizobium* + PSB (T_3). Similar to total potassium uptake, the treatments with 75 % RDF + organic manures + biofertilizers also recorded higher values for potassium % in seed than the treatment with 50 % RDF with organic manures and biofertilizers. Further, the potassium % in straw (table-54) was reported to be higher with 75 % RDF+ NC + *Rhizobium* + PSB (T_9) and it was at par with 75 % RDF + PM +

Rhizobium + PSB (T_7).

The lowest values were reported in T_{10}, T_8 and T_6 treatments for potash % in seed and T_8 and T_6 treatments for potash % in straw. The lower contents of potassium in seed and straw with poor growth might have resulted in reduced uptake of potassium by the plant particularly in T_{10}, T_8, T_6 and T_4 treatments.

In general the treatments with 75 % RDF with *Rhizobium* and biofertilizers performed on par with 100 % RDF with bioferrtilizers in case of potassium uptake. The increased potassium uptake with higher nitrogen fertilization has been earlier reported by Subbaiah *et al.* (1982) and Kaminwar and Rajagopal (1993). The higher uptake of potassium due to application of organic manures may be attributed to the beneficial effect of organic manures on reduction of potassium fixation and interaction of organic manures with clay to release potassium ions from the non exchangeable fraction to the available pool (Reddy and Reddy, 1998).

5.2.5 Available nitrogen, phosphorus and potassium in soil after harvest of fenugreek

A consideration of results (table-56) on soil analysis for nutrients revealed that significant differences among treatments were recorded in available nitrogen phosphorus whereas, no significant differences were reported with respect to available potassium in the soil.

The highest available nitrogen (195.70 kg ha^{-1}) was recorded with application of 75 % RDF + PM + *Rhizobium* + PSB (T_7) followed by application of 75 % RDF + NC + *Rhizobium* + PSB (T_9). The treatments *viz.*, T_6, T_5, T_3, T_8 were on par with T_9. Jat and Shakhawat (2003) also reported increase in available nitrogen in soil with application of *Rhizobium* + PSB in fenugreek. The increase in available nitrogen in soil in T_7 and T_9 treatments may be attributed to inoculation of *Rhizobium* with higher nitrogen fixation capacity and also due to slow release of nitrogen from organic manures thus improving the available nitrogen in soil even after harvest of fenugreek.

Similarly, increase in available phosphorus in soil was also reported with application of 75 % RDF + PM + *Rhizobium* + PSB (T_7) followed by 50 % RDF + VC + *Rhizobium* + PSB (T_6). The treatments, T_8 and T_5 were on par with each other. The increase in soil phosphorus was also reported by Jat *et al.* (2003) with application of *Rhizobium* + PSB in fenugreek. The build up of available phosphorus in the soil could be due to the organic acids formed during decomposition of organic matter (poultry manure and vermicompost) leading to increase in available phosphorous in the soil and PSB which might have solublized the residual and insoluble phosphate available in soil and converting them in to orthophosphates in the soil water solution (Gaur, 1982). Similarly, poultry manure used in the investigation was found to be superior in phosphorus content which might have also contributed for improvement in available phosphorus in the soil.

5.2.6 Quality parameters

In this study the effect of various INM treatments on grain quality was assessed in terms of crude fibre, diosgenin and crude protein content in the seed.

5.2.6.1 Crude protein content in seed

The higher protein content (table-57) in the seed can be considered beneficial for human consumption since the seed is used as condiment. It is evident from the data that the highest protein content was observed in T_2: 100 % RDF with biofertilizers (*Rhizobium* + PSB) but it was at par with 75 % RDF with poultry manure + biofertilizers (T_7), 75 % RDF with vermicompost + biofertilizers (T_5) and 75 % RDF + FYM + biofertilizers (T_3). The treatments with 50 % RDF + FYM +

