ORGANIC CULTIVATION OF FENUGREEK

(*Trigonella foenum-graecum* L.)

SINDHURANI, J.

PALB 4227

DEPARTMENT OF HORTICULTURE

UNIVERSITY OF AGRICULTURAL SCIENCES

BENGALURU – 560 065

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Thesis submitted to the

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IN

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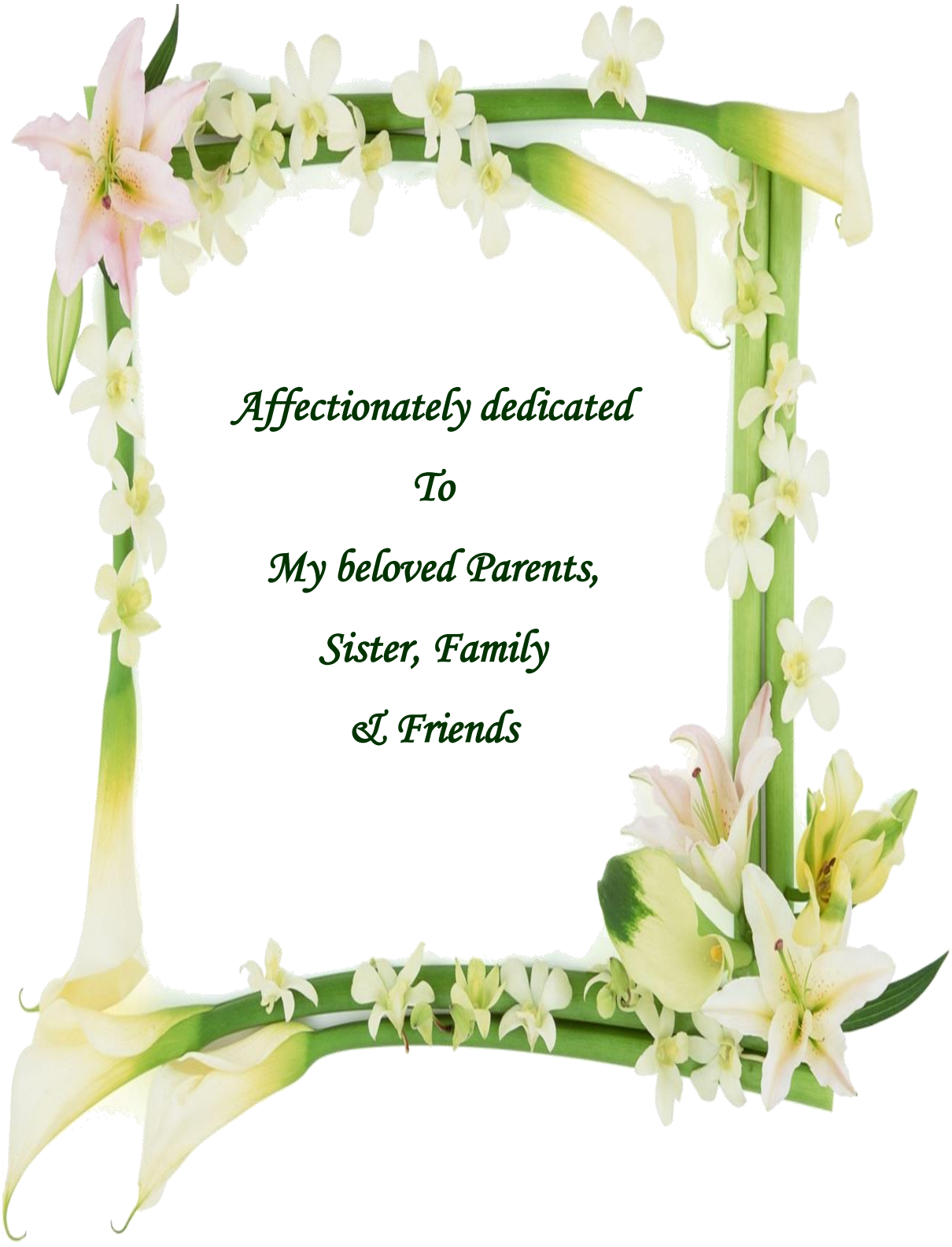
Affectionately dedicated
To
My beloved Parents,
Sister, Family
& Friends

DEPARTMENT OF HORTICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU – 560 065

CERTIFICATE

This is to certify that the thesis entitled **"Organic cultivation of fenugreek (*Trigonella foenum-graecum* L.)"** submitted by **Miss. SINDHURANI, J. ID No. PALB 4227,** in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (Agriculture) in HORTICULTURE** to the University of Agricultural Sciences, GKVK, Bengaluru, is a bonafide record of research work carried out by her during the period of her study in this university under my guidance and supervision and the thesis has not previously formed the basis of the award of any other degree, diploma, associate-ship, fellowship or any other similar titles.

Bengaluru
September, 2016

(B.S. Sreeramu)
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Bengaluru *(SINDHURANI, J.)*
September, 2016

ORGANIC CULTIVATION OF FENUGREEK

(*Trigonella foenum-graecum* L.)

SINDHURANI, J.

ABSTRACT

A field experiment on "Organic cultivation of fenugreek (*Trigonella foenum-graecum* L.)" was conducted at the Department of Horticulture, UAS, GKVK, Bangalore during *rabi* season of 2015-16. The treatments comprised of two levels of nitrogen (100 and 150 %), three organic manures like vermicompost, poultry manure and farm yard manure with and without *Rhizobium* seed treatment along with RDF as control. Application of 4.5 t ha^{-1} poultry manure + *Rhizobium* seed treatment recorded the maximum values for all growth, yield and quality parameters such as plant height (14.90 cm at 30 DAS, 36.07 cm at 60 DAS and at harvest), member of primary branches (3.90 at 30 DAS and 5.10 at 60 DAS and at harvest), number of pods per plant (32.50), number of seeds per pod (12.10), test weight of seeds (1.78 g / 100 seeds), seed yield (1567.69 kg ha^{-1}), straw yield (2331.48 kg ha^{-1}) and crude protein content (Leaves -12.43 % and seeds - 20.00 %). The highest gross (Rs. 125415 ha^{-1}) and net returns (Rs. 65473 ha^{-1}) were also obtained under the same treatment with a B:C ratio of 3.72. Thus, it can be inferred that application of poultry manure at 4.5 t ha^{-1} with *Rhizobium* seed treatment is better for realizing sustainable yield and good quality seeds in fenugreek.

September, 2016

Dept. of Horticulture
UAS, GKVK, Bengaluru

(B. S. Sreeramu)
Major Advisor

ಮೆಂತ್ಯೆ (*ಟ್ರೈಗೋನೆಲ್ಲ ಫೋನಂ–ಗ್ರಾಕಂ* ಎಲ್.) ಬೆಳೆಯ ಸಾವಯವ ಬೇಸಾಯ

ಸಿಂಧೂರಾಣಿ, ಜೆ.

ಸಾರಾಂಶ

ಮೆಂತ್ಯೆ ಬೆಳೆಯ ಸಾವಯವ ಬೆಳವಣಿಗೆಯ ಅಧ್ಯಯನವನ್ನು ತೋಟಗಾರಿಕಾ ವಿಭಾಗ ಗಾಂಧಿ ಕೃಷಿ ವಿಜ್ಞಾನ ಕೇಂದ್ರ, ಜಿಕೆವಿಕೆಯಲ್ಲಿ ೨೦೧೫–೧೬ ರ ಹಿಂಗಾರಿನಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಈ ಪ್ರಯೋಗವು ಎರಡು ಸಾರಜನಕ ಪ್ರಮಾಣಗಳು (೧೦೦ ಮತ್ತು ೧೫೦%), ಮೂರು ಸಾವಯುವ ಗೊಬ್ಬರಗಳು (ಎರೆಹುಳುಗೊಬ್ಬರ, ಕೋಳಿ ಗೊಬ್ಬರ ಮತ್ತು ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ), ರೈಜೋಬಿಯಂ ಬೀಜೋಪಚಾರ, ರೈಜೋಬಿಯಂ ಬೀಜೋಪಚಾರವಿಲ್ಲದೆ ಮತ್ತು ಅದರೊಂದಿಗೆ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಾಸಾಯನಿಕ ಗೊಬ್ಬರಗಳ ಉಪಚಾರಗಳನ್ನು ಒಳಗೊಂಡಿತ್ತು. ಹೆಕ್ಟೇರಿಗೆ ೪.೫ ಟನ್ ಕೋಳಿ ಗೊಬ್ಬರ + ರೈಜೋಬಿಯಂ ಬೀಜೋಪಚಾರ ಮಾಡಿದ ಉಪಚಾರದಲ್ಲಿ ಮೆಂತ್ಯೆದ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗೂ ಗುಣಮಟ್ಟ ಉತ್ತಮವಾಗಿತ್ತು. ಈ ಉಪಚಾರದಲ್ಲಿ ಗಿಡದ ಎತ್ತರ (೧೪.೯೦ ಸೆ. ಮೀ. ಬಿತ್ತನೆಯ ೩೦ ದಿನಗಳ ನಂತರ, ೩೬.೦೭ ಸೆಂ. ಮೀ. ಬಿತ್ತನೆಯ ೬೦ ದಿನಗಳ ನಂತರ, ೩೬.೦೭ ಸೆಂ. ಮೀ. ಕೊಯ್ಲಿಗೆ ಬಂದ ನಂತರ), ಗಿಡದ ಕೊಂಬೆಗಳ ಸಂಖ್ಯೆ (೩.೯೦ ಬಿತ್ತನೆಯ ೩೦ ದಿನಗಳ ನಂತರ, ೫.೧೦ ಬಿತ್ತನೆಯ ೬೦ ದಿನಗಳು ಮತ್ತು ಕೊಯ್ಲಿಗೆ ಬಂದ ನಂತರ), ಪ್ರತಿ ಗಿಡದಲ್ಲಿ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ (೩೨.೫೦), ಪ್ರತಿ ಕಾಯಿಯಲ್ಲಿ ಬೀಜಗಳ ಸಂಖ್ಯೆ (೧೨.೧೦), ಬೀಜಗಳ ತೂಕ (೧.೭ ಗ್ರಾಂ./೧೦೦ ಬೀಜಗಳು), ಬೀಜದ ಇಳುವರಿ (೧೫೬೭.೬೬ ಕಿ. ಗ್ರಾಂ. ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ), ಒಣಗಿದ ಸಸ್ಯದ ತೂಕ (೨೩೩೧.೪೮ ಕಿ. ಗ್ರಾಂ. ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ) ಮತ್ತು ಕಚ್ಚಾ ಪ್ರೋಟೀನ್ ಅಂಶ (ಎಲೆ – ೧೨.೪೩೧ % ಮತ್ತು ಬೀಜ – ೨೦ %) ಗರಿಷ್ಠ ಪ್ರಮಾಣದಲ್ಲಿರುವುದು ಕಂಡುಬಂದಿರುತ್ತದೆ. ಅಲ್ಲದೆ ಇದೇ ಉಪಚಾರದಲ್ಲಿ ಗರಿಷ್ಠ ಒಟ್ಟು ಆದಾಯ (ರೂ. ೧೨೫೪೪೧ ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ) ಮತ್ತು ನಿವ್ವಳ ಆದಾಯ (ರೂ. ೬೫೪೬೩ ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ) ಹಾಗೂ ಆದಾಯ ಖರ್ಚಿನ ಅನುಪಾತಗಳು ೩.೭೨., ಕಂಡುಬಂದಿದೆ. ಈ ಫಲಿತಾಂಶಗಳ ಪ್ರಕಾರ ಮೆಂತೆ ಬೆಳೆಗೆ ೪.೫ ಟನ್‌ಗಳನ್ನು ಕೋಳಿಗೊಬ್ಬರ + ರೈಜೋಬಿಯಂ ಬೀಜೋಪಚಾರ ಮಾಡಿದಾಗ ಇಳುವರಿ ಹಾಗೂ ಗುಣಮಟ್ಟ ಉತ್ತಮವಾಗಿರುತ್ತದೆ.

ಸೆಪ್ಟೆಂಬರ್, ೨೦೧೬

ತೋಟಗಾರಿಕಾ ವಿಭಾಗ (ಬಿ. ಎಸ್. ಶ್ರೀರಾಮು)

ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ, ಗಾ.ಕೃ.ವಿ.ಕೇ., ಬೆಂಗಳೂರು ಮುಖ್ಯ ಸಲಹೆಗಾರರು

Organic cultivation of Fenugreek (*Trigonella foenum-graecum* L.)

SindhuRani, J. and B. S. Sreeramu,
Department of Horticulture, UAS Bangalore, GKVK, Bengaluru-65

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an annual leguminous crop belonging to the family Fabaceae. It is locally known as *methi*. It is valued primarily for spice and also as a leafy vegetable and fodder. Rajasthan(77%) and Gujarat(12%) are the major fenugreek producing states in India.

Traditionally the nutrient management of fenugreek is done by the application of chemical fertilizers. Research works on many crops including seed spices have shown that excessive and imbalance use of chemical fertilizers and pesticides have deteriorated the physical, chemical and biological properties of soil. Moreover, the demand for quality seed spices all over the world is increasing which is possible to produce under organic farming.

Therefore an attempt was made to evaluate different organic sources of nutrition like vermicompost, Poultry manure and farm yard manure along with and without *Rhizobium* seed treatment to increase the growth and seed yield of fenugreek with the following objectives-

OBJECTIVES

- To study the effect of different organic manures on growth and seed yield of fenugreek.
- To workout the economics of fenugreek cultivation.

MATERIALS AND METHODS

The experiment was conducted at the Department of Horticulture, UAS, Bangalore during 2015-2016.

Experimental details-
No. of treatments- 13
No. of replications- 3
Design – RCBD
Spacing- 30cmx15cm
Plot size- 2.4mx1.5m
Season- *Rabi*
Situation- Irrigated condition
Variety- Ajmer Fenugreek-1

Treatment details:

T_1- 60:90:50 Kg NPK ha-1 (RDF)
T_2-100% N through VC without R seed treatment
T_3-150% N through VC without R seed treatment
T_4-100% N through PM without R seed treatment
T_5-150% N through PM without R seed treatment
T_6-100% N through FYM without R seed treatment
T_7-150% N through FYM without R seed treatment
T_8-100% N through VC with R seed treatment
T_9-150% N through VC with R seed treatment
T_{10}-100% N through PM with R seed treatment
T_{11}-150% N through PM with R seed treatment
T_{12}-100% N through FYM with R seed treatment
T_{13}-150% N through FYM with R seed treatment
(FYM- 10t ha^{-1} is common for all the treatments)

Note:
VC- Vermicompost
PM- Poultry manure
FYM- Farm Yard Manure
R- *Rhizobium*

RESULTS

Growth parameters like plant height and primary branches per plant were significantly influenced by different sources of organic manures.

The plant height and number of primary branches per plant was significantly higher in the treatment (T_{11}) with the application of poultry manure (4.5t ha^{-1}) with *Rhizobium* seed treatment followed by the treatment (T_8) with the application of vermicompost (3.5t ha^{-1}) with *Rhizobium* seed treatment.

The highest seed yield of 1567.69kg ha^{-1} was obtained in the same treatment (T_{11}) with the application of 4.5t ha^{-1} of poultry manure with *Rhizobium* seed treatment followed by (T_8) *i.e.,* 1514.08kg ha^{-1} with the application of 3.5t ha^{-1} vermicompost with *Rhizobium* seed treatment.

The economics is an important and ultimate factor which decides the optimum level of inputs to be used in the production of any crop. The cost of cultivation ranges from Rs.31950 ha^{-1} to Rs.69212 ha^{-1} due to various treatments. The highest expenditure was incurred in raising the crop under T_9 and lowest in case of T_1. But the maximum net returns was from T_{11} (Rs. 89453 ha^{-1}).With regard to B:C ratio maximum return per rupee is from the treatment T_1 (2.72) and least in case of T_3 (0.27).

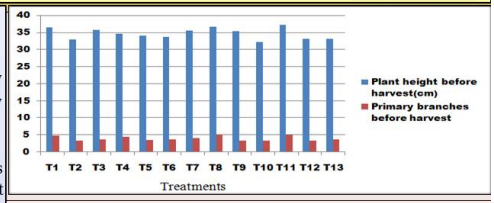

Fig. 1 Effect of different organic manures on growth parameters of fenugreek

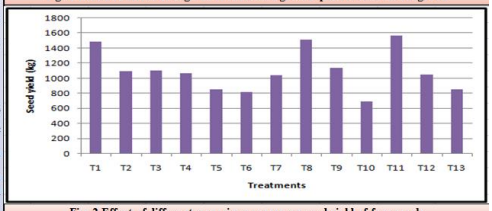

Fig. 2 Effect of different organic manures on seed yield of fenugreek

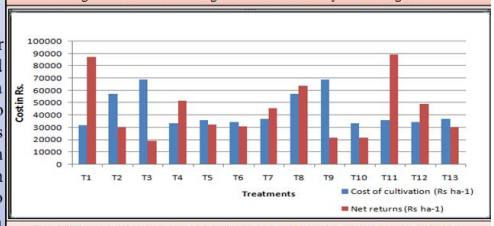

Fig. 3 Effect of different organic manures on the economics of fenugreek cultivation

DISCUSSION

The present study showed significant differences among the different treatments related to growth and yield parameters.

The highest plant height, number of primary branches and also the highest seed yield was recorded under the treatment T_{11} by the application of 4.5t ha^{-1} of poultry manure with *Rhizobium* seed treatment.

Increase of growth and yield parameters could be due to the presence of growth promoting substances and the high nitrogen content in the poultry manure which in turn stimulated the efficiency of nutrient uptake.

The positive influence of the nitrogen on growth parameters might be due to the increase in cell division and cell elongation. Application of higher doses of nitrogen produces maximum vegetative growth and influences the yield parameters as well.

The application of bio-fertilizer *Rhizobium* as seed treatment also had profound influence on the growth parameters of fenugreek.

Related to the economics of fenugreek cultivation , the cost of input differs from treatment to treatment based on the quantity of manures required. Therefore the highest cost of cultivation is recorded was under (T_9) and lowest was in case of (T_1)since RDF is the source of nutrition. Because of highest seed yield the net return was highest under (T_{11}).
The B:C ratio it is maximum in (T_1) since the input cost is very low compared to other treatments.

Plate. 1 General view of experimental plot

SUMMARY

The experiment was conducted with two levels of nitrogen with different sources of organic manures with and without *Rhizobium* seed treatment.
The yield is a complex character which involves the interaction of several factors. Application of poultry manure with *Rhizobium* seed treatment was more effective in increasing the growth and yield potential of fenugreek.