Rhizobium + PSB (T_4), 75 % RDF + NC + *Rhizobium* + PSB (T_9) and 100 % RDF (T_1) were also at par with each other. The lowest protein content was noticed in T_{10}: 50 % RDF + NC + *Rhizobium* + PSB followed by T_8. The higher protein content observed in treatments *i.e.*, T_2, T_7 and T_5 might be due to the fact that protein content of seed would be indirect effect of its nitrogen content. The improvement in nitrogen content in seed may be attributed to higher uptake due to increased availability of nitrogen from *Rhizobium* and 75 % recommended dose of nitrogenous fertilizer. The results are in agreement with the findings of Sharma *et al.* (2006) in fenugreek. However, further study is required to confirm these trends.

5.2.6.2 Crude fibre content in seed

The crude fibre % in seed (table-58) was found to be higher with application of 75 % RDF + NC + *Rhizobium* + PSB (T_9) and it was comparable with 50 % RDF + NC + *Rhizobium* + PSB (T_{10}) and 75 % RDF + VC + *Rhizobium* + PSB (T_5). The lowest value was reported in T_4: 50 % RDF + FYM + *Rhizobium* + PSB and the treatments, T_6, T_1, T_7 and T_8 were at par with T_4. Similar increase in crude fibre content with the application of vermicompost was also reported in cucumber (Bindhya, 2004). An increase in the crude fibre content would be advantageous for human consumption as it adds roughage to human diet. However, the reason for an increase in fibre content is not understandable and requires further study.

5.2.6.3 Diosgenin content in seed

In this study, the combination of inorganic fertilizers, organic manures and biofertilizers however did not influence the 'diosgenin' content in fenugreek seed (table-59). Further, it appears from earlier reports that the diosgenin content could be a varietal character and may not be influenced by nutrient application (Bhavasar *et al.*, 1980).

A perusal of the results in this study indicate that the quality in fenuegreek in terms of crude fibre and protein content in seed can be improved by certain INM treatments *viz*., T_9, T_{10} and T_5 (crude fibre) and T_2, T_7 and T_5 (crude protein). Fenugreek is of use as spice and condiment in cooking and the results do have profound practical significance in the light of human nutrition. However, further research is required to confirm the above trends.

5.2.7 Benefit : cost ratio (BCR)

It was observed (table-61)that highest benefit cost ratio (1.54) was recorded by application of 100 % RDF + *Rhizobium* + PSB (T_2) followed by 100 % RDF: T_1 (1.19 B:C ratio) and 75 % RDF + PM + *Rhizobium* + PSB : T_7 (1.12 B:C ratio). Though, the application of 75 % RDF + VC + *Rhizobium* + PSB (T_5) recorded higher grain yield than 75 % RDF + PM + *Rhizobium* + PSB (T_7), the B : C ratio was found to be lower due to high cost of vermicompost. Similarly, the lowest B : C ratio was observed in T_6.

Keeping the seed yield and B : C ratio and nutritional values of seed and straw in view, it can be concluded from the results of this experiment that an application of (T_5) 75 % RDF + VC + *Rhizobium* + PSB followed by T_7 *i.e*., 75 % RDF + PM + *Rhizobium* + PSB can be recommended to the farmers of fenugreek for the agroclimate of Andhra Pradesh.

Therefore, an integrated approach with specific emphasis on organic manures and biofertilizer components along with chemical fertilizers may be encouraged keeping quality of produce and soil health in view for popularising the cultivation of fenugreek under agroclimate of Andhra Pradesh.

Future line of work

1. Application of organic manures centers on fertilizing the soil rather than the crop. Soil's capacity to act as sink for organics within safer limits of environmental quality needs to be worked out through sustained experimentation. Therefore, basic data on nutrient cycles, flow and flux of nutrients operating in the system on their conversion to the organics need to be generated and quantified.
2. As there is positive response in seed yield to application of organic manures in combination rather than application of manures alone, further research may be taken up to work out various combinations with organic manures to establish synchronicity between crop demand and nutrient supply from organic manures and to standardize the optimum and suitable combination for Agroclimatic conditions of Andhra Pradesh.
3. Under integrated nutrient management, efforts should be made to understand and to exploit the interaction effect between the synthetic fertilizers and organic manures and to evaluate the comprehensive performance of organic manures and chemical fertilizers in spices production with reference to especially sustainability of yields in fenugreek.
4. The residual effects of soil fertility as affected by various organic manures and INM treatments need further study.

Chapter VI

SUMMARY

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SUMMARY

Present investigation entitled **'Studies on the effect of organic sources and Integrated Nutrient Management on growth, yield and quality of fenugreek'** was conducted at Horticultural Research Station, Kovvur (A.P). The study was divided into two field experiments and conducted for two *rabi* seasons (2008-09 and 2009-10) of each. In experiment-I entitled **'Effect of different organic sources on growth, yield and quality of fenugreek'** organic manures *viz.*, vermicompost (VC), farmyard manure (FYM), poultry manure (PM) and neem cake (NC), their combinations *viz.*, VC + FYM, VC + PM, VC + NC, FYM + PM, FYM + NC and PM + NC were evaluated for growth, yield and quality. The organic sources were compared with two inorganic fertilizer doses *viz.*, 100 % recommended dose of inorganic fertilizers (RDF) and 50 % RDF.

In experiment - II entitled **'Effect of Integrated Nutrient Management on growth, yield and quality of fenugreek'** the effects of inorganic fertilizers, certain organic manures *viz.*, vermicompost, farm yard manure, poultry manure and neem cake combined with biofertilizers like *Rhizobium* and phosphate solubilizing bacteria (PSB) with an INM concept on growth, yield and quality were studied. Results obtained from the above experiments are summarized here under:

EXPERIMENT-I

Effect of different organic sources on growth, yield and quality of fenugreek.

1 Application of 100 % RDF (T_{12}) has shown significant effect on vegetative characters and recorded higher plant height, number of leaves, dry matter production, leaf area, leaf area index, CGR for dry matter production (25-50 DAS).

$_6$) vermicompost + poultry manure and (T_8) farmyard manure + poultry manure exhibited profound influence on vegetative parameters and recorded better plant height, number of leaves, dry matter production, leaf area, leaf area index, AGR for plant height and CGR for dry matter production comparable with that of (T_{12}) 100 % RDF. The plant height in T_7, dry matter production in T_3 and T_4 and leaf area in T_4 and T_7 treatments were lower and the remaining treatments recorded intermediate values.

2 The application of 100 % RDF (T_{12}) recorded higher values for seed yield and yield attributing characters such as number of pods plant^{-1}, number of seeds pod^{-1}, test weight and seed yield plant^{-1} resulting in higher seed yield (12.01 q ha^{-1}). Next to (T_{12}) 100 % RDF, the better pod length, number of pods plant^{-1} were recorded with the application of (T_8) farmyard manure + poultry manure resulting in higher seed yield (9.60 q ha^{-1}). Similarly, the treatment consisting of (T_6) vermicompost + poultry manure also exhibited better performance in terms of test weight and seed yield plant^{-1} leading to higher seed yield (9.55 q ha^{-1}) next to 100 % RDF. The treatments; T_8 and T_6 recorded 4.58% and 4.00 % increase in yield over T_{11}: 50 % RDF. It was also noticed that T_4 and T_9 recorded lower seed yields and the rest of the treatments recorded intermediate values. With respect to test weight and seed yield plant^{-1}, T_{12} recorded higher values followed by T_6. Similarly, the grain shelling % was found to be higher in T_8 and T_7. Further, it was observed that T_{12}, T_6, T_8 and T_{11} recorded higher straw yield and biological yield. However, in case of grain filling % no significant differences were observed among the treatments. Further, with respect to harvest index all the treatments except T_6 were on par with

$_{12}$, T_8 and T_{11} recorded higher B : C of 1.46, 1.02 and 0.98 respectively.