In the present study, the highest net returns is obtained by the application of poultry manure along with *Rhizobium* seed treatment. But highest B:C ratio is obtained in the treatment where RDF is the source of nutrition.

From this study we can conclude that even though the organic sources improves soil health and also gives good yield it is not remunerative to the farming community, since their requirement will be in large quantity and thus, the input cost will be more compared to the inorganic source of nutrition for cultivation.

ADVISORY COMMITTE

Chairperson:
Sreeramu, B.S.
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Chandre Gowda, M.
Umesha, K.
Bhaskar, S.

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I INTRODUCTION

India, the land of spices is the world's largest producer, consumer and exporter of spices. These spices add flavour, taste, aroma, colour and pungency to the food. Indian spices have earned high reputation in the international market. Among the 63 spices grown in the country 17 are seed spices and fenugreek is one among the first three seed spices grown in the country.

Fenugreek (*Trigonella foenum-graecum* L.) is an annual leguminous crop belonging to the family Fabaceae. It is commonly known as *Greekays* and also *Methi*. It is valued primarily for spice and also as vegetable and fodder. The seed is used as spice, tender leaves and tender pods are considered as vegetable for human consumption and also as a fodder for cattle. Besides, fenugreek has a number of medicinal uses.

Fenugreek is indigenous to countries bordering the Eastern shores of the Mediterranean regions, extending to Central Asia and South Eastern Europe. The genus *Trigonella* consists of 50 species. Fenugreek is mainly grown in Africa, Argentina, Southern France, China, Pakistan, Morocco and Lebanon in the world. The major international markets are Saudi Arabia, Japan, Sri Lanka, Singapore and United Kingdom.

India is also a leading producer of fenugreek with a production of 1,13,000 t in an area of about 93,000 hectare (Anon, 2013). It stands third with respect to seed spices in India after Coriander and Cumin. In India, Rajasthan (77 %) and Gujarat (12 %) are the major fenugreek producing states followed by Haryana (7 %) (Anon, 2013). It is also cultivated in Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Maharashtra, Punjab and Karnataka.

Fenugreek is a quick growing herb, up to 30-90 cm in height and produces erect shoots. The leaves are dark green in colour and with or without pink margin. It produces 2-3 small white coloured flowers at the base of each leaf. The flowers are papilionacious. The pods are slender and straw coloured when ripe, beak shaped and is about 8 to 10 cm long with 8 to 15 yellowish brown coloured and smooth surfaced seeds.

Fenugreek is a typical self-pollinated crop in which fertilization occurs within unopened buds. The predominance of self-fertilization facilitates maintenance of germplasm and also multiplication of seed materials is easier in fenugreek compared to other seed spices.

The leaves are rich in minerals (1.5 g), vitamin A (6450 IU), vitamin C (54 mg) and protein (4.4 g) (per 100 g of edible portion). 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 %), diosgenin (1.0 g), gigotenin (0.1 g) and a trace of triogenin (per kg of dried seed). The oil content in the seed is about seven per cent. The fatty acid composition of seed consists largely of linoletic, oleic and linolenic acids. It has marked drying properties; the dried oil is golden yellow in colour

and insoluble in ether. The oil has a disagreeable odour and bitter taste. The volatile oil content of fenugreek is very less (< 0.02 %). It is brown in colour and slightly odorous.

In fenugreek, both herb and seeds are economic parts. Fenugreek has been used as both food and food additive, as well as in medicine. Fresh tender pods, leaves and shoots which are rich in iron, calcium, protein, vitamin A and vitamin C are eaten as curried vegetable since ancient times in India, Egypt *etc*. In North India, the crop is grown for seeds while in South India; it is used as a green leafy vegetable.

In Egypt and Ethiopia, fenugreek is a popular ingredient of bread known to the Arabs as 'Hulba' and in Ethiopia by the 'Abhish'. In Greece, the seeds boiled or raw are eaten with honey. It has medicinal uses like 'papyri' from ancient Egyptian tombs reveal that that it was used (seeds soaked in water until swelled in to thick paste, which is then fed to the patients) both to reduce fever and also as food. The seeds are used in colic flatulence, dysentery, diarrhea, dyspepsia with loss of appetite, chronic cough, dropsy, enlargement of liver and spleen, rickets, gout and diabetics. The seeds are used as carminative, tonic, aphrodisiac and its infusion given to small pox patients as a cooling drink, seeds roasted and then infused are used in dysentery. Medicinally, the leaves are refrigerant and aperient they are given internally for vitiated conditions of *pitta*.

The seeds are used in India to induce lactation during post-natal period. The seeds also find application in the synthesis of sex hormones as oral contraceptives. The powdered seeds are used in the veterinary medicines. A mixture of fenugreek seeds and cotton seed powder fed to milch cattle will increase the flow of milk. The fenugreek pepper paste developed by the Spices Board of India used for coating bamboo mats, for drying black pepper for obtaining better quality and hygienic product.

Intensification of agriculture, characterized by raising of more crops per unit time and space involving heavy dependence of fertilizers has progressively depleted the soil and its 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.

At present, the use of organic manures by the farmers has reduced due to the reduction of cattle population, high cost of organic manures, involvement of large number of labours, risk in management of cattle and other farm animals.

Sharma, (2003) reported that crop yields during initial phase of transition from conventional to organic agriculture generally decline in many cases. However, yields recover in 2-3 years, which substantially improve the economic status eventually and bring in health and quality consciousness. There is very good scope for production and export of organic spices from India. India has near monopoly in seed spices and our growth in spices export is remarkable. However, we are facing stiff competition from other exporting countries due to their higher productivity, low unit cost and quality.

Rhizobium is a soil habitat bacterium, which is able to colonize the legume roots and fixes the atmospheric nitrogen symbiotically. The morphology and physiology of

Rhizobium will vary from free-living condition to the bacteroid of nodules. They are the most efficient bio-fertilizer as per the quantity of nitrogen fixed concerned.

Inoculation of seed with *Rhizobium* significantly influence the plant growth parameters and nitrogen content of soil which consequently lead to improve soil fertility and can reduce the production cost of next crop through reduces input in the form of nitrogen fertilizers, which in turn also minimize the health hazard effects. Rhizobial inoculation was found to be more effective and produce better yield through positive effect on yield through positive effect on yield components when compared with no inoculation.

Traditionally the nutrient management of fenugreek is being done by the application of chemical fertilizers. Works on many crops including seed spices have shown that excessive and imbalance use of chemical fertilizers and pesticides have deteriorated physical, chemical and biological properties of soil and polluted our environment which is not conducive for sustainable crop production as well as maintenance of soil health for longer period.

However, the information on the effect of organic source of nutrition with biofertilizer seed treatment in fenugreek and nutrient requirement of crop at different stages is meagre. Therefore, an attempt was made to evaluate different organic sources of nutrition with and without *Rhizobium* seed treatment to get higher seed yield and profitability of fenugreek production under Bangalore conditions with following objectives-

1. To study the effect of different organic manures on growth, seed yield and quality of fenugreek.
2. To workout the economics of fenugreek cultivation under Bangalore conditions.

II REVIEW OF LITERATURE

Plant nutrition is one of the major factors that influence the growth, development and yield of the crops that are commercially grown. The maximum yield in any plant can be obtained by adjusting the nutrient supply upon its requirements through balanced nutrition.

Although information on the nutrient requirement of fenugreek is available, the literature on the requirement of organic manures for fenugreek cultivation under Bangalore conditions is meagre.

Hence, relevant literature pertaining to organic cultivation of fenugreek (*Trigonella foenum-graecum* L.) and other related crops has been reviewed and presented under the following headings in this chapter.

2.1 Effect of different organic manures on the growth and yield attributes.

2.2 Effect of different organic manures on the quality parameters.

2.3 Effect of different organic manures on the economics of cultivation.

2.4 Effect of FYM, Vermicompost and Poultry manure.

2.1 Effect of different organic manures on the growth and yield attributes

2.1.1 Fenugreek

Field investigations were carried out to study the effect of different levels of farmyard manure and phosphorus on growth of two fenugreek genotypes in sandy loam soils. Plant height was significantly higher with increase of FYM up to 15 t ha^{-1} at all stages of crop growth, except at 30 DAS. Seed yield was also enhanced significantly with the application of FYM up to 15 t ha^{-1} (Khiriya *et al*., 2001).

A field experiment was conducted to evaluate the beneficial effect of different biofertilizers and organic manures alone as well as their combinations on fenugreek. Maximum number of branches per plant, pods per plant and seed yield was recorded with application of recommended dose of NPK being *at par* with seed inoculation with *Rhizobium* and application of nitrogen supplemented with FYM and seed inoculation with *Rhizobium* and PSB (Chaudhary *et al.,* 2009).

Naidu *et al*. (2010) conducted a field experiment on the effect of different organic sources of nutrients on growth, yield and quality of fenugreek. Considering the seed yield it is concluded that application of FYM 2.8 t ha^{-1} + poultry manure 3.5 t ha^{-1} was found promising and could be recommended for obtaining higher yield in fenugreek.

A field experiment was conducted to evaluate the effect of integrated nutrient management on productivity and nutrient uptake of fenugreek (*Trigonella foenum-graecum* L.) and its residual effect on fodder pearl millet (*Pennisetum glaucum* L.). Results revealed that integration of 50 per cent RDN through poultry manure + 50 per

cent RDN through inorganic sources to fenugreek recorded higher growth attributes, *viz.*, plant height, branches plant^{-1} and yield attributes, *viz.*, pods plant^{-1}, seeds pod^{-1}, test weight and seed yield (1.76 t ha^{-1}) (Choudhary *et al.*, 2011).

Dubey *et al.* (2012) evaluated the response of integrated nutrient management on nutrient uptake, protein content and seed yield of fenugreek (*Trigonella foenum-graecum* L.). Ten treatments consisting of control (T_1) , vermicompost 5 t along with *Rhizobium* + 40 kg N ha^{-1} (T_2), vermicompost 5 t along with *Rhizobium* + 30 kg N ha^{-1} (T_3), vermicompost 5 t along with *Rhizobium* + 20 kg N ha^{-1} (T_4), *Rhizobium* along with vermicompost 5 t ha^{-1} (T_5), *Rhizobium* along with vermicompost 10 t ha^{-1} (T_6), vermicompost 5 t ha^{-1} (T_7), vermicompost 10 t ha^{-1} (T_8) , 40 kg N ha^{-1} (T_9) and *Rhizobium* inoculation (T_{10}) were tested. Application of vermicompost at 5 t ha^{-1} along with *Rhizobium* + 40 kg N ha^{-1} resulted in the highest seed and straw yields.

Godara *et al.* (2012) conducted a field experiment on effect of different combinations of organic and inorganic nutrient sources on productivity and profitability of fenugreek (*Trigonella foenum-graecum)*. It was inferred that application of 50 per cent RDF along with 50 per cent vermicompost or poultry manure is better for realizing good soil health and sustainable higher yield levels.

Adak and Sachan (2013) conducted a field experiment at Pantnagar on a clay loam soil to appraise the productivity, nutrient uptake and soil fertility status in fenugreek under an integrated nutrient management module. The results indicated highest total biological yield (70.71 q ha^{-1}) obtained in the treatment involving NPK + *Sinorhizobium* + *Bacillus* + FYM @ 5.0 t ha^{-1}.

A field experiment was conducted to study the effect of vermicompost and sulphur on growth, yield and nutrient uptake of fenugreek. Application of vermicompost up to 4 t ha^{-1} significantly increased plant height, branches per plant at 60, 90 DAS and at harvest, seed (15.26 q ha^{-1}) and straw yields (39.02 q ha^{-1}) (Verma *et al.*, 2014).

Patel *et al.* (2014) studied the effect of different organic manures and biofertilizers on yield, nutrient uptake and economics of fenugreek (*Trigonella foenum-graecum* L.) under organic farming. Results revealed that conjunctive use of 50 per cent RDN through castor cake + *Rhizobium* and PSB seed inoculation, remarkably improved soil fertility compared to RDF through inorganic fertilizers and sole application of either organic manures or biofertilizers.

Naimuddin *et al.* (2014) reported that seed yield was higher in fenugreek by the application of organic manures [Vermicompost (VC), Sheep manure (SM) and Farmyard manure (FYM)] and seed inoculation with *Rhizobium*. Plant height and number of branches were higher with the application of FYM.

An experiment was conducted to assess the influence of integrated nutrient management on growth and physiological attributes of *kasuri methi* (*Trigonella corniculata* L.). At 90 days after sowing and at harvest, maximum plant height (42.81 and

45.64 cm), number of leaves (58.89 & 86.05) and number of branches (23.51 and 25.64) were recorded in the treatment supplied with 75 per cent Nitrogen + Recommended Dose of Phosphorus and Potassium + FYM (7.5 t ha^{-1}) + *Rhizobium* (1.5 t ha^{-1}) + *Azospirillum* (5kg ha^{-1}) + Phosphate Solubilising Bacteria (5 kg ha^{-1}) (Sunanda *et al*., 2014).

Anitha *et al.* (2015) concluded that application of 50 per cent inorganic fertilizers, and 50 per cent organic manures along with bio fertilizer seed inoculation gives good seed yield in fenugreek.

Results of an field experiment concluded that application of recommended dose of fertilizers through inorganic form (50 per cent) + neem cake at 638 kg ha^{-1} + *Rhizobium melilotii* + phosphate solubilising bacteria (PSB) recorded the highest plant height of 34.98 cm, leaves of 82.35 and branches of 5.5 at the final harvest stage (Anitha *et al*., 2016).

A research work was carried out, undertaking twelve treatments with three replications. The results of the investigation indicated that the vegetative growth in terms of plant height, number of branches per plant and leaf area were increased due to different organic sources of nutrients and *Rhizobium* with PSB as seed treatment. The combination FYM + *Rhizobium* and PSB as seed treatment with 25g kg^{-1} seed was found superior for increasing yield of fenugreek (Tagad *et al.*, 2016).

2.1.2 Other crops

A field study was undertaken by Vadiraj *et al.* (1998) to study the response of three cultivars of coriander (*Coriandrum sativum*) to graded levels of vermicompost in comparison with chemical fertilization (NPK). The study indicated that application of vermicompost significantly increased herbage and seed yields.

Influence of *Azospirillum sp*., nitrogen fertilizer, FYM and their combinations on coriander was studied at Ajmer. Results revealed that *Azospirillum* sp. inoculation along with nitrogen and FYM increased the plant height and number of primary branches per plant as compared to *Azospirillum sp*. alone and control (Malhotra *et al*., 2006).

A field experiment was conducted to study response of cumin (*Cuminum cyminum* L.) to inorganic N, FYM and biofertilizer. Maximum number of branches $plant^{-1}$ (5.92), umbels per plant (21.28), umbellets per umbel (5.28), seeds per umbel (32.8) and test weight of seeds (4.50 g) were recorded with the application of inorganic N (100 %) + *Azospirillum* @ 1.5 kg ha^{-1} + 5 t FYM ha^{-1}. Significantly higher seed and straw yields were also obtained under the same treatment (Choudhary *et al.*, 2006).

An investigation was carried out to study the effect of organic sources of nutrients on growth and yield of French bean by using various nutrient compositions. Vermicompost treatment recorded the highest values in all observations except biomass of whole plant. Thus, it was concluded that vermicompost was found useful than any other type of treatments under irrigated condition of Srinagar valley (Singh and Chauhan, 2009).

Meena *et al.* (2009) conducted a field experiment at Ajmer to study the influence of sheep manure, vermicompost and bio-fertilizer on growth and yield of ajowan (*Trachyspermum ammi*). The highest seed (16.35 q ha^{-1}), stover (33.14 q ha^{-1}) and biological yields (49.49 q ha^{-1}) of ajowan were obtained with application of sheep manure @ 10 t ha^{-1} with *Azotobacter sp.*

Singh *et al.* (2009) concluded that phosphorus and sulphur enriched compost or vermicompost by HGPR and gypsum gave statistically *at par* (17.01 and 17.60 q ha^{-1}) seed yield of coriander to direct application of phosphatic fertilizer and gypsum (16.26 and 16.31q ha^{-1}).

Field experiment was conducted at Bangalore (semi-arid tropical climate) to study the influence of vermicompost and chemical fertilizers (NPK and sulphur) on growth, seed and oil yield and oil quality of coriander (*Coriandrum sativum*). The results of the study revealed that application of vermicompost (7.5 t ha^{-1}) + 25 % recommended NPK (25:12.5:12.5 kg ha^{-1}) produced maximum biomass (28.2 q ha^{-1}) and seed yield (10.82 q ha^{-1}) of coriander which was *at par* with other treatments except full organic manure and control which indicated that 75 per cent NPK requirement can be supplemented through vermicompost without loss of yield (Singh, 2011).

A field study on the effect of various sources of organic with and without biofertilizer (*Azotobacter sp*.) on performance of cumin (*Cuminum cyminum* L.) was conducted. Results showed that the association of biofertilizers with all sources of nutrients proved beneficial and resulted in higher growth and yield (Mehta *et al.*, 2012).

A field experiment on effect of different organic modules and varieties on the yield attributes, yield and quality parameters of coriander was conducted by Lal *et al.* (2012). The results of present study demonstrated that cultivation of ACr-1 with the application of organic Module-1 comprising of soil application of vermicompost, *Trichoderma* and neem cake as well as seed treatment of *Azotobacter,* PSB and *Trichoderma* with the foliar spray of garlic extract and neem oil exhibited maximum values for all the yield attributing characters.

Darzi (2012) conducted a field experiment to study the effect of organic manure and biofertilizer application on flowering and some yield traits of coriander (*Coriandrum sativum*). The factors were cattle manure in four levels (5, 10, 15 and 20 tons ha^{-1}) and nitrogen fixing bacteria in three levels (inoculation with *Azotobacter*, inoculation with *Azospirillum* and inoculation together). Results showed that the highest umbel number per plant was obtained with application of 15 tons ha^{-1} cattle manure.

A pot experiment was conducted by Dhaka *et al*. (2013) to study the response of cowpea to organic manures and soil salinity. The seed yield of cowpea increased to the extent of 13.5 and 27.3, 24.9 and 32.3 and stover yield to the extent of 8.6 and 13.2, 12.4 and 19.9 per cent with the application of 5 and 10 t FYM ha^{-1} and 2.5 and 5 t vermicompost ha^{-1}, respectively over control.

Godara *et al*. (2014) conducted a field experiment to study the effect of organic and inorganic sources of fertilizers on growth, yield and economics of fennel cultivation under semi-arid conditions with eight treatments (absolute control and varying proportions of organic and inorganic sources of nutrients). Results revealed that RDN through fertilizers and combinations of different organic and inorganic sources produced significantly higher grain yield over absolute control.