3 Data pertaining to nutrient uptake in fenugreek with application of different organic manures revealed that application of (T_{12}) 100 % RDF significantly increased the NPK uptake followed by T_8 (FYM + PM) and T_6 (VC + PM). Similarly, in addition to above treatments, 50 % RDF also recorded better uptake of phosphorus and potassium comparable with T_8 and T_6. The total uptake of nitrogen by the plant in T_2 and T_9; phosphorous uptake in T_4 and T_9 and potassium uptake in T_1, T_4 and T_9 were found to be lower. The treatments *viz.*, T_{12}, T_6, T_8 for nitrogen content in seed, T_4 for phosphorus content in seed and T_8, T_{12} for crude protein content in seed recorded higher values. Similarly, nitrogen content in straw was also reported to be higher in T_4 and T_8.

4 Significant differences were not observed in available nitrogen and potassium in the soil after harvest of fenugreek. But, with regards to available phosphorus in the soil, significant differences were however observed among the treatments.

5 Among quality attributes, crude protein content in seed was significantly influenced by the application of organic manures and their combinations. The treatment, 100 % RDF recorded highest crude protein (16.61%) as compared to other treatments. However, the treatments, T_6 (16.19 %), T_5 (15.98 %) and T_8 (15.87 %) also recorded better crude protein % comparable with (T_{12}) 100 % RDF. Similarly, the crude fibre (7.75 %) in seed was significantly higher with application of (T_9) farm yard manure + neem cake and it was at par with (T_{12}) 100 % RDF and (T_8) farm yard manure + poultry manure. It was found that the diosgenin content was not affected by various treatments.

EXPERIMENT-II:

Effect of Integrated Nutrient Management on growth, yield and quality of fenugreek.

1 Application of 100 % RDF with *Rhizobium* and PSB (T_2) has shown significant effect on vegetative characters and as such higher values were registered for plant height, dry matter production at harvest stage, leaf production (75 DAS), number of branches (75 DAS), leaf area, leaf area index (75 DAS) and AGR for plant height (25-50 DAS). Similarly, next to T_2: 100 % RDF + *Rhizobium* + PSB, T_5: 75 % RDF + VC + *Rhizobium* + PSB and T_7: 75 % RDF + PM + *Rhizobium* + PSB also recorded higher plant height, dry matter production at harvest stage, number of leaves (75 DAS), number of branches (75 DAS), leaf area, leaf area index and AGR for plant height (25-50 DAS). However, the treatments; T_{10} and T_4 recorded lower plant height and dry matter production. Similarly, T_4 and T_7 also recorded lower value for leaf area and LAI. The remaining treatments recorded intermediate values for vegetative characters.

2 Application of (T_2) 100 % RDF + *Rhizobium* + PSB recorded higher grain yield of 12.50 q ha^{-1} as compared to rest of the treatments. The above treatment recorded higher values for yield attributing characters also such as number of seeds pod^{-1}, harvest index, straw yield and better pod length, test weight, number of pods $plant^{-1}$, seed yield $plant^{-1}$ and grain shelling % . Further, the number of pods $plant^{-1}$, grain shelling % were reported to be highest with application of (T_7) 75 % RDF + PM + *Rhizobium* + PSB, whereas the pod length, test weight, seed yield $plant^{-1}$ were found to highest with application of 75 % RDF + VC + *Rhizobium* + PSB (T_5).