Godara *et al.* (2014) concluded that, RDF through fertilizers and combinations of different organic and inorganic sources produced significantly higher grain yield over absolute control in coriander.

Singh (2015) reported that application of FYM (15 t ha^{-1}) + RDF (50N : $40P_2O_5$: $30K_2O$ kg ha^{-1}) was best in improving the growth attributes of coriander and increased the yield by 105.26 per cent over control.

Application of 10 t FYM ha^{-1} + 45:75:60 kg ha^{-1} NPK + *Rhizobium* + PSB culture showed significantly maximum plant height (65.87cm), number of leaves $plant^{-1}$ (157.90), number of pods per plant (26.40), number of seeds per pod (7.01) and yield (26.54 q ha^{-1}) in pea (Uikey *et al*., 2015).

2.2 Effect of different organic manures on the quality parameters

2.2.1 Fenugreek

Naidu *et al*. (2010) concluded that application of FYM 2.8 t ha^{-1} + poultry manure 3.5 t ha^{-1} was found promising to obtain improved quality fenugreek.

Dubey *et al.* (2012) studied the response of integrated nutrient management on nutrient uptake, protein content and seed yield of fenugreek (*Trigonella foenum-graecum* L.). Application of vermicompost 5 t along with *Rhizobium* + 40 kg N ha^{-1} resulted in the highest protein content (21.75 %).

An experiment was carried out by Naimuddin *et al.* (2014) to study the effect of organic manures and *Rhizobium* on performance of fenugreek (*Trigonella foenum-graecum*). Result revealed that protein content was highest with the application of FYM.

Sunanda *et al.* (2014) concluded that in *kasuri methi* the quality attributes like crude protein in herb (13.31 %) and seed (21.33 %) were higher with the application of 75 per cent Nitrogen + Recommended Dose of Phosphorus and Potassium + Farm Yard Manure (7.5 t ha^{-1}) + *Rhizobium* (1.5 t ha^{-1}) + *Azospirillum* (5 kg ha^{-1}) + Phosphate Solubilizing Bacteria (5 kg ha^{-1}).

Anitha *et al.* (2015) evaluated the quality aspects of fenugreek seeds under different combinations of manures and fertilizers application. The quality parameter like protein content (9.36 mg 100 g^{-1}) reached maximum in the combination of 50 per cent inorganic fertilizers and 50per cent organic manures (*viz.*, poultry manure, vermicompost, neem cake, FYM) and biofertilizers inoculation.

The results of the investigation carried out by Tagad *et al.* (2016) indicated that the qualitative parameters *viz.*, protein content (26.35 %) and fiber content (65.02 %) were superior in the combination FYM + *Rhizobium* and PSB seed treatment.

2.2.2 Other crops

Effect of the application of vermicompost and nitrogen fixing bacteria on quality of the essential oil in dill (*Anethum graveolens*) was studied by Darzi *et al.* (2012). Results showed that the maximum essential oil yield was obtained by the application of vermicompost at 8 ton ha^{-1}.

Mohammadi *et al*. (2014) conducted a field experiment to study the influence of compost and bio-fertilizer on yield and essential oil of dill (*Anethum Graveolens* L.). The maximum essential oil yield was obtained with the application of 10 ton ha^{-1} compost and biofertilizers.

Lal *et al.* (2012) demonstrated that cultivation of ACr-1 with the application of organic Module-1 comprising of soil application of vermicompost, *Trichoderma* and neem cake as well as seed treatment of *Azotobacter*, PSB and *Trichoderma* with the foliar spray of garlic extract and neem oil exhibited maximum values for essential oil content (0.41 g / kg).

Patel *et al*. (2003) studied the effect of organic manures [castor cake, mustard cake and farmyard manure (FYM)] alone or in combination with inorganic fertilizers on quality of winter fennel (*Foeniculum vulgare* Mill.). Application of different organic manures alone or mix with inorganic fertilizers significantly improved the oil content of fennel (1.56 to 1.64 %).

A field experiment was conducted to study the effect of partial shade, inorganic, organic and bio-fertilizers on morphological parameters, yield and quality of turmeric cv. CL-147 Regarding the quality parameters, provision of shade improved the curcumin (5.42 %), oleoresin (10.15 %) and essential oil (5.60 %) content in the treatment involving 50 per cent FYM + coir compost + *Azospirillum* (10 kg ha^{-1}) + phosphor bacteria (10 kg ha^{-1}) + 3 per cent Panchagavya (Padmapriya and Chezhiyan 2009).

The research work carried out by Farhad *et al*. (2009) showed that parameters like plant height, number of rows per cob, number of grains per row, 1000 gain weight, grain yield were significantly affected by the application of poultry manure in maize.

2.3 Effect of different organic manures on the economics for cultivation

2.3.1 Fenugreek

Results of an experiment conducted by Patel *et al.* (2014) revealed that conjunctive use of 50 per cent RDN through castor cake + *Rhizobium* and PSB seed inoculation recorded maximum net returns and benefit: cost ratio.

Verma *et al.* (2014) concluded that application of vermicompost upto 4 t ha^{-1} significantly increased the net returns of fenugreek cultivation by 12.60 and 3.95 per cent over control and 2 t ha^{-1} vermicompost, respectively.

Anitha *et al.* (2016) reported that maximum net returns and benefit cost ratio were obtained in the combination of 50 per cent recommended dose of fertilizer (RDF) + poultry manure (PM) @ 1000 kg ha^{-1} + *Rhizobium melilotii* + phosphate solubilising bacteria (PSB).

2.3.2 Other crops

Choudhary *et al.* (2006) reported that combined application of 100 per cent inorganic N + *Azospirillum* @ 1.5 kg ha^{-1} + 5 t FYM ha^{-1} recorded the highest net returns of Rs. 6,357 ha^{-1} and benefit:cost ratio of 1.39 : 1.

A field experiment on influence of varying organic sources of nutrients on growth and yield of coriander was conducted at research farm of NRCSS, Ajmer. It is inferred that application of 7.5 t ha^{-1} sheep manure with *Azotobacter* is better for realizing the highest net return and BCR in coriander (Mehta *et al.*, 2011).

Mehta *et al.* (2012) reported that application of recommended doses of fertilizer with seed inoculation by biofertilizer in cumin proved to be superior for realizing higher net return and benefit:cost ratio.

Lal *et al.* (2012) concluded that module-1 comprising of soil application of vermicompost, *Trichoderma* and neem cake as well as seed treatment of *Azotobacter*, PSB and *Trichoderma* with the foliar spray of garlic extract and neem oil was found beneficial for obtaining maximum values for net returns (Rs. 105518.25) with B:C ratio (3.92:1) in coriander.

The experimental results showed that application of RDN (100 %) through fertilizers exhibited highest net returns (Rs. 62,091 ha^{-1}) and benefit cost ratio (3.01), it was closely followed by 50 per cent RDN through fertilizers + 50 per cent RDN through vermicompost in fennel (Godara *et al*., 2014).

Godara *et al*. (2014) concluded that application of RDN 100 per cent through fertilizers exhibited highest net returns (Rs. 59556 ha^{-1}) and benefit cost ratio (3.66), which was closely followed by 50 per cent RDN through fertilizers + 50 per cent RDN through vermicompost in coriander.

Singh (2015) conducted a field experiment to study the effect of nutrient supplementation through organic manures on coriander. Results revealed that application of FYM (15 t ha^{-1}) + RDF ($50N_2O$: $40P_2O_5$:$30K_2O$ kg ha^{-1}) gave the highest net return of Rs.68370 ha^{-1} with benefit cost ratio of 2.67.

Uikey *et al.* (2015) taken up a study to know the influence of organic, chemical and biofertilizer on growth and yield of pea. The result revealed that 10 t FYM ha^{-1} +

45:75:60 kg ha^{-1} NPK + *Rhizobium* + PSB culture showed significantly maximum net income (Rs. 135741.7) and B:C ratio (1:6.78).

2.4 Effect of FYM, Vermicompost and Poultry manure on growth and yield of different crops

2.4.1 Effect of FYM

Wey and Obton (1978) obtained increased yield of haulm (47 per cent) and pods (24 per cent) in groundnut by the application of 10 t ha^{-1} of FYM. Loganathan *et al.* (1979) found that FYM is more effective in groundnut during *rabi* season, specially on red sandy loam soil.

Results of field experiments indicated that FYM or compost application a month prior to sowing resulted to an average yield response in rice and irrigated wheat. Similarly direct and residual effects of FYM at 10-25 t ha^{-1} have been obtained in sorghum, maize and at 5-7.5 t ha^{-1} in pulses and groundnut (Krishnamurthy and Kothandaraman, 1982).

Agasmani and Hosamani (1989) reported that the application of 7.5 t ha^{-1} FYM increased the pod yield and also yield components compared to no FYM application. For the organic method of fenugreek cultivation, the Spice Board has recommended the application of well rotten cattle manure or compost at the rate of 4 to 5 t ha^{-1} at the time of sowing.

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

Cisse (1998) reported that the application of 10 t ha^{-1} organic manure increased the number of branches per plant, growth rate at later stages and nutrient uptake rates were 2-3 folds greater during the period 20-60 days after germination in groundnut than in control. According to Palaniappan and Annadurai (1999), compost contain 0.5-1.0 per cent N, 0.6 per cent P_2O_5 and 0.5 per cent K_2O. Thus 10 tons of compost will supply 50-100 kg N, 20 kg P_2O_5 and 50 kg K_2O.

2.4.2 Effect of Vermicompost

Field studies on the effect of vermicompost on fenugreek are meager. However, studies on other field or horticulture crops are reviewed here

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). The application of vermicast to wheat crop has been found to increase the plant height, number of leaves, total dry matter and grain number per year (Nijhawan and Kanwar, 1952)

A study conducted by Radha and Kubra (1987) in summer paddy revealed that the vegetative growth was influenced by the application of vermicast in a better way than chemical fertilizers. While, the seed weight increased significantly with the application of vermicompost over the other treatments in sunflower (Radha *et al.,* 1992).

Hapse (1993) concluded that the application of vermicompost @ 5 t ha^{-1} increased the cane yield by 12.7 per cent and sugar recovery by 0.92 per cent as compared to the application of chemical fertilizers in sugarcane (cv. Co 7219).

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 and four times more nitrogen fixing bacteria.

In groundnut, the application of vermicompost at 2 t ha^{-1} gave highest pod yield, when compared with FYM (10 t ha^{-1}) and 1t ha^{-1} of vermicompost (Pattar *et al.,* 1999).

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

2.4.3 Effect of poultry manure

The excreta of birds ferment quickly, and if left exposed, 50 per cent of its nitrogen is lost within 30 days. Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures.

Singh *et al.* (1979) reported that grain yield was found to increase with the application 12 t ha^{-1} of poultry manure and overall performance of maize crop was better as compared to cow dung or inorganic fertilizers (Ponsica *et al.,* 1983).

Among the different sources of organic matter, incorporation of poultry manure, castor cake and FYM in to the soil brought about a significant increase in maize yield compared to control (Sharma and Sexena, 1985).

Stefanescu and Dasca (1985) found that in wheat and maize grain yields were 3.54 and 4.56 t ha^{-1}, respectively with no fertilizer and increased to 5.39 and 6.92 t ha^{-1} with the application of 4 t ha^{-1} poultry manure. The grain yield, quality and straw yields were found to increase with increased rate of chicken manure application at 0, 4.1, 8.25, 16.5 and 33 t ha^{-1} (Magid *et al.,* 1995).

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

Row application of poultry manure at 1 t ha^{-1} recorded significantly higher cob weight (156.75 g), grain weight per plant (157.92 g), 100 grain weight (24.62 g) and grain number per plant (831.55) over other organic sources like vermicompost, FYM and no organics in hybrid maize (Venkatesh, 1999).

The cost: benefit ratio of application of poultry manure revealed higher gross returns and net returns compared to FYM in maize (Kataraki, 2000).

Application of FYM at 10 t ha^{-1} and poultry manure at 5 t ha^{-1} in groundnut significantly increased the number of branches per plant, pod and biological yield over control (Rao and Shaktawat, 2001).

In sunflower, the application of poultry manure at 5 t ha^{-1} recorded significantly higher seed yield, over 8 t ha^{-1} of FYM and no organic manure. The per cent increase in grain yield was to the tune of 32.8 and 17.4 with the application of poultry manure (Kulkarni *et al.,* 2001).

In brinjal, the application of 20 t ha^{-1} of poultry manure or 30 t ha^{-1} of FYM in conjugation with *Azospirillum* and phosphate solubilizing bacteria, yielded fruits of higher girth and greater number over 28 kg N + 20 t FYM and 1.2 t vermicompost (Naidu, 1999). The average nutrient content was 3.03 per cent N, 2.63 per cent P_2O_5 and 1.4 per cent K_2O (Guled *et al.,* 2003).

III MATERIALS AND METHODS

A field experiment entitled "Organic cultivation of fenugreek (*Trigonella foenum-graecum* L.)" was conducted during *rabi* season (October, 2015 to February, 2016) at the Department of Horticulture, University of Agricultural Sciences, GKVK, Bangalore. The details of methods followed and materials used in the experiment are detailed below.

3.1 Geographical location of the experimental plot

The site of experimental plot located at an elevation of 924 meters above MSL at latitude 30° 05' N and longitude 77° 34' E.

3.2 Soil characteristics of the experimental plot and climatic conditions

The soil of the experimental site was red loamy with uniform fertility. Soil samples were collected from a depth of 0-30 cm from randomly selected spots. Samples were drawn as per the treatment before sowing and after the crop harvest and were analysed for pH, electrical conductivity, organic carbon and available nitrogen, phosphorus, potassium contents (Appendix- I, II and III). The meteorological data recorded during the experiment is presented in Appendix-IV)

3.3 Experimental Details

Design	:	Randomized Complete Block Design (RCBD)
Number of treatments	:	13
Number of replications	:	3
Plot size	:	2.4 m × 1.5 m
Spacing	:	30 cm × 15 cm
Season	:	*Rabi*, 2015-16
Situation	:	Irrigated crop
Variety	:	Ajmer Fenugreek-1
Seed rate	:	15 kg per hectare
Date of sowing	:	17th October 2015

Salient features of the variety used

The variety used in this experiment was Ajmer fenugreek-1 released from Directorate of seed spices, Ajmer. The plants of this variety are bushy, green with medium sized golden yellow seeds. It matures in 140-150 days and the yield potential is 20 q per hectare. The variety is tolerant to root rot, powdery mildew, caterpillars and aphids with good quality and yield. It is a dual purpose variety.

Treatment details

T_1- 60:90:50 Kg NPK ha^{-1} (RDF)

T_2- 100 % N through Vermicompost without *Rhizobium* seed treatment

T_3- 150 % N through Vermicompost without *Rhizobium* seed treatment

T_4- 100 % N through Poultry manure without *Rhizobium* seed treatment

T_5- 150 % N through Poultry manure without *Rhizobium* seed treatment

T_6- 100 % N through Farm Yard Manure without *Rhizobium* seed treatment

T_7- 150 % N through Farm Yard Manure without *Rhizobium* seed treatment

T_8- 100 % N through Vermicompost with *Rhizobium* seed treatment

T_9- 150 % N through Vermicompost with *Rhizobium* seed treatment

T_{10}- 100 % N through Poultry manure with *Rhizobium* seed treatment

T_{11}- 150 % N through Poultry manure with *Rhizobium* seed treatment

T_{12}- 100 % N through Farm Yard Manure with *Rhizobium* seed treatment

T_{13}- 150 % N through Farm Yard Manure with *Rhizobium* seed treatment

(FYM- 10 t ha^{-1} is common for all the treatments)

3.4 Cultural practices

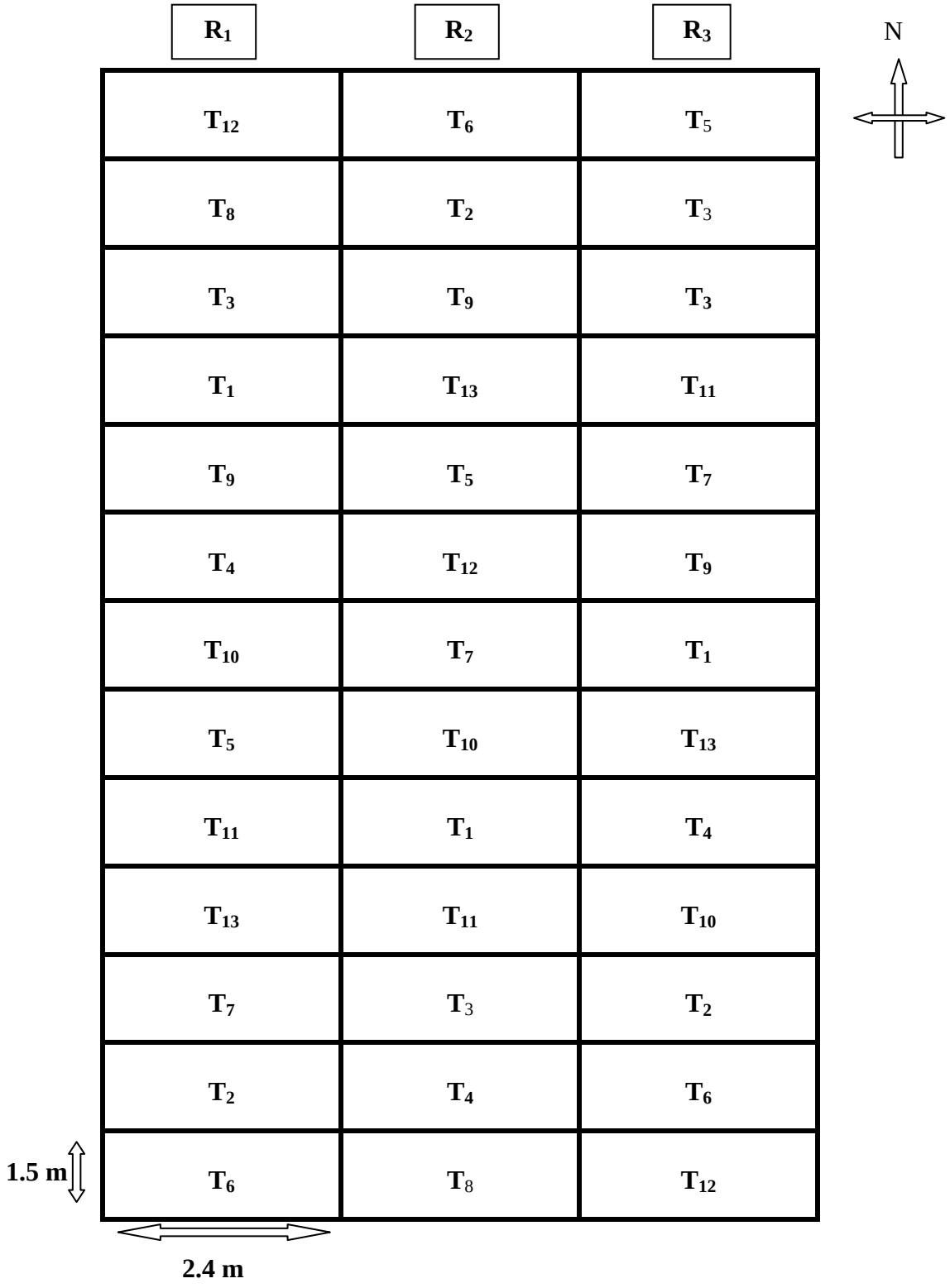
3.4.1 Preparation of experimental plot

The experimental site was ploughed thrice by using tractor and brought to a fine tilth and the land was divided into plots of required size and number by bunding (75 cm width). Sufficient space (1 m) was left between replications to avoid movement of rain water and nutrients. Each plot was levelled before the application of organic manures.