$_5$ and T_7) recorded higher seed yield of 11.83 q ha^{-1} and 10.91 q ha^{-1} respectively. The treatments; T_2, T_5 and T_7 recorded 16.72 %, 12 % and 4.58 % increase in grain yield over T_1 (Control) respectively. In this study, lower yields were recorded by T_{10}, T_6 and T_4. The remaining treatments recorded intermediate values. The yield attributing characters such as number of seeds pod^{-1}, test weight and seed yield $plant^{-1}$ were found to be higher in T_2, T_7 and T_5 as compared to other treatments. Similarly, grain shelling % was highest in T_7 followed by T_2. Further, T_2, T_5, T_1 and T_3 recorded higher biological yield. However, no significant differences were observed in treatments with respect to straw yield. The treatments *viz.*, T_8, T_{10} for number of seeds pod^{-1} and T_8, T_6 for grain shelling % and T_{10}, T_8, T_4 for test weight and T_5, T_2, T_7 for seed yield $plant^{-1}$ and the treatments *viz.*, T_2, T_5, T_1, T_3 for biological yield recorded lower values. The treatments *viz.*, T_2, T_1, T_7 recorded higher B : C ratio of 1.54, 1.19 and 1.12 respectively.

3 The data pertaining to nutrient uptake in fenugreek with application of different organic manures revealed that application of (T_2) 100 % RDF + *Rhizobium* + PSB significantly increased the NPK uptake followed by T_5 (75 % RDF + VC + *Rhizobium* + PSB) and T_7 (75 % RDF + PM + *Rhizobium* + PSB). Similarly, in addition to above treatments, T_3 and T_9 also recorded better uptake of potassium. Similarly, the total uptake of nitrogen by the plant in T_{10}, T_8 and T_6; phosphorous uptake in T_{10}, T_4, T_6 and T_8 and potassium uptake in T_{10}, T_6 and T_4 were found to be lower. Further, the treatments *viz.*, T_2, T_7, T_5 for nitrogen % in seed, T_5, T_7 and T_9 for phosphorus % in seed and T_2 and T_3 for potassium % in seed recorded

higher values. The nitrogen, phosphorous and potassium content in straw was reported to be higher in T_2, T_5 and T_9 respectively.

4 Soil analysis for major nutrients after harvest of fenugreek revealed that significant differences were recorded in respect of available nitrogen and phosphorous whereas, no significant differences were recorded in case of available potassium in the soil.

5 With respect to grain quality, highest crude protein % was noticed in T_2: 100 % RDF + *Rhizobium* + PSB and it was at par with T_5: 75 % RDF + VC + *Rhizobium* + PSB, T_7: 75 % RDF + PM + *Rhizobium* + PSB and T_3: 75 % RDF + FYM + *Rhizobium* + PSB %. Interestingly, the crude fibre % in seed was found to be highest with T_9: 75 % RDF + NC + *Rhizobium* + PSB and it was at par with T_{10} and T_5. However, no significant differences were noticed among the treatments in case of diosgenin content in seed. Further, it was observed that T_{10}, T_8 for crude protein % in seed and T_4 and T_6 for crude fibre % in seed recorded lower values for above quality parameters.

CONCLUSION

From the foregoing results of expt-I, it can be concluded that application of 100 % RDF (60-50-50 NPK kg ha^{-1}) had promoted the vegetative growth and recorded highest seed yield. However, the present investigation was conducted with the prime objective of testing the effect of organic manures and their combinations on growth, yield, quality and nutrient uptake of fenugreek by comparing with inorganic fertilizer applications. Accordingly, among organic manures the combination of (T_8) farmyard manure @ 2.8 t ha^{-1} + poultry manure @ 3.5 t ha^{-1} and (T_6) vermicompost @ 3.3 t ha^{-1} + poultry manure

@ 3.5 t ha^{-1} were found to be superior in vegetative growth, yield, nutrient uptake and protein% in seed. Similarly, a higher benefit: cost ratio (1.02) was also registered by (T_8) farmyard manure @ 2.8 t ha^{-1} + poultry manure @ 3.5 t ha^{-1}.

Considering the seed yields and B : C ratio and nutritive value of seed and straw in view, it can be concluded that application of T_8 : Farm yard manure @ 2.8 t ha^{-1} + Poultry manure @ 3.5 t ha^{-1} was found promising and can be recommended for obtaining higher yield with improved quality of fenugreek.