3.4.2Application of manures and fertilizers

Well rotten farmyard manure at the rate of 10 t per hectare was applied 30 days prior to sowing. The FYM for each plot was weighed separately and spread uniformly in the entire plot and incorporated into the soil by using hand fork.

Fertilizers like urea, single super phosphate and murriate of potash were weighed according to the treatments and applied to the respective plots. Likewise, the manures like vermicompost, poultry manure and farm yard manure were also weighed separately for all the plots according to the treatments and applied to the respective plots and incorporated in to the soil uniformly. The quantity of fertilizers or organic manure applied to each plot as per treatment is as follows and the nutrient contents of manures are presented in Appendix-VI.



Layout plan of the experiment

Treatments	Manure and fertilizers	Quantity plot^{-1} (3.6 m^2)
T_1	RDF (NPK)	21.6:202.5:30.6 g
T_2	Vermicompost	1.2 kg
T_3	Vermicompost	1.8 kg
T_4	Poultry manure	1.03 kg
T_5	Poultry manure	1.54 kg
T_6	FYM	1.96 kg
T_7	FYM	2.94 kg
T_8	Vermicompost	1.2 kg
T_9	Vermicompost	1.8 kg
T_{10}	Poultry manure	1.03 kg
T_{11}	Poultry manure	1.54 kg
T_{12}	FYM	1.96 kg
T_{13}	FYM	2.94 kg

3.4.4 Sowing of seeds

Pure, healthy and good quality seeds of fenugreek cv. Ajmer Fenugreek -1 were treated with *Rhizobium* culture at 15 g kg^{-1} and 3-4 seeds were sown at a depth of 2 cm by maintaining a spacing of 30 cm × 15 cm, following a seed rate of 15 kg per hectare. The seeds were properly covered with a thin layer of soil and the plots were irrigated immediately after sowing.

3.4.5 Thinning of seedlings

Excess seedlings were thinned out manually after 10 days of sowing and two healthy vigorous seedlings were retained per hill. The final thinning was done at 30 days after sowing, retaining only one seedling per hill to maintain a spacing of 15 cm between seedlings.

3.4.6 Weeding

In order to keep the crop free from weeds regular hand weeding was done. First weeding was done at 20 days after sowing and later at 40 and 70 days after sowing.

3.4.7 Irrigation

Irrigation water is provided immediately after sowing and thereafter at 3 days interval for 10 days and subsequently at 5-6 days interval. Good drainage was provided to prevent water logging.

Plate 1. General view of the experimental plot (30 DAS)

3.4.8 Stage of harvest and harvesting

The seed crop was harvested when majority of the plants in the plot were almost bare without leaves and pods turned yellow. Plants from the net plot area were uprooted, bundled and dried under sun on clean concrete floor. The dried plants were threshed using wooden sticks to separate the seeds form the pods and the seeds are cleaned by winnowing and the weight of the seeds and straw were recorded and expressed in kg per hectare.

3.4.9 Plant protection

During the cropping period, Powdery mildew (*Erisiphe polygoni*) infestation and damping off (*Rhizoctonia solani*) were noticed. The crop was sprayed with wettable sulphur 30 WP at 3 g per litre to check the powdery mildew at 25 and 45 DAS and the soil was drenched with carbendazim at 1 g per litre of water to prevent damping off of seedling as a spot application.

3.5 Observations recorded

Observations on growth parameters were recorded using five labelled plants selected randomly from the net plot area. The observations on growth parameters were recorded at 30, 60 DAS and before harvest. The various observations recorded and methodologies followed are detailed below-

3.5.1 Growth parameters

3.5.1.1 Plant height (cm)

Plant height of all the five labelled plants in the net plot area was measured from the ground level to the growing tip of the main stem at 30, 60 days after sowing (DAS) and before harvest. The mean height was calculated for each stage of observation.

3.5.1.2 Number of branches

The number of branches in five randomly selected plants in each net plot were counted at 30, 60 DAS and before harvest. The average was computed and expressed as number of branches per plant.

3.5.2 Reproductive parameters

3.5.2.1 Days to first flowering

This parameter was recorded by counting the number of days taken by the plants to flower after sowing the seeds. The parameter was recorded in all the treatments and replications and average was worked out.

3.5.2.2 Days to 50 per cent flowering

This parameter was recorded by counting the number of days from sowing to flowering in 50 per cent plants. The parameter was recorded in all the treatments and replications and average was worked out.

3.5.2.3 Days to maturity

This parameter was recorded by counting the number of days from sowing to harvest of the crop. The parameter was recorded in all the treatments and replications and average was worked out.

3.5.3 Yield parameters

3.5.3.1 Number of pods per plant

The number of pods present in five randomly selected plants in the net plot area at harvest was recorded and average number of pods was worked out.

3.5.3.2 Pod length (cm)

Twenty pods were randomly picked among the pods separated from the five randomly selected plants in the net plot area at harvest. Their length was measured and the average was worked out.

3.5.3.3 Number of seeds per pod

After measuring the length of pods, the same pods were utilised for recording number of seeds per pod by threshing the pods and counting the seeds and the average was worked out.

3.5.3.4 Test weight of seeds (g per 100 seeds)

The seeds obtained after threshing the plants were utilized for the purpose. The weight of hundred seeds drawn randomly from each treatment was recorded as per the procedures given by ISTA rules (Anon, 1999).

3.5.3.5 Seed and straw yield per hectare (kg)

In all the treatments, the seed crop was harvested when plants dried up before the dehiscence of the pods. The border plants were first uprooted and kept separately. The plants in the net plot area (without five labelled plants) were harvested, bundled and transported to drying yard. After thorough drying, the plants were threshed to separate the seeds. The seed and straw weights were recorded and computed for the net plot. From the net plot yield the seed and straw yield per hectare were calculated and expressed in kg per hectare.

3.5.4.1 Quality attributes

3.5.4.1.1 Crude protein content (%)

Nitrogen content in samples was determined by digesting the samples in concentrated sulphuric acid with K_2SO_4 + $CuSO_4$ + Se mixture and distilled in an alkaline medium (Jackson, 1973) and crude protein content of the leaves and seeds was estimated by multiplying the nitrogen content of seeds by 6.25 and expressed in per cent.

Plate 2. General view of the experimental plot before harvest

3.5.4.1.2 Soil analysis

The soil samples collected before sowing and after the harvest of the crop were analysed for the following parameters.

3.5.4.1.3 Soil pH

The pH of soil was measured in 1:2.5 soil water suspensions after stirring the contents intermittently for half an hour. The pH value was recorded using technical model pH C 1-2 meter with combination of glass electrodes (Jackson, 1973).

3.5.4.1.4 Electrical conductivity

The soil and water suspension used for measuring pH was filtered and the electrical conductivity of the solution was measured with the help of electrical conductivity bridge and expressed in ds m^{-1}.

3.5.4.1.5 Organic matter

Organic matter is calculated by multiplying the per cent organic carbon by 1.724 which is called Vin Bensonlen factor.

3.5.4.1.6 Available nitrogen

The available nitrogen content was determined through alkaline potassium permanganate method (Subbaiah and Asija, 1956) by digestion, distillation and collection of NH_3 in four per cent boric acid and titrating it against standard sulphuric acid and expressed in kg per hectare.

3.5.4.1.7 Available phosphorus

Available phosphorus in the soil was extracted with the help of Bray's No.1 extract (0.03 N ammonium fluoride + 0.025 N HCl). Further, phosphorous in the filtered extract was determined by chlorostannous reduced molybdo-phosphate blue colour method (Jackson, 1973). The intensity of colour was read on UV spectrometer (nm) and was expressed in kg per hectare.

3.5.4.1.8 Available potassium

The available potassium in the soil was estimated by flame photometer method as suggested by Jackson (1973) and expressed in kg per hectare.

3.6 Economics of cultivation (Rs. ha^{-1})

3.6.1 Cost of cultivation

The prices of inputs that were prevailing at the time of their use were considered to work out the cost of cultivation.

3.6.2 Gross income

Gross income was calculated based on the prevailing market price of seed.

3.6.3 Net income

Net income per hectare was calculated by subtracting cost of cultivation from gross income.

3.6.4 Benefit: Cost Ratio

The Benefit: Cost ratio was worked out using the following formula.

$$\text{Benefit: Cost Ratio} = \frac{\text{Net income (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})} \times 100$$

3.6.5 Statistical analysis

The experimental data recorded on various biometric parameters during the course of investigation were subjected to statistical analysis as outlined by Sundararaj *et al.* (1972). The results have been discussed at 5 per cent probability.

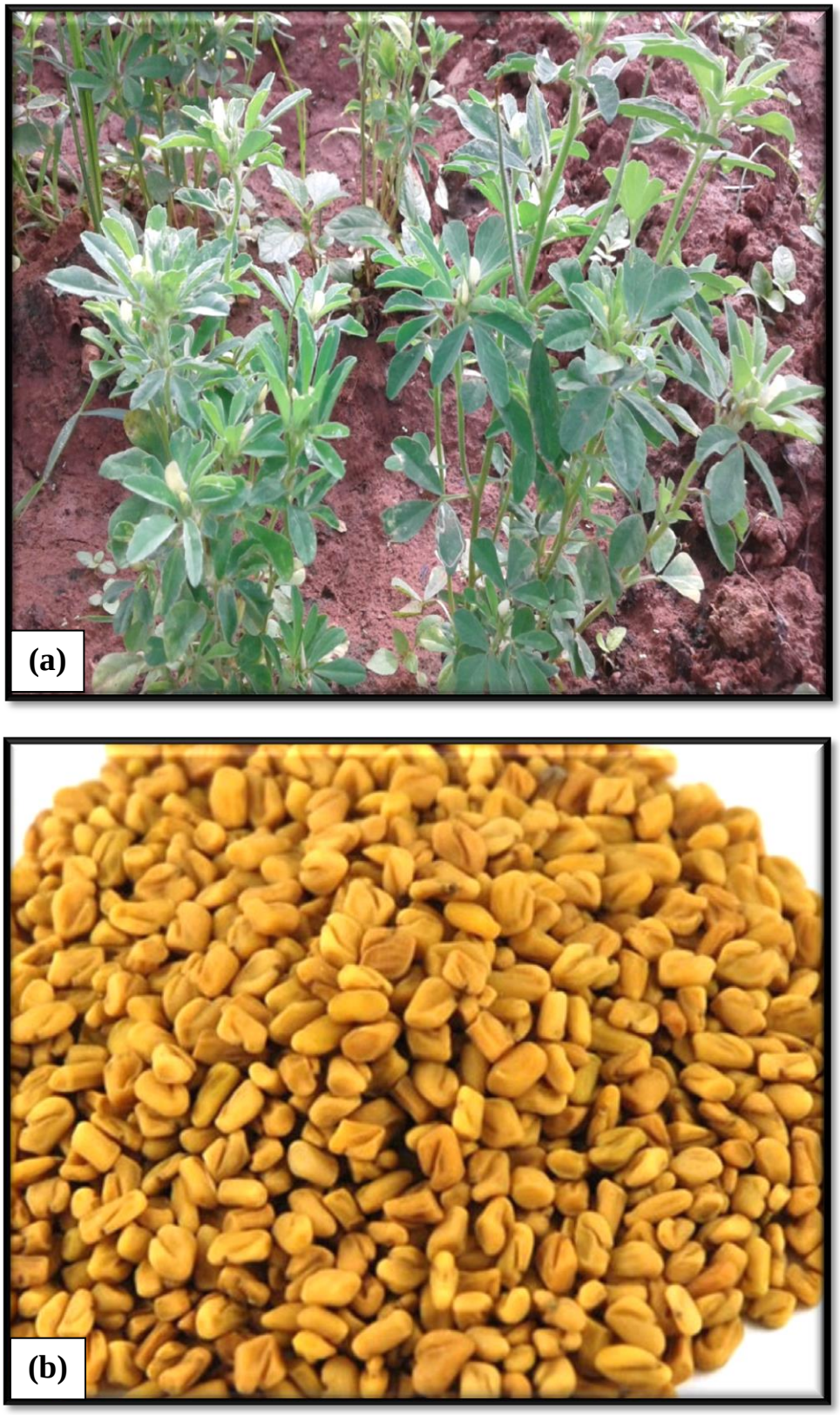


Plate 3. Crop at pod setting stage (a) and seeds (b) of fenugreek (*Trigonella foenum-graecum* L.)

IV EXPERIMENTAL RESULTS

Results of the experiment entitled "Organic cultivation of fenugreek (*Trigonella foenum-graecum* L.)" are presented in this chapter under the following headings.

4.1 Effect of different organic manures on growth and flowering of fenugreek.

4.2 Effect of different organic manures on yield and quality of fenugreek.

4.3 Effect of different organic manures on economics of fenugreek cultivation under Bangalore conditions.

4.1 Effect of different organic manures on growth and flowering of fenugreek

4.1.1 Growth parameters

4.1.1.1 Plant height (cm)

The data on plant height presented in Table 1 and illustrated in Fig. 1 indicated significant difference among the treatments at all stages of plant growth.

At 30 DAS, poultry manure applied at 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}) resulted in maximum plant height (14.90 cm) and this treatment was *on par* with the treatment (T_8) involving the application of 3.5 t ha^{-1} vermicompost + *Rhizobium* seed treatment (14.77 cm). The least plant height (10.533 cm) was recorded in (T_4) where poultry manure was applied at 3.0 t ha^{-1} + without *Rhizobium* seed treatment.

At 60 DAS also poultry manure applied at 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}) resulted in maximum plant height (36.07 cm) and this treatment was *on par* with the treatment (T_8) which received 3.5 t ha^{-1} vermicompost + *Rhizobium* seed treatment (35.57 cm). The least plant height was recorded in (T_{10}) where poultry manure was applied at 3.0 t ha^{-1}+ *Rhizobium* seed treatments (30.40 cm) were used.

At the time of harvesting the plant height was found highest in the treatment (T_{11}) with the application of poultry manure applied at 4.5 t ha^{-1} + *Rhizobium* seed treatment (36.07 cm) and was *on par* with the treatment (T_8) which received 3.5 t ha^{-1} vermicompost + *Rhizobium* seed treatment (35.57 cm). The least plant height was recorded in (T_{12}) with the application of 5.5 t ha^{-1} FYM + *Rhizobium* seed treatment (30.40 cm).

4.1.1.2 Number of primary branches

The data pertaining to number of primary branches is presented in Table 2 and illustrated in Fig 2.

At 30 DAS, highest number of primary branches were noticed in the treatment (T_{11}) with the application of poultry manure applied at 4.5 t ha^{-1} + *Rhizobium* seed treatment (3.90) which was *on par* with the treatment (T_8) which received 3.5 t ha^{-1} vermicompost + *Rhizobium* seed treatment (3.73) and also the treatment (T_1) with the application of RDF-60:90:50: kg N, P_2O_5 and K_2O ha^{-1} (3.63). Least number of primary

Table 1: Plant height of fenugreek (*Trigonella foenum–graceum* L.) as influenced by different sources of organic manures

Treatments	Plant height (cm)		
	30 DAS	**60 DAS**	**At harvest**
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	13.90	35.31	35.31
T_2-100 % N through VC without *Rhizobium* seed treatment	10.60	30.67	30.67
T_3-150 % N through VC without *Rhizobium* seed treatment	11.23	33.57	33.57
T_4-100 % N through PM without *Rhizobium* seed treatment	10.53	33.17	33.17
T_5-150 % N through PM without *Rhizobium* seed treatment	11.37	31.83	31.83
T_6-100 % N through FYM without *Rhizobium* seed treatment	12.40	31.67	31.67
T_7-150 % N through FYM without *Rhizobium* seed treatment	12.43	33.43	33.43
T_8-100 % N through VC with *Rhizobium* seed treatment	14.77	35.57	35.57
T_9-150 % N through VC with *Rhizobium* seed treatment	12.53	35.36	35.36
T_{10}-100 % N through PM with *Rhizobium* seed treatment	12.23	30.40	30.40
T_{11}-150 % N through PM with *Rhizobium* seed treatment	14.90	36.07	36.07
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	11.83	31.53	31.53
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	12.43	30.57	30.57
Mean	**12.40**	**32.79**	**32.79**
S.Em±	**0.15**	**0.21**	**0.21**
C.D. @ 5 %	**0.45***	**0.62***	**0.62***

Note: *****Significant, N - Nitrogen, VC - Vermicompost, PM - Poultry manure, FYM - Farm Yard Manure

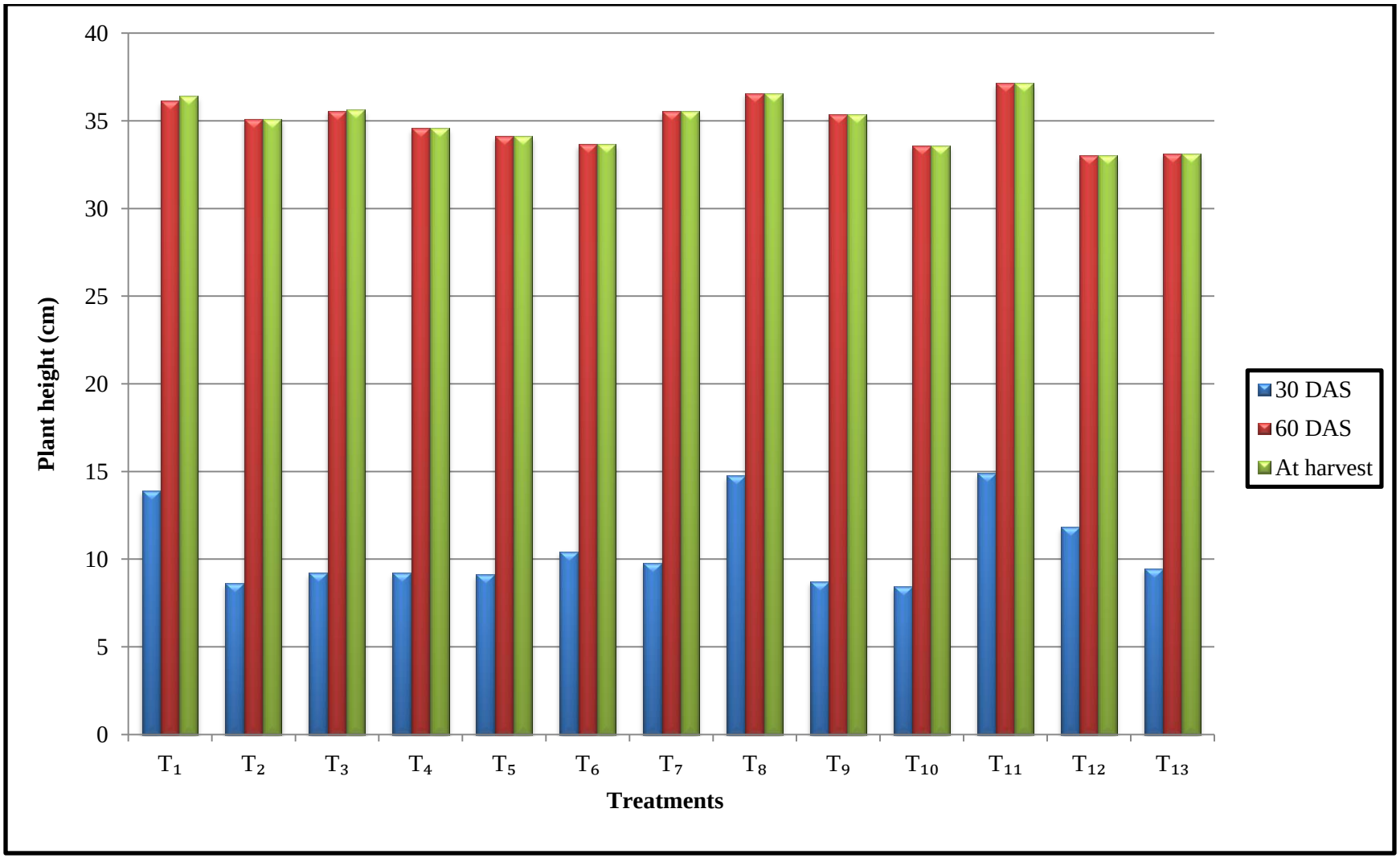


Fig. 1: Plant height of fenugreek (*Trigonella foenum-graecum* L.) as influenced by different sources of organic manures

Table 2: Number of primary branches of fenugreek (*Trigonella foenum–graecum* L.) as influenced by different sources of organic manures

Treatments	Number of primary branches		
	30 DAS	**60 DAS**	**At harvest**
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	3.63	4.90	4.90
T_2-100 % N through VC without *Rhizobium* seed treatment	2.40	3.37	3.37
T_3-150 % N through VC without *Rhizobium* seed treatment	2.80	3.67	3.67
T_4-100 % N through PM without *Rhizobium* seed treatment	2.87	4.47	4.47
T_5-150 % N through PM without *Rhizobium* seed treatment	2.43	3.60	3.60
T_6-100 % N through FYM without *Rhizobium* seed treatment	2.47	3.73	3.73
T_7-150 % N through FYM without *Rhizobium* seed treatment	2.77	4.10	4.10
T_8-100 % N through VC with *Rhizobium* seed treatment	3.73	4.97	4.97
T_9-150 % N through VC with *Rhizobium* seed treatment	3.40	3.40	3.40
T_{10}-100 % N through PM with *Rhizobium* seed treatment	2.37	3.30	3.30
T_{11}-150 % N through PM with *Rhizobium* seed treatment	3.90	5.10	5.10
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	3.33	3.40	3.40
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	3.70	3.70	3.70
Mean	**2.98**	**3.98**	**3.98**
S.Em±	**0.13**	**0.19**	**0.19**
C.D. @ 5 %	**0.39***	**0.55***	**0.55***

Note: *****Significant, N - Nitrogen, VC - Vermicompost, PM - Poultry manure, FYM - Farm Yard Manure

branches was obtained in the treatment (T_{10}) with the application of poultry manure 3.0 t ha^{-1} + *Rhizobium* seed treatment (2.37).

At 60 DAS, highest number of primary branches (5.10) was obtained in the treatment (T_{11}) with application of poultry manure applied at 4.5 t ha^{-1} + *Rhizobium* seed treatment which was *on par* with (T_8) which received 3.5 t ha^{-1} vermicompost + *Rhizobium* seed treatment (4.97) and the treatment (T_1) which received the RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1}as the source of nutrition (4.90). Least number of branches was obtained in (T_{10}) with the application of poultry manure 3.0 t ha^{-1} + *Rhizobium* seed treatment (3.30).

At harvest also the treatment (T_{11}) with the application of poultry manure applied at 4.5 t ha^{-1} + *Rhizobium* seed treatment recorded highest number of branches (5.10) which was *on par* with (T_8) which received 3.5 t ha^{-1} vermicompost + *Rhizobium* seed treatment (4.97) and the treatment (T_1) which received the RDF-60:90:50: kg N, P_2O_5 and K_2O ha^{-1}as the source of nutrition (4.90). Least number of branches was obtained in (T_{10}) with the application of poultry manure 3 t ha^{-1} + *Rhizobium* seed treatment (3.30).

4.1.2 Reproductive parameters

The data pertaining to first flower appearance of fenugreek, days to 50 per cent flowering and maturity of the crop have been presented in the Table 3 and illustrated in Fig 3, revealed significant differences among the parameters by the application of different organic manures.

4.1.2.1 Days to first flowering

Application of different organic manures had significant impact on the time taken for first flowering in fenugreek. Earliest flowering (27.43 DAS) was observed in plants applied with 8.0 t ha^{-1} FYM + *Rhizobium* seed treatment (T_9), while the most delayed flowering (33.67 DAS) was recorded in the plants applied with vermicompost 5 t ha^{-1} + *Rhizobium* seed treatment (T_3).

4.1.2.2 Days to 50 per cent flowering

With regard to days to 50 per cent flowering , 8.0 t ha^{-1} FYM + *Rhizobium* seed treatment (T_{13}) resulted in early flowering (40.67 DAS) while, flowering was delayed in the treatment T_3 consisting of vermicompost 5 t ha^{-1} + *Rhizobium* seed treatment (43.67 DAS).

4.1.2.3 Days to maturity

The early maturity in fenugreek (90.67 DAS) was obtained in the treatments (T_1) and (T_{13}) which received RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} and 8.0t ha^{-1} FYM + *Rhizobium* seed treatment, respectively. The maturity of the crop was delayed (93.33 DAS) by the application of vermicompost 5 t ha^{-1} + without *Rhizobium* seed treatment (T_3), poultry manure 3 t ha^{-1} + without *Rhizobium* seed treatment (T_4) and vermicompost 3.5 t ha^{-1} + *Rhizobium* seed treatment (T_8).

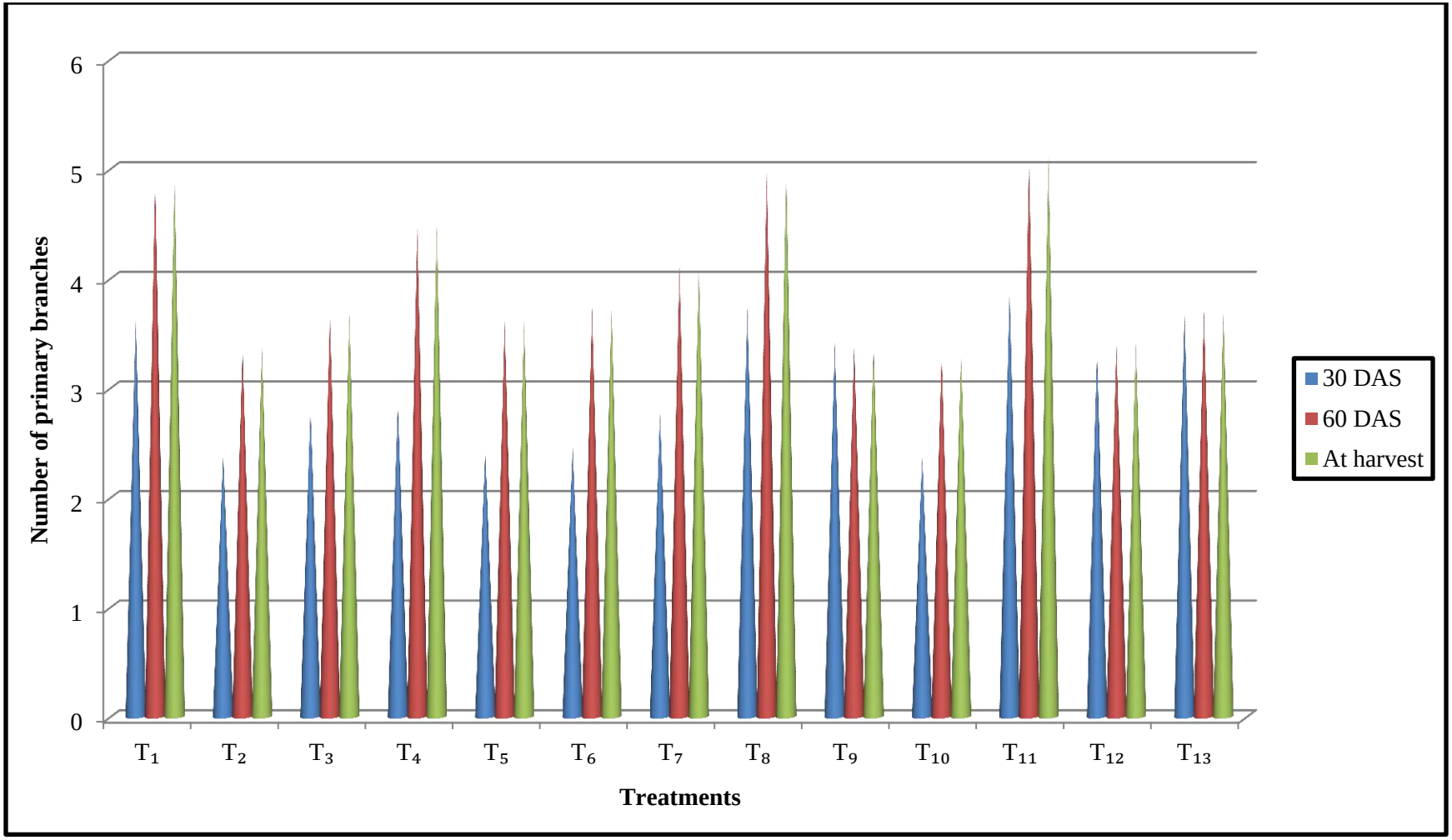


Fig. 2: Number of primary branches of fenugreek (*Trigonella foenum-graecum* L.) as influenced by different sources of organic manures

Table 3: Influence of different sources of organic manures on days to first flowering, days to 50 per cent flowering and maturity of fenugreek (*Trigonella foenum–graecum* L.)

Treatments	Days to first flowering	Days to 50 per cent flowering	Days to maturity
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	31.33	41.33	90.67
T_2-100 % N through VC without *Rhizobium* seed treatment	31.33	41.33	91.67
T_3-150 % N through VC without *Rhizobium* seed treatment	33.67	43.67	93.33
T_4-100 % N through PM without *Rhizobium* seed treatment	33.00	43.00	93.33
T_5-150 % N through PM without *Rhizobium* seed treatment	33.00	43.00	92.67
T_6-100 % N through FYM without *Rhizobium* seed treatment	31.67	41.67	91.33
T_7-150 % N through FYM without *Rhizobium* seed treatment	31.33	41.33	91.33
T_8-100 % N through VC with *Rhizobium* seed treatment	31.33	41.67	93.33
T_9-150 % N through VC with *Rhizobium* seed treatment	30.67	42.00	91.33
T_{10}-100 % N through PM with *Rhizobium* seed treatment	31.67	41.67	91.33
T_{11}-150 % N through PM with *Rhizobium* seed treatment	32.67	42.67	92.67
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	32.33	42.33	92.33
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	27.43	40.67	90.67
Mean	**32**	**42.03**	**92**
S.Em±	**0.49**	**0.47**	**0.38**
C.D. @ 5 %	**1.44***	**1.36***	**1.12***

Note: *****Significant, N - Nitrogen, VC - Vermicompost, PM - Poultry manure, FYM - Farm Yard Manure

4.2 Effect of different organic manures on yield and quality of fenugreek

4.2.1 Yield parameters

4.2.1.1 Number of pods per plant

The number of pods per plant of fenugreek varied significantly due to the application of different organic manures. (Table 4)

Maximum number of pods per plant (32.50) were observed in the treatment (T_{11}) where poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment were imposed and it was *on par* with the treatment (T_8) with the application of vermicompost 3.5 t ha^{-1} + *Rhizobium* seed treatment (31.83) and also with the treatment (T_1) which receives RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} as the source of nutrition (31.50). Least number of pods per plant (23.17) was recorded under treatment (T_{10}) where poultry manure 3.0 t ha^{-1} + *Rhizobium* seed treatment was the source of nutrition.

4.2.1.2 Pod length (cm)

Length of pod also varied significantly due to the application of different organic manures. (Table 4)

Longer pods (12.53 cm) were obtained by the application of RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} (T_1). This treatment was *on par* with the treatments (T_8) and (T_{11}) involving vermicompost 3.5 t ha^{-1} + *Rhizobium* seed treatment (12.37 cm) and poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment (12.33 cm), respectively. The least pod length (8.37 cm) was obtained by the application of FYM 8.0 t ha^{-1} + *Rhizobium* seed treatment (T_{13}).

4.2.1.3 Number of seeds per pod

Different sources of organic manures had significant impact on the number of seeds per pod in fenugreek. (Table 5)

Application of poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}), produced maximum number of seeds per pod (12.10) which was *at par* with the treatments (T_8), (T_1) and (T_9) where vermicompost 3.5 t ha^{-1} + *Rhizobium* seed treatment (12.07), RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} (12.00) and vermicompost 5.0 t ha^{-1} + *Rhizobium* seed treatment (11.50) were used. The minimum number of seeds per pod (8.30) was noticed in (T_5) by the application of poultry manure 4.5 t ha^{-1} + without *Rhizobium* seed treatment.

4.2.1.4 Test weight of seeds (g per 100 seeds)

Different sources of organic manures had significant impact on the test weight of seeds per pod in fenugreek. (Table 5)

Highest test weight of seeds (1.78 g per 100 seeds) was recorded in (T_{11}), with the application of poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment and was *on par* with other treatments like T_8- 3.5 t ha^{-1} vermicompost + *Rhizobium* seed treatment, T_3-5 t ha^{-1}

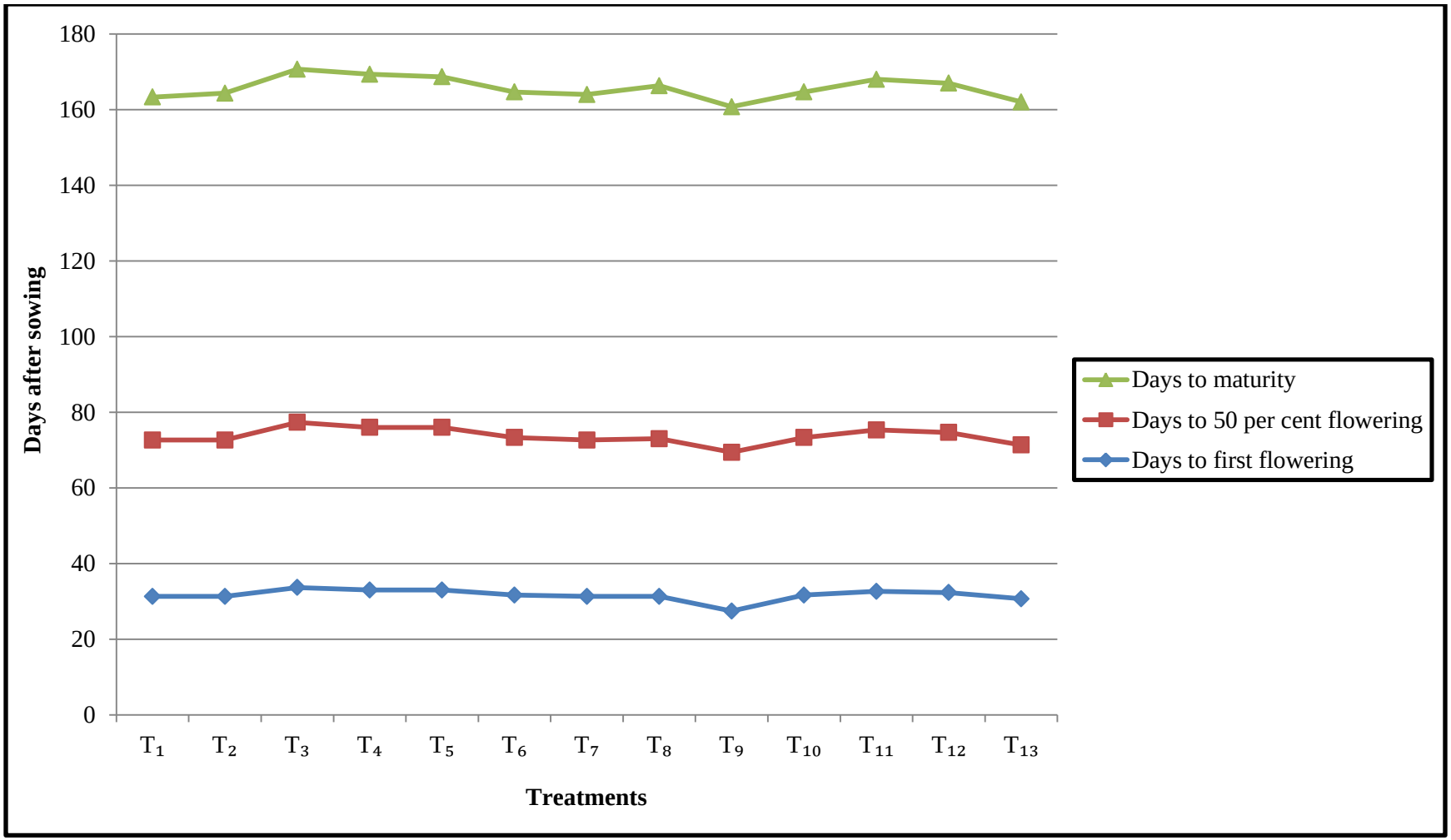


Fig. 3: Influence of different sources of organic manures on days to first flowering, days to 50 per cent flowering and maturity of fenugreek (*Trigonella foenum–graecum* L.)