Further, the results of expt-II revealed that 100 % RDF along with biofertilizers like *Rhizobium* and PSB recorded highest grain yield due to improvement in growth and yield atributing characters. Similarly, application of (T_5) 75 % RDF + VC+ *Rhizobium* + PSB and (T_7) 75 % RDF + PM + *Rhizobium* + PSB also recorded better seed yield comparable with 100 % RDF + *Rhizobium* + PSB with increased nutrient uptake and reasonable grain quality. Further, a higher B : C ratio was also achieved by application of 100 % RDF + *Rhizobium* + PSB (1.54) followed by 100 % RDF (1.19) and 75 % RDF + poultry manure @ 3.5 t ha^{-1} + *Rhizobium* + PSB (1.12) on account of better yield and lower cost of cultivation.

Considering the higher seed yield and nutritional quality in view application of (T_5) 75 % RDF + VC+ *Rhizobium* + PSB and (T_7) 75 % RDF + PM + *Rhizobium* + PSB was found promising and can be recommended to the farmers for popularizing the cultivation of fenugreek under agroclimatic conditions of Andhra Pradesh.

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*Originals not seen

APPENDIX

Appendix - I: Weekly meteorological data during the crop period (2008-09 and 2009-10)

` Standard week	Date and month	Mean Temperature (^0C)				Mean relative humidity				Rainfall (mm)		Rainy days	
		2008-09		2009-10		2008-09		2009-10					
		Max.	Min.	Max.	Min.	7.16 hr.	14.00 hr.	7.16 hr.	14.00 hr	2008-09	2009-10	2008-09	2009-10
42	15Oct.- 21Oct.	34.57	24.14	35.42	23.42	78.71	55.28	74.14	55.71	-	-	-	-
43	22Oct.-28 Oct.	32.71	22.85	35.28	21.85	80.00	66.14	66.71	44.71	10.8	-	2	-
44	29 Oct.- 4 Nov.	34.41	20.42	34.71	23.14	74.28	51.57	70.28	50.14	-	-	-	-
45	5 Nov.-11 Nov.	34.71	20.14	31.85	24.42	74.00	47.00	77.85	65.57	-	-	-	-
46	12Nov.- 18 Nov.	31.71	22.14	34.00	24.00	80.85	66.71	78.28	69.28	31.8	18.0	2	2
47	19Nov.- 25 Nov.	32.00	21.70	32.14	23.85	78.14	58.71	82.85	65.71	-	18.0	-	2
48	26Nov.- 2 Dec.	29.42	20.85	32.57	20.57	80.71	59.86	78.28	43.57	4.20	-	1	-
49	3 Dec.- 9 Dec.	32.42	20.28	32.57	21.42	80.42	52.14	78.00	48.85	-	-	-	-
50	10Dec.- 16 Dec.	32.84	20.28	31.85	20.71	79.57	51.00	76.57	51.28	-	-	-	-
51	17Dec.-23 Dec.	31.71	19.42	30.85	21.57	79.14	49.57	79.85	52.28	-	-	-	-
52	24Dec.- 31 Dec	32.37	19.00	32.42	18.57	83.50	53.50	74.42	41.57	-	-	-	-
1	1 Jan.-7 Jan.	30.57	19.14	33.00	18.85	85.71	52.28	80.42	53.85	-	-	-	-
2	8 Jan.-14 Jan.	30.28	19.85	32.00	22.71	82.00	55.28	88.42	64.85	-	2.9	-	-
3	14 Jan.-21 Jan.	30.42	18.57	32.14	21.14	81.00	49.71	87.71	52.14	-	6.2	-	1
4	22 Jan.-28 Jan.	31.14	18.71	29.14	18.85	84.57	49.14	82.00	50.71	-	-	-	-
Total Rainfall										46.8	45.1	5	5