Table 4: Number of pods per plant and pod length of fenugreek (*Trigonella foenum–graecum* L.) as influenced by different sources of organic manures

Treatments	No. of pods plant^{-1}	Length of the pod (cm)
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	31.50	12.53
T_2-100 % N through VC without *Rhizobium* seed treatment	23.67	11.03
T_3-150 % N through VC without *Rhizobium* seed treatment	28.07	10.53
T_4-100 % N through PM without *Rhizobium* seed treatment	27.57	10.13
T_5-150 % N through PM without *Rhizobium* seed treatment	26.63	8.57
T_6-100 % N through FYM without *Rhizobium* seed treatment	24.70	9.63
T_7-150 % N through FYM without *Rhizobium* seed treatment	25.80	10.57
T_8-100 % N through VC with *Rhizobium* seed treatment	31.83	12.37
T_9-150 % N through VC with *Rhizobium* seed treatment	27.50	11.50
T_{10}-100 % N through PM with *Rhizobium* seed treatment	23.17	9.27
T_{11}-150 % N through PM with *Rhizobium* seed treatment	32.50	12.33
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	26.93	10.97
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	26.67	8.37
Mean	**27.43**	**10.68**
S.Em±	**0.56**	**0.22**
C.D. @ 5 %	**1.63***	**0.64***

Note: *****Significant, N - Nitrogen, VC - Vermicompost, PM - Poultry manure, FYM - Farm Yard Manure

Table 5: Number of seeds per pod and Test weight of fenugreek (*Trigonella foenum–graecum* L.) seeds as influenced by different sources of organic manures

Treatments	No. of seeds pod^{-1}	Test weight (g per 100 seeds)
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	12	1.72
T_2-100 % N through VC without *Rhizobium* seed treatment	10.50	1.60
T_3-150 % N through VC without *Rhizobium* seed treatment	9.93	1.73
T_4-100 % N through PM without *Rhizobium* seed treatment	9.90	1.71
T_5-150 % N through PM without *Rhizobium* seed treatment	8.30	1.50
T_6-100 % N through FYM without *Rhizobium* seed treatment	9.33	1.55
T_7-150 % N through FYM without *Rhizobium* seed treatment	10.20	1.71
T_8-100 % N through VC with *Rhizobium* seed treatment	12.07	1.76
T_9-150 % N through VC with *Rhizobium* seed treatment	11.50	1.61
T_{10}-100 % N through PM with *Rhizobium* seed treatment	9.03	1.45
T_{11}-150 % N through PM with *Rhizobium* seed treatment	12.10	1.78
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	10.70	1.61
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	8.93	1.52
Mean	**10.33**	**1.74**
S.Em±	**0.25**	**0.06**
C.D. @ 5 %	**0.72***	**0.18***

Note: *****Significant, N - Nitrogen, VC - Vermicompost, PM - Poultry manure, FYM - Farm Yard Manure

vermicompost + without *Rhizobium* seed treatment, T_1- RDF (60:90:50 kg ha^{-1}), T_4- 3 t ha^{-1} poultry manure without *Rhizobium* seed treatment, T_7- 8 t ha^{-1} FYM + *Rhizobium* seed treatment, T_9- 5 t ha^{-1} vermicompost + without *Rhizobium* seed treatment and T_{12}- 5.5 t ha^{-1} FYM + *Rhizobium* seed treatment. The lowest test weight of seeds (1.45 g per 100 seeds) was obtained by the application of poultry manure 3.0 t ha^{-1} + *Rhizobium* seed treatment (T_{10}).

4.2.1.5 Seed yield (kg per ha^{-1})

Seed yield of fenugreek as influenced by different sources of organic manures is presented in Table 6 and illustrated in Fig 4, which clearly indicates the significant impact of different organic manures in all the treatments.

Maximum seed yield of 1567.69 kg per hectare was recorded with the application of 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}), followed by (T_8) the application of vermicompost 3.5 t ha^{-1} + *Rhizobium* seed treatment (1514.08 kg per ha). Whereas, the minimum seed yield 691.66 kg per hectare was obtained by the application poultry manure 3.0 t ha^{-1} + *Rhizobium* seed treatment (T_{10}).

4.2.1.6 Straw yield (kg per ha^{-1})

Different sources of organic manures had significant effect on the straw yield of fenugreek (Table 6 and Fig 4).

Application of 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}) produced maximum straw yield of 2331.48 kg per ha followed by (T_1) where RDF-60:90:50 N, P_2O_5 and K_2O kg ha^{-1} (2104.63 kg per ha) were used. The lowest straw yield of 1606.48 kg per hectare was obtained under the treatment (T_2) with the application of vermicompost 3.5 t ha^{-1} + without *Rhizobium* seed treatment.

4.2.2 Quality parameters

4.2.2.1 Crude protein content (%)

Crude protein content as influenced by different sources of organic manures have been presented in Table 7, which clearly indicates the significant impact of different sources of organic manures on crude protein content in fenugreek seeds.

The crude protein content in seeds varied from 17.50 – 20.00 per cent. It was maximum in the treatment (T_{11}) which received 4.5 t ha^{-1} poultry manure + *Rhizobium* seed treatment (20.00 %), it was *on par* with application of vermicompost 3.5 t ha^{-1} + *Rhizobium* seed treatment (19.97 %) (T_8), RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} (19.90 %) (T_1), vermicompost 3.5 t ha^{-1} + without *Rhizobium* seed treatment (19.63 %) (T_2), vermicompost 5.0 t ha^{-1} + *Rhizobium* seed treatment (19.50 %) (T_9). Lowest crude protein content (17.50 %) was obtained in (T_{12}) where FYM 5.5 t ha^{-1} + *Rhizobium* seed treatment were used and (T_6) involving 5.5 t ha^{-1} FYM + without *Rhizobium* seed treatment.

Table 6: Seed and straw yield of fenugreek (*Trigonella foenum–graecum* L.) as influenced by different sources of organic manures

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	1488.3	2104.63
T_2-100 % N through VC without *Rhizobium* seed treatment	1094.72	1606.48
T_3-150 % N through VC without *Rhizobium* seed treatment	1105.5	1723.15
T_4-100 % N through PM without *Rhizobium* seed treatment	1066.6	1711.11
T_5-150 % N through PM without *Rhizobium* seed treatment	855.08	1692.59
T_6-100 % N through FYM without *Rhizobium* seed treatment	818.41	1709.26
T_7-150 % N through FYM without *Rhizobium* seed treatment	1037.5	1817.59
T_8-100 % N through VC with *Rhizobium* seed treatment	1514.08	2034.25
T_9-150 % N through VC with *Rhizobium* seed treatment	1139.44	1727.77
T_{10}-100 % N through PM with *Rhizobium* seed treatment	691.66	1817.59
T_{11}-150 % N through PM with *Rhizobium* seed treatment	1567.69	2331.48
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	1050.27	1771.29
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	848.61	1876.85
Mean	**1062.15**	**1840.31**
S.Em±	**13.06**	**10.27**
C.D. @ 5 %	**38.13***	**29.97***

Note: *****Significant, N - Nitrogen, VC - Vermicompost, PM - Poultry manure, FYM - Farm Yard Manure

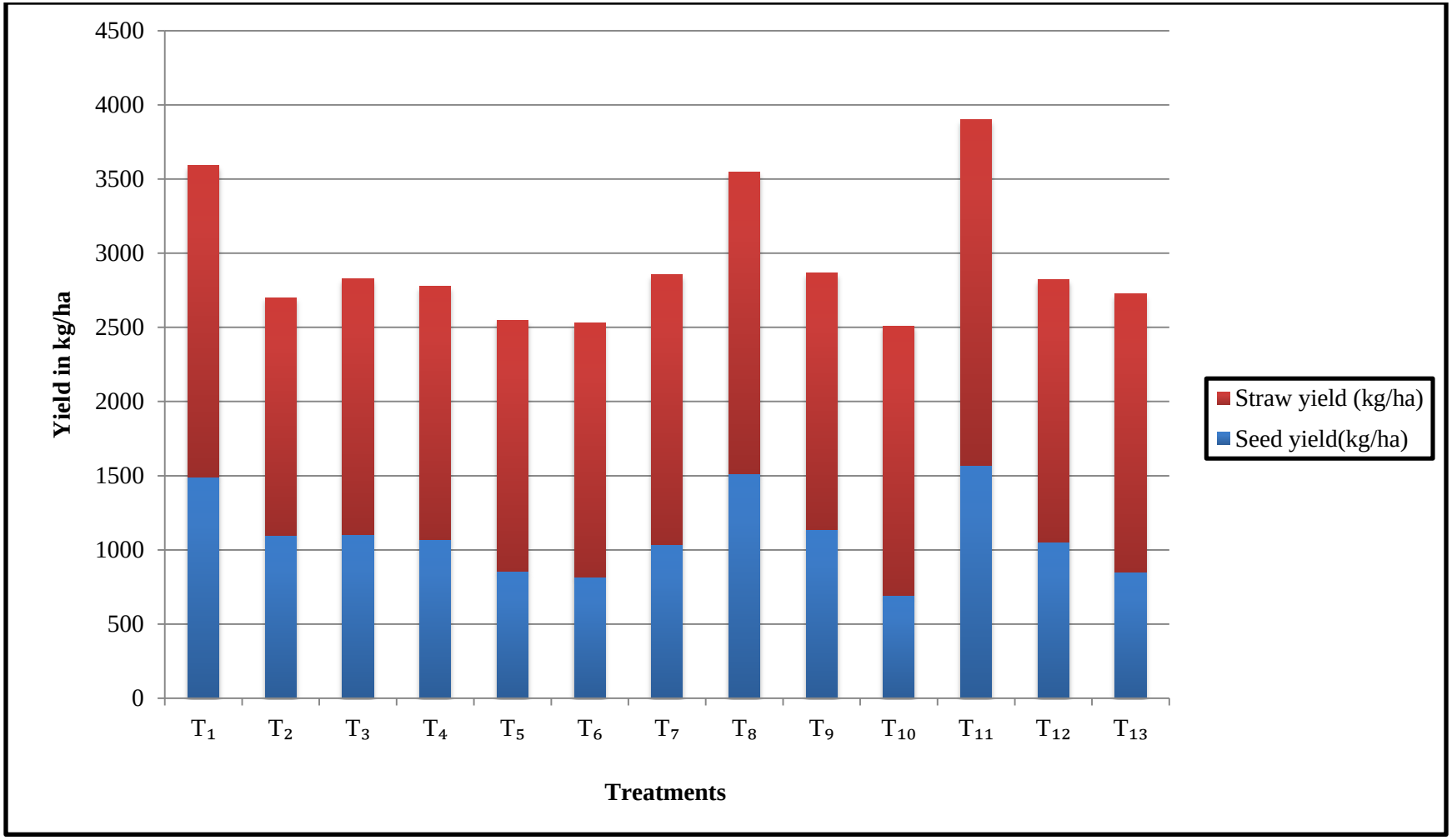


Fig. 4: Seed and straw yield of fenugreek (*Trigonella foenum-graecum* L.) as influenced by different sources of organic manures

Table 7: Influence of different sources of organic manures on crude protein content of fenugreek seeds

Treatments	Crude protein content in leaves (%)	Crude protein content in seed (%)
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	12.37	19.90
T_2-100 % N through VC without *Rhizobium* seed treatment	11.23	19.63
T_3-150 % N through VC without *Rhizobium* seed treatment	11.53	18.13
T_4-100 % N through PM without *Rhizobium* seed treatment	10.63	18.50
T_5-150 % N through PM without *Rhizobium* seed treatment	11.43	18.57
T_6-100 % N through FYM without *Rhizobium* seed treatment	9.93	17.50
T_7-150 % N through FYM without *Rhizobium* seed treatment	10.40	19.00
T_8-100 % N through VC with *Rhizobium* seed treatment	11.47	19.97
T_9-150 % N through VC with *Rhizobium* seed treatment	10.46	19.50
T_{10}-100 % N through PM with *Rhizobium* seed treatment	9.40	18.37
T_{11}-150 % N through PM with *Rhizobium* seed treatment	12.43	20.00
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	11.23	17.50
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	10.37	18.80
Mean	**10.99**	**18.87**
S.Em±	**0.11**	**0.26**
C.D. @ 5 %	**0.33***	**0.75***

Note: *****Significant, N - Nitrogen, VC - Vermicompost, PM - Poultry manure, FYM - Farm Yard Manure

The crude protein content in leaves varied from 9.40 – 12.43 per cent. The maximum crude protein content (12.43 %) was obtained in the treatment (T_{11}) involving 4.5 t ha^{-1} poultry manure + *Rhizobium* seed treatment and it was *at par* with T_1 where RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} is applied (12.37 %). Lowest value (9.40 %) was recorded under the treatment T_{10} with the application of poultry manure 3.0 t ha^{-1} + *Rhizobium* seed treatment.

4.3 Effect of different organic manures on economics of fenugreek cultivation under Bangalore conditions

Economics is an important and ultimate factor which decides the optimum levels of inputs to be used in the production of any crop. The data on the economics of fenugreek cultivation as influenced by different organic manures is presented in Table 8 and graphically represented in Fig. 5. The details of estimation of cost of cultivation have been presented in appendix VI.

The cost of cultivation ranges from Rs. 31950 ha^{-1} to Rs. 69212 ha^{-1} due to various treatments. Highest expenditure (Rs. 69212 ha^{-1}) was incurred in raising the crop using vermicompost applied at 5.0 t ha^{-1} + *Rhizobium* seed treatment (T_9). The expenditure was least (Rs.31950 ha^{-1}) for raising the crop when RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} (T_1).

The perusal of data on gross returns showed wide differences due to various treatments imposed. The highest gross return (Rs. 125415 ha^{-1}) was obtained from the plants applied with poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}) and lowest (Rs. 65473 ha^{-1}) was obtained from the treatment (T_6) with the application of FYM 5.5 t ha^{-1} + without *Rhizobium* seed treatment.

Similarly, the highest net returns (Rs. 89453 ha^{-1}) was obtained from the crop subjected to the application of 4.5 t ha^{-1} poultry manure + *Rhizobium* seed treatment (T_{11}). Low net returns (Rs.19240 ha^{-1}) was obtained under the treatment (T_3) with the application of vermicompost 5.0 t ha^{-1} + without *Rhizobium* seed treatment. With regard to B:C ratio, maximum returns per rupee (2.72) was from the treatment (T_1) which received RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} as the source of nutrition and it was followed by T_{11} with the application of 4.5 t ha^{-1} poultry manure + *Rhizobium* seed treatment (3.48). B:C ratio was lowest (0.27) from the treatment (T_3) applied with vermicompost 5.0 t ha^{-1} + without *Rhizobium* seed treatment.

Table 8: Economics of fenugreek (*Trigonella foenum–graecum* L.) cultivation as influenced by different sources of organic manures under Bangalore conditions

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	31950	119064	87114	3.72
T_2-100 % N through VC without *Rhizobium* seed treatment	57200	87578	30378	1.53
T_3-150 % N through VC without *Rhizobium* seed treatment	69200	88440	19240	1.27
T_4-100 % N through PM without *Rhizobium* seed treatment	33700	85328	51628	2.53
T_5-150 % N through PM without *Rhizobium* seed treatment	35950	68406	32456	1.9
T_6-100 % N through FYM without *Rhizobium* seed treatment	34700	65473	30773	1.88
T_7-150 % N through FYM without *Rhizobium* seed treatment	37200	83000	45800	2.23
T_8-100 % N through VC with *Rhizobium* seed treatment	57212	121126	63914	2.11
T_9-150 % N through VC with *Rhizobium* seed treatment	69212	91155	21943	1.31
T_{10}-100 % N through PM with *Rhizobium* seed treatment	33712	55333	21621	1.64
T_{11}-150 % N through PM with *Rhizobium* seed treatment	35962	125415	89453	3.48
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	34712	84022	49310	2.42
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	37212	67889	30677	1.82

Note: Seeds- 80 Rs./kg

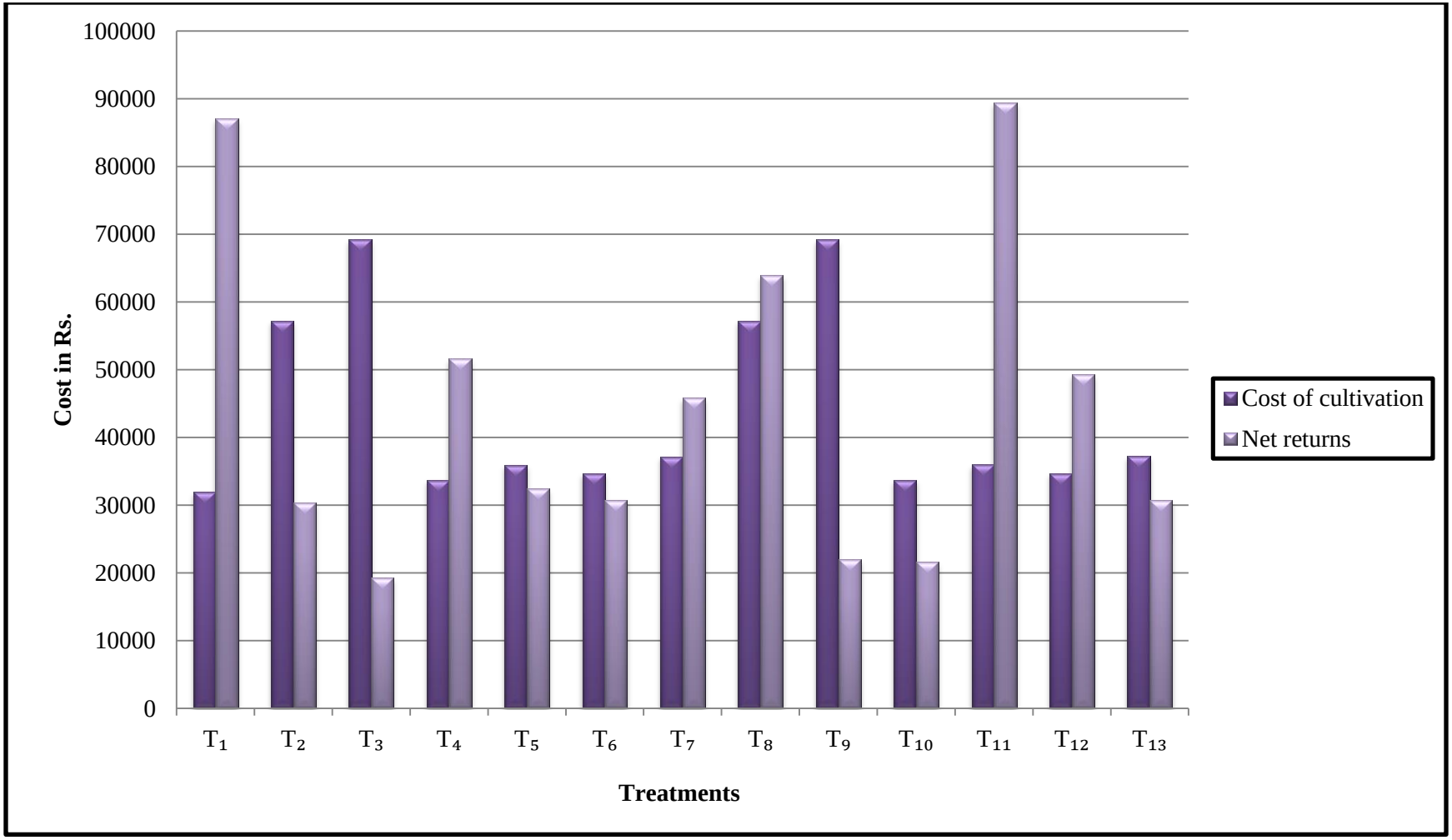


Fig. 5: Economics of fenugreek (*Trigonella foenum–graecum* L.) cultivation as influenced by different sources of organic manures under Bangalore conditions

V DISCUSSION

Health problems, quality consciousness and degradation of natural resources have thrown new challenges on the environment and society. Due to these burning problems, organic farming is gaining importance towards achieving sustainability in crop production. Use of organic manures is inherent in Indian farming system. However, after the advent of chemical fertilizers, the importance of organic manuring has received least attention among the farming community, leading to increased toxicity in soil and farm produce.

Drought, coupled with high temperatures and intensive cultivation have exhausted the organic matter contents in the soil. Therefore, soil organic matter content has to be built up by recycling the organic wastes, so that the production level is sustained at a desired level. Organics also provide balanced nutrition in addition to enhancing water holding capacity and improving physical, chemical and biological properties of soil which assist in better uptake of nutrients.

Fenugreek is one of the important seed spices cultivated in India. Apart from being used as spice and condiment, it finds a prominent place in ayurvedic medicine owing to its immense medicinal properties. Unfortunately, the production potential of this crop is low and quality is often substandard. Hence, it is time to think not only of increasing the production potential but also to improve the quality by applying advancements in scientific production to meet the increasing demand and boost up the export earnings. Therefore, a study was undertaken to find out the influence of organic manures and bio fertilizers on growth, yield and quality parameters of fenugreek, and to work out the economics of organic cultivation of this crop.

The results of investigation are discussed in this chapter under following headings-

5.1 Effect of different organic manures on growth and flowering of fenugreek.

5.2 Effect of different organic manures on yield and quality of fenugreek.

5.3 Effect of different organic manures on economics of fenugreek cultivation under Bangalore conditions.

5.1 Effect of different organic manures on growth and flowering of fenugreek.

5.1.1 Growth parameters

5.1.1.1 Plant height (cm)

Basically plant height is a genetically controlled character but it is also being influenced by environmental conditions and management practices.

The present study revealed significant differences in plant height among the treatments at all growth stages which are illustrated in Fig 1. The maximum plant height at 30, 60 DAS and before harvest (14.90 cm, 36.07 cm and 36.07 cm, respectively) was

recorded in the treatment (T_{11}) involving the application of poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment at all growth stages. While the lowest plant height was recorded in T_4 where, poultry manure was applied at 3.0 t ha^{-1} + without *Rhizobium* seed treatment at 30 DAS (10.53 cm) and in T_{10} (5.5 t ha^{-1} FYM + *Rhizobium* seed treatment) at 60 DAS (30.40 cm) and before harvest (30.40 cm). These results are in conformity with the reports of Channabasavanna *et al*. (2001) and Mehta *et al*. (2011) who revealed the maximum plant height of maize and coriander respectively due to application of poultry manure.

Poultry manure contains higher nitrogen content (2.1 %) as compared to other two organic manures considered in the experiment. Positive influence of the nitrogen content present in the manure tends to the increase cell division and cell elongation which in turn increased the plant height. This result is in conformity with the findings of Farhad *et al*. (2009) in maize crop.

Seed inoculation with *Rhizobium* also increases plant growth by various such as production of plant growth harmones, vitamins, siderophores and by solubilisation of phosphates. (Pawar *et al.,* 2014)

5.1.1.2 Primary branches

The application of organics and biofertilizer seed treatment had profound effect on number of primary branches which is illustrated in Fig 2. Number of primary branches is also found to be higher in T_{11} where poultry manure was applied at 4.5 t ha^{-1} + *Rhizobium* seed treatment at 30 DAS, RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} (T_1) at 60 DAS and before harvest (3.90, 5.10 and 5.10, respectively). The lowest number of primary branches (2.37 at 30 DAS, 3.30 at 60 DAS and before harvest) was recorded in T_{10} where, poultry manure is applied at 3.0 t ha^{-1} + *Rhizobium* seed treatment.

Poultry manure is excellent organic manure as it contains high N, P, K and other essential nutrients and it more readily supplies phosphorous to plants than other organic sources.

As poultry manure and *Rhizobium* supplies the essential nutrients during crop growth good number of primary branches were developed. Similar results were obtained in the experiment conducted by Abuselaha (1992), Rao and Shaktawat (2001) who reported improvement in number of branches in okra and ground nut, respectively due to the application poultry manure.

5.1.2 Reproductive parameters

The time of flowering and maturity are important factors affecting crop productivity and adoption to diverse agro-climatic situations.

5.1.2.1 Days to first flower appearance, 50 per cent flowering and maturity of the crop

Earliest flowering and 50 per cent was observed in plants applied with 8.0 t ha^{-1} FYM + *Rhizobium* seed treatment (T_{13}). While delayed flowering was recorded in the plants applied with vermicompost 5 t ha^{-1} + *Rhizobium* seed treatment (T_9). This behaviour of plant exhibiting early flowering may be attributed due to higher doses of organic manure along with *Rhizobium* seed treatment which enhances the nitrogen and phosphorous status and made plant to enter into reproductive phase early. These results are in agreement with findings of Singh and Singh (1992), Renuka and Shankar (2001) in tomato.

Early maturity was observed in the treatments T_1 and T_{13} with RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} and 8.0 t ha^{-1} FYM + *Rhizobium* seed treatment, respectively. But maturity was delayed with the application of vermicompost 5 t ha^{-1} + without *Rhizobium* seed treatment (T_3), vermicompost 3.5 t ha^{-1} + *Rhizobium* seed treatment (T_8) and poultry manure 3 t ha^{-1} + without *Rhizobium* seed treatment (T_4).

It is well known that nitrogen plays a pivotal role in determining the time taken for the plant to enter into reproductive phase. Application of higher doses of nitrogen along with *Rhizobium* seed treatment causes the maximum diversion of photosynthates to produce foliage, which in turn made plant to enter in to reproductive phase and stimulate early maturity of the crop. Similar results were obtained by Jagadale *et al.* (2010) in fenugreek. The plant growth regulators present in the FYM also hastened flowering and helps in early maturity of the crop. This result is in conformity with the findings of Naimuddin *et al.,* 2014 in fenugreek.

5.2 Effect of different organic manures on yield and quality of fenugreek.

Grain yield is the manifestation of morphological, physiological and growth parameters in any crop. Seed yield in fenugreek is the product of several of its components such as number of pods per plant, number of seeds per pod, test weight of 100 seeds *etc.,*

5.2.1 Yield parameters

5.2.1.1 Number of pods per plant

Maximum number of pods per plant (32.50) was observed in the treatment T_{11} where poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment were imposed. The increased plant height, number of branches and long growing period due to timely availability of nutrients through growing season by the application of poultry manure as it also improves soil fertility by adding major and essential nutrients to soil and made available to plants. Higher vegetative growth resulting in the synthesis of greater amount of food materials, which in turn supported profuse flowering and higher pod setting. This result is in accordance with Purbey and Sen (2005) in fenugreek.

5.2.1.2 Pod length (cm)

Significantly longer pods (12.53 cm) were obtained in T_1 due to the application of RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1}. Pod length was positively influenced by higher nitrogen level. The nutrients supplied through RDF helps the plants to synthesise greater amount of food material which in turn supported greater pod setting and increase in pod length. This result was in conformity with the findings of Godara *et al.* (2012) in fenugreek.

5.2.1.3 Number of seeds per pod

Application of poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}) produced maximum number of seeds per pod (12.10). This might be due to the availability of nutrients required by the plants throughout the growing season enabling good vegetative growth, better pod setting, grain filling and longer pods. These results are in line with the findings of Datta *et al.* (2005) in fenugreek.

5.2.1.4 Test weight of seeds (g per 100 seeds)

With respect to 100 seeds weight the highest weight (1.78 g per 100 seeds) was recorded in T_{11} with the application of poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment. This result is supported by the research work conducted by Naidu *et al.* (2010), in fenugreek seeds.

Among various parts of fenugreek seeds are the richest source of protein. Since poultry manure contains good nitrogen content (2.1 %) and could be due to the balanced supply of food nutrients from the manure through atmospheric N fixation in the root nodules. It contributes for the increase in protein synthesis besides other photosynthates and translocation in to the developing pods and thereby adds to the weight of seeds. The findings of Deora and Singh (2004), Purbey and Sen (2005) in fenugreek endorse the results of the present investigation.

5.2.1.5 Seed yield (kg per ha^{-1})

Maximum seed yield of 1567.69 kg per hectare was obtained due to the application of 4.5 t ha^{-1} of poultry manure + *Rhizobium* seed treatment. This result is in conformity with the research findings of Anitha *et al.* (2015) in fenugreek.

Seed yield is an output of sequential metamorphosis from source to sink. Application of poultry manure and *Rhizobium* through seed treatment provides good source of nitrogen produces maximum vegetative growth and influences the reproductive parameters as well. The growth and reproductive parameters such as plant height, number of branches, flowering, number of pods per plant, pod length, number of seeds per pod, test weight improved with this dose of nitrogen, which resulted in increased seed yield. Inoculation of *Rhizobium sp*. caused an increase in yield (Akhtar and Siddiqui, 2009).

5.2.1.6 Straw yield (kg per ha^{-1})

Different sources of organic manures had significant effect on the straw yield of fenugreek. Application of poultry manure at 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}) produced maximum straw yield of 2331.48 kg per hectare. This could be due to sufficient vegetative and reproductive growth with the application of higher doses of organic manure along with *Rhizobium* seed treatment. These experimental results are in conformity with findings of Naidu *et al.* (2010) in fenugreek.

Increase in straw yield of *Rhizobium* inoculated plant may be attributed due to enhanced nodulation, increased nitrogen fixation and general improvement in root development (Erum and Bano, 2008)

5.2.2 Quality parameters

5.2.2.1 Crude protein content (%)

Among the various plant parts of fenugreek, seeds contain maximum protein followed by the herb and straw.

The crude protein content in seeds and leaves was maximum in the treatment T_{11} which received 4.5 t ha^{-1} poultry manure + *Rhizobium* seed treatment (20.00 % and 12.43 % respectively). The increase in crude protein content with higher dose of nitrogen application through poultry manure may be due to direct involvement of nitrogen in protein metabolism as nitrogen is an integral part of amino acids, which are building blocks of protein. It is supported by the studies conducted by Naidu *et al.* (2010) in fenugreek.

Fenugreek has a potential to fix a substantial amount of atmospheric nitrogen and inoculation of fenugreek with suitable strains of *Rhizobium* is expected to improve the quality of produced seeds. (Abdelgani, 1999)

5.3 Effect of different organic manures on economics of fenugreek cultivation under Bangalore conditions

Economics is an important and ultimate factor which decides the optimum levels of inputs to be used in the production of any crop.

With regard to the cost of cultivation it was found highest (Rs. 69212 ha^{-1}) in the treatment T_9 applied with vermicompost 5.0 t ha^{-1} + *Rhizobium* seed treatment. This was in conformity with the findings of Mehta *et al.* (2012) in cumin. As the cost of vermicompost is comparatively higher and quantity applied is also higher than other two manures included in the research work, the highest expenditure was incurred in the above treatment.

A perusal of data on gross returns shows wide differences due to various treatments imposed. The highest gross return (Rs. 125415 ha^{-1}) was obtained from the treatment T_{11} applied with poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment. As the

seed yield was highest, this in turn gave the highest gross returns under this treatment compared to other treatments.

Similarly, the maximum net returns (Rs. 89453 ha^{-1}) was obtained from T_{11} due the application of 4.5 t ha^{-1} poultry manure + *Rhizobium* seed treatment. With respect to B: C (3.72) it was found maximum in the treatment T_1 applied with RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1}. This is in conformity with the findings of Godara *et al.* (2014) in fenugreek.

Though net return per rupee was highest in the treatment T_1 where, RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} is used, but for realizing good soil health and sustainable production application 50 per cent RDF along with 50 per cent poultry manure along with *Rhizobium* seed treatment is a better option.

VI SUMMARY

A field experiment entitled "Organic cultivation of fenugreek (*Trigonella foenum-graecum* L.)" was conducted during *rabi* season of 2015-2016 at the Department of Horticulture, College of Agriculture, UAS, GKVK, Bangalore.

The experiment consisted of twelve treatments, with three organic manures *viz.*, vermicompost, poultry manure and FYM with and without *Rhizobium* seed treatment and RDF as control. This experiment was conducted to assess the influence of organic manures on growth, yield and quality of fenugreek. The experiment was laid out in Randomized Block Design with three replications. The results obtained are summarized in this chapter.

1. The plant height (14.90 cm at 30 DAS and 36.07 cm at 60 DAS and 92.67 DAS at harvest) and number of primary (3.90 at 30 DAS and 5.10 at 60 DAS and 92.67 DAS at harvest) branches were higher in treatment with the application of poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}).

2. The reproductive parameters, days to flower initiation (27.43 DAS) and 50 per cent flowering (40.67 DAS) were found early under the treatment T_{13} with the application of 8.0 t ha^{-1} FYM + *Rhizobium* seed treatment. The crop matured early (90.67 DAS) in the treatment T_1 which received RDF-60:90:50: kg N, P_2O_5 and K_2O ha^{-1} and 8.0 t ha^{-1} FYM + *Rhizobium* seed treatment as the source of nutrition (T_{13}).

3. Application of poultry manure at 4.5 t ha^{-1} + *Rhizobium* seed treatment (T_{11}) resulted in maximum values for all the yield parameters like number of pods per plant (32.50), number of seeds per pod (12.10), test weight of seeds (1.78 g / 100 seeds), seed (1567.69 kg ha^{-1}) and straw yields (2331.48 kg ha^{-1}). The highest pod length (12.53 cm) was obtained in the treatment T_1 involving the application of RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} as the source of nutrition.

4. Among all the treatments the crude protein content of leaves (12.43 %) and seeds (20.00 %) was found maximum in the treatment which received 4.5 t ha^{-1} poultry manure + *Rhizobium* seed treatment (T_{11}).

5. With respect to the economics of fenugreek cultivation under Bangalore conditions, in the present study the highest expenditure (Rs. 69212 ha^{-1}) was incurred in the treatment T_9 where vermicompost was applied at 5.0 t ha^{-1} + *Rhizobium* seed treatment. The least (Rs. 31950) was in case of RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} (T_1).Whereas, the highest gross (Rs. 125415 ha^{-1}) and net returns (Rs. 65473 ha^{-1}) were obtained in T_{11} (Poultry manure 4.5 t ha^{-1} + *Rhizobium* seed treatment). With regard B:C ratio, maximum returns per rupee (2.72) was from the crop which received RDF-60:90:50 kg N, P_2O_5 and K_2O ha^{-1} (T_1) as the source of nutrition.

Conclusion

Maintaining soil fertility as well as sustainability of crop production by using different organic manures like vermicompost, poultry manure and FYM should be advocated to the farmers to replace the use of chemical fertilizers.

From this study it can be concluded that, for maintenance of soil health and to realize sustainable production in fenugreek application 4.5 t ha^{-1} poultry manure along with *Rhizobium* seed treatment is a better option.

Future line of work

Based on the results obtained in the present study, it is evident that there is a wide scope in future for research on the following for increasing production and improving quality of fenugreek.

1. Field trials can be done by using poultry manure alone at different levels.
2. Further research can be done to study the influence of organic manures on other quality parameters in fenugreek seeds.

VII REFERENCES

ABDELGANI, M. E., ELSHEIKH, E. A. E. AND MUKHTAR, N. O., 1999, The effect of *Rhizobium* inoculation and chemical fertilization on seed quality of fenugreek. *Food Chemistry*, **64**(1): 289-293.

ABUSELEHA, 1992, Effect of different sources and forms of nitrogen on the uptake of major nutrients in okra. *Ind. J. Hort.*, **49**(2): 192-196.

ADAK, T. AND SACHAN, R. S., 2013, An appraisal of productivity, nutrient uptake and soil fertility status in fenugreek (*Trigonella foenum-graecum* L.) under an integrated nutrient management module. *Ind. J. of Soil Conservation*, **41**(3): 262-267.

AGASMANI, C. A. AND HOSMANI, M. M., 1989, Response of groundnut crop to farm yard manure, nitrogen and phosphorus in rice fallows in coastal sandy soils. *J. of Oil Seed Res.*, **6**(2): 360-363.

AHMED, A. G., EBTSAM, EL-HOUSINI, A., HASSANEIN, M. S. AND NABILA, ZAKI, M, 2012, Influence of organic and bio-fertilizer on growth and yield of two fenugreek cultivars grown in sandy soil. Australian J. of Basic and Applied Sci., **6**(10): 469-476.

AHMED, S. R, 1993, Influence of composted coconut coir dust on soil physical properties, growth and yield of tomato. *South Ind. Hort.*, **41**: 264-269.

AKHTAR, M.S. AND SIDDIQUI, Z.A. 2009. Effect of phosphate solublizing microorganisms and *Rhizobium* sp., on the growth, nodulation, yield and root-rot disease complex of chickpea under field conditions. *African J. of Biotechnology*, **8**(15): 3489-3496.

ANITHA, M., SWAMI, D. V. AND KUMAR, P. B., 2015, Effect of integrated nutrient management on yield and yield attributes of fenugreek (*Trigonella foenum-graecum* L.). *Environment and Ecology*, **33**(1): 95-98.

ANITHA, M., SWAMI, D. V., KUMAR, B. P. AND SUNEETHA, D. R. S., 2016, Evaluation of nutrient management for better growth, yield and economics of fenugreek. *J. of Spices and Aromatic Crops*, **25**(1): 34-40.

ANONYMOUS, 1999, International Rules for Seed Testing, *Seed sci. Tech*., **4**(2): 53-55.

ANONYMOUS, 2013, National Horticulture Board Database, http://www.nhb.gov.in.

BANO, K., KALE, R. D. AND GAJANAN, G. G., 1987, Culturing earthworm for cast production and assessment of worm cast as biofertilizer. *J. of Soil Biology and Ecology*, **7**: 98-104.

CHANNABASAVANNA, A. S., BIRADAR, D. P. AND YELAMALI, S. G., 2001, Effect of poultry manure and N.P.K. on growth and yield of maize, *Karnataka J. of Agric. Sci.,* **15**(2): 353-355.

CHATTOPADADHYAY, N. C. AND CHAKRABARTHY, A. K., 1990, *Tomato nutrition of Vegetable Crops*. Ed. Mitra, S. K., Sadhu, M. K. and Bose, T. K., Naya Prakash, Calcutta, p.74.

CHAUDHARY, R., TEHLAN, S. K. AND YADAV, A. C., 2009, Effect of biofertilizers and organic manures on growth and seed yield of fenugreek (*Trigonella foenuni-graecum* L.). *Haryana J. of Hort. Sci.,* **38**(1): 104-105.

CHOUDHARY, B. R., GUPTA, A. K., PARIHAR, C. M., JAT, S. L. AND SINGH, D. K., 2011, Effect of integrated nutrient management on fenugreek (*Trigonella foenumgraecum*) and its residual effect on fodder pearlmillet (*Pennisetum glaucum*). *Ind. J. of Agronomy.,* **56**(3): 189-195.

CHOUDHARY, G. R., JAIN, N. K., AND JAT, N. L., 2006, Response of cumin (*Cuminum cyminum*) to inorganic nitrogen, farmyard manure and bio-fertilizer. *Ind. J. of Agronomy*, **51**(4): 334-336.

CISSE, L., 1998, Effect of organic matter application on millet and groundnut on a degraded soil in North Senegal, *Agronomie*, **8**(5): 411-417.

DARZI, M, T., 2012, Effects of organic manure and bio-fertilizer application on flowering and some yield traits of coriander (*coriandrum sativum*). *Int. J. of Agric. and Crop Sci*., 103-107.

DARZI, M. T., HADI, M. H. S. AND REJALI, F., 2012, Effects of the application of vermicompost and nitrogen fixing bacteria on quantity and quality of the essential oil in dill (*Anethum graveolens*). *J. of Medicinal Plants Res.,* **6**(21): 3793-3799.

DATTA, S., ALAM, K. AND CHATTERJEE, R., 2005, Effect of different levels of nitrogen and leaf cutting on growth, leaf and seed yield of fenugreek (*Trigonella foenum.graecum* L.). *Ind. J. Agric. Sci.,* **75**(9): 580-581.

DEORA, N.S., SINGH, G. AND REAGER, M. L., 2004, Studies on nutrient management and seed rate on growth and herbage yield of fenugreek (*Trigonella corniculata* L.) cv. Kasuri in Rajasthan., *J. Spices Aromatic Crops,***18**(1): 19-21.

DESHPANDE, 1996, Management of environmental pollution- organic waste management through conventional and vermicomposting, published by Association for promotion of organic farming, 1359, J.P Nagar, I phase, Bangalore, pp. 108-115.

DHAKA, B. R., PATHAN, A. R. K. AND DHAYAL, R. S., 2013, Response of cowpea to organic manures and soil salinity. *Crop Res.,* **45** (1, 2 & 3): 192-195.

DUBEY, P. K., PANDEY, C. S., KHANDAY, A. S. AND MISHRA, G., 2012, Effect of integrated nutrient management on nutrient uptake, protein content and yield of fenugreek. *Inter. J. of Food, Agric. and Veterinary Sci.,* **2** (1).

ERUM, S. AND BANO, A., 2008, Variation in phytohormone production in *Rhizobium* strains at different altitudes of Northern Areas of Pakistan. *Int. J. of Agric. Biol.,* **10**(5): 563-540.

FARHAD, W., SALEEM, M. F., CHEEMA, M. A. AND HAMMAD, H. M., 2009, Effect of poultry manure levels on productivity of spring maize (Zea mays L.). *The J. of Animal and sci.,* **19**(3): 122-125.

GODARA, A. S, GUPTA, U. S, LAL, G. AND SINGH, R., 2014, Influence of organic and inorganic source of fertilizers on growth, yield and economics of coriander (*Coriandrum sativum* L.). *Int. J. Seed Spices.* **4**(2): 77-80.

GODARA, A. S., GUPTA, U. S., LAL, G. AND SINGH, R., 2014, Influence of organic and inorganic sources of fertilizers on growth, yield and economics of fennel (*Foeniculum vulgare* Mill.) cultivation under semi-arid conditions. *J. of Spices and Aromatic Crops,* **23**(2): 200–204.

GODARA, A. S., GUPTA, U. S., SINGH, R. AND MEHTA, R. S., 2012, Effect of different combinations of organic and inorganic nutrient sources on productivity and profitability of fenugreek (*Trigonella foenum-graecum*). *Int. J. of Seed Spices,* **2**(2): 34-37.

GULED, M. B., SARAWAD, I. M. AND GUNDLUR, S. S., 2003, Organic manures. *The Elixir of Plant Nutrition in Tropical Agric*., **2**(8): 62.

HAPSE, D. G., 1993, Organic farming in the light of reduction in use of chemical fertilizers. *Proceedings of 43rd Annual Deccan Sugar Technologists Association,* Pune, Part-I. SA 37 SASI.

JACKSON, M. L., 1973, *Soil Chem. Anal*., Published by Prentice Hall India Private Limited, Delhi, pp. 66-90.

JAGADALE, Y.L., AND DALVE, P.D., 2010, Effect of nitrogen and phosphorous on seed yield and quality of fenugreek. *Asian j. Hort.,* **6**(1): 81-84.

KATARAKI, N., 2000, Influence of organics and inorganics on growth and yield of maize under irrigation. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

KHIRIYA, K. D., SHEORAN, R. S. AND SINGH, B. P., 2001, Growth analysis of fenugreek (*Trigonella foenum-graecum* L.) under various levels of farmyard manure and phosphorus. *J. of Spices and Aromatic Crops,* **10**(2): 105-110.

KRISHNAMURTHY AND KODANDARAMAN, 1982, *Organic Farming Theory and Practice.* Scientific publishers, Jodhpur, 42-47.

KULKARNI, S. S., BABU, R. AND PUJARI, B. T., 2001, Growth, yield and yield parameters of sunflower as influenced by organic manures, bio-fertilizers and micronutrients under irrigation. *Karnataka J. of Agric. Sci.,* **8**(1): 253-255.

LAL, G., VASHISTH, T., MEHTA, R.S. AND ALI, S.F., 2012, Studies on different organic modules for yield and quality of coriander (*Coriandrum sativum* L.). *Int. J. Seed Spices,* **2**(1): 1-6.

LOGANATHAN, S., NARASIMHAN, V., NARASIMHAN, C. R. L. AND SURENDRAN, R., 1979, Physical properties and yield of groundnut as influenced by application of soil amendments to soil. *Madras Agric. J.*, **66**(4): 278-280.

MAGID, A. H. M., ALI, A.S. I., RABIF, R. K. AND SABRAH, R. E. A., 1995, Chicken manuring as a bio-fertilizer for wheat in sandy soils. *J. of Arid Environment*, **27**(3): 413-420.

MALHOTRA, S. K., VASHISHTA, B. B. AND APPARAO, V. V., 2006, Influence of *Azospirillum sp.* and farm yard manure on growth, yield and incidence of stem gall disease in coriander (*Coriandrum sativum* L.). *J. of Spices and Aromatic Crops,* **15**(2): 115-117.

MEENA, S. S., MEHTA, R. S. AND VASHISHTHA, B. B., 2009, Influence of sheep manure, vermicompost and *Azotobactor sp.* on growth and yield of ajowan (*Trachyspermum ammi* Sprague). *J. of Spices and Aromatic Crops,* **18**(2): 100–103.

MEHTA, R. S., ANWER, .M. M., MALHOTRA, S. K., LAL, G., AISHWATH, O. P., MEENA, S. S., KANT, K. AND KHAN, M. A., 2011, Growth and yield of coriander (*Coriandrum sativum* L)) as affected by sheep manure, vermicompost and bio-fertilizer. *Int. J. Seed Spices,* **1**(1): 22-28.

MEHTA, R. S., ANWER, M. M. AND MALHOTRA, S. K., 2012, Influence of sheep manure, vermicompost and biofertilizer on growth, yield and profitability of cumin (*Cuminum cyminum* L.) production. *J. of Spices and Aromatic Crops*, **21**(1): 16-19.

MOHAMMADI, F. S., DARZI, M. T. AND HADI, M. H. S., 2014, Influence of compost and biofertilizer on yield and essential oil of dill (*Anethum graveolens* L.). *Int. J. of Advanced Biological and Biomedical Res.,* **2**(2): 446-455.

NAIDU, A. K., KUSHWAH, S. S. AND DWIVEDI, Y. C., 1999, Influence of organic manures, chemical and biofertilizers on growth, yield and economics of brinjal. *South Ind. Hort.,* **50**(4-6): 370-376.

NAIDU, M. M., RAO, R. D. V., SARKAR, D. K., REDDY, K. C. AND SHANKAR, K. S., 2010, Effect of different organic sources of nutrients on growth, yield and quality of fenugreek.

NAIMUDDIN, AISHWATH, O. P., LAL, G., KANT, K., SHARMA, Y. K. AND ALI, S. F., 2014, Response of *Trigonella foenum-graecum* to organic manures and *Rhizobium* inoculation in a Typic Haplustept. *J. of Spices and Aromatic Crops*, **23**(1): 110-114.

NIJHAWAN, S. D., AND KANWAR, J. S., 1952, Physico-chemical properties of earthworm castings and their effect on the productivity of soil. *Ind. J. of Agric. Sci.*, **2**: 357-373.

PADMAPRIYA, S. AND CHEZHIYAN, N., 2009, Effect of shade, organic, inorganic and biofertilizers on morphology, yield and quality of turmeric. *Ind. J. Hort.*, **66**(3): 333-339.

PALANIPPAN, S. P. AND ANNADURAI, K., 1999, *Organic Farming Theory and Practice*. Scientific publishers, Jodhpur, 176-179.

PATEL, D. M, PATEL, G. N, PATEL, J. C, PATEL, S. M. AND PATEL, J. K., 2014, Nitrogen management in fenugreek (*Trigonella foenum-graecum* L.) under organic farming. *Res. on Crops,* **15**(2): 526-531.

PATEL, B.S., AMIN, A.U., PATEL, K.P., PATEL, M.M., 2003, Influence of organic manures alone or in combination with inorganic fertilizer on productivity of winter drilled fennel (*Foeniculum vulgare*). Indian Journal of Agronomy, **48**(3): 232-234.

PATTAR, P. S., NADAGOWDA, V. B., SALKINKOP, S. R., KANNUR, V. S. AND GADDI, A.V., 1999, Effect of organic manures and fertilizer level on nutrient uptake, soil nutrient status and yield of groundnut. *J. of Oil seeds Res.,* **16**: 123-127.

PAWAR, V. A., PAWAR, P. R., ASOK, M. B. AND CHAVAN, S. V., 2014, Effect of Rhizobium on seed germination and growth of plants. *J. of Industrial Res.,* **3**(2) 84-88.

PIPER, C. S., 1966, *Soil and Plant Analysis*, Hans publishers.

PONSICA, E. P., ESCALDA, R. G. AND QUIROL. B. F., 1983, Effect of animal manure application on growth and yield of corn. *Annuals of Tropical Res.*, **5**(3-4): 106-116.

PRABHAKARAN, C., 2003, Nutrient uptake and yield of tomato with different organic manures. *J. of Res*., **15**(1): 131-134. PURBEY, S. K. AND SEN, N. L., 2005b, Effect of bioinoculant and bioregulators on productivity and quality of fenugreek (*Trigonella foenum-graecum* L.). *Indian J. Agric. Sci.,* **75**(9): 608-611.

PURBEY, S. K. AND SEN, N. L., 2005, Effect of bioinoculant and bioregulators on productivity and quality of fenugreek (*Trigonella foenum-graecum* L.). *Indian J. Agric. Sci.,* **75**(9): 608-611.

RADHA, K. D. AND KUBRA, B., 1987, Field trials with vermicompost an organic fertilizer. *Proceedings of National Seminar an Organic waste Utilization, Vermicompost,* pp. 151-160.

RADHA, K. D., MALLESH, B. C., BANO, K. AND RAJ, B. D. J., 1992, Influence of vermicompost application on the available micronutrients and selected microbial populations in paddy field. *Soil Biology and Biochemistry*, **24**(2): 1317-1320.

RAO, S. S. AND SHAKTAWAT, 2001, Effect of organic manure, phosphorus and gypsum on growth, yield and quality of groundnut. *Ind. J. of Plant Physiology,* **6**(3): 306-311.

RENUKA, B. AND SHANKAR, R. C., 2001, Effect of organic manures on growth and yield of tomato. *South Indian Hort*., **49(**1): 216-220.

SAVANUR, V., 1999, Influence of inorganic nitrogen levels, *Azospirillum sp*. and organics on yield and quality of paprika (*Capsicum annum* L.). *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

SHARMA, A., POTDAR, M. P., PUJARI, B. T. AND DHARMARAJ, P. S., 2003, Studies on response of pigeonpea to canopy modification and plant geometry, *J. Agric. Res.,* **16**(1): 1-3.

SHARMA, J. P. AND SAXENA, S. N., 1985, Utilization of phosphorus by maize as influenced by various sources of organic matter and applied phosphorus, *J. of Ind. Society of soil Sci.,* **33**(1): 561-567.

SINGH, A. B., AND SINGH, S. S., 1992, Effect of various levels of nitrogen and spacing on growth, yield and quality of tomato. *Vegetable sci*., **19**(1): 1-6.

SINGH, B., SINGH, B., MASIH, M. R. AND CHOUDHARY, R. L., 2009, Evaluation of P and S enriched organic manures and their effect on seed yield and quality of coriander (*Coriandrum sativum* Linn.). *Int. J. of Agric. Sci.,* **5**(1): 18-20.

SINGH, I. K. AND CHAUHAN, J. S., 2009, Response of french bean (*phaseolus vulgaris* l.) to organic manures and inorganic fertilizer on growth & yield parameters under irrigated condition. *Nature and Science,* **7**(5): 1545-1740.

SINGH, M., 2011, Effect of vermicompost and chemical fertilizers on growth, yield and quality of coriander (*Coriandrum sativum* L.) in a semi-arid tropical climate. *J. of Spices and Aromatic Crops,* **20**(1): 30–33.

SINGH, R. P., PRASAD, R. N., SINHA, H. AND SINGH, K. D. N., 1979, Effect of organic amendments in zinc availability to maize and soybean in calcareous soil. *J. of Ind. Society of Soil Sci.,* **27**(3): 321-324.

SINGH, S. P., 2015, Effect of organic manures on growth, yield and economics of coriander (*Coriandrum sativum* L.). *J. of Eco-friendly Agric.,* **10**(2): 124-127.

SITAL, J. S, KAUR, K., SHARMA, S., SANDHU, J. S AND SINGH, S., 2011, Effect of *Rhizobium* Inoculation, Phosphorus and Nitrogen Supplements on Protein Quality in Developing Lentil (*Lens culinaris*) Seeds. *Ind. J. Agric. Biochem.* **24**(1): 17-22.

STEFANESCU, M. AND DASCA, J., 1985, The effect of application of organic and chemical fertilizers on wheat and maize. *Probleme de Agrofito Technique,* **10**(1): 15-24.

SUBBIAH, B. V. AND ASIJA, G. L., 1956, A rapid procedure for estimation of available nitrogen in soils. *J. Cur. Sci.,* **25**(8): 259-260.

SUNANDA, B. B., SHETTY, G. R. AND VENKATESH, J., 2014, Influence of integrated nutrient management on growth, yield and quality of *Kasuri Methi* (*Trigonella corniculata* L.) under hill zone of Karnataka. *Int. J. Seed Spices,* **4**(2): 62-67.

SUNDARARAJ, N., NAGARAJU, S. S., VENKATARAMU, N. AND JAGANATH, M. K., 1972, *Design and Analysis of Field Experiment.*

TAGAD, S. G., SRINIVAS, J., KALE, V. S. AND NAYAK, S., 2016, Effect of different organic nutrient sources on growth and yield of fenugreek. *Int. J. of Farm Sci.,* **6(1)**: 97-101.

UIKEY, K., VERMA, H. AND NAWANGE, D., 2015, Influence of organic, chemical and biofertilizer on growth and yield of pea. *Agric. Sci. Digest,* **35**(3): 237-240.

VADIRAJ, B. A., SIDDAGANGAIAH AND NARAYANA POTTY, S., 1998, Response of coriander (*Coriandrum sativum* L.) cultivars to graded levels of vermicompost. *J. of Spices and Aromatic Crops,* **7**(2): 141-143.

VENKATESH, R., 1999, Response of hybrid maize to row application of organics and nitrogen in transitional tract of Northern Karnataka. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad.

VERMA, S. R., SHIVRAN, A. C., BHANWARIA, R. AND SINGH, M., 2014, Effect of vermicompost and sulphur on growth, yield and nutrient uptake of fenugreek (*Trigonella foenum-graecum* L.). *The Bioscan,* **9**(2): 667-670.

WEY, J. F. AND OBTON, 1978, The physical basis of variation in yield. *Advances in Agronomy,* **4**(1): 101-144.

APPENDIX-I

Chemical properties of the soil in the experimental site

Sl. No.	Properties	Value obtained	Method employed
1	Soil p^H	6.4	p^H meter (Piper, 1996)
2	Electrical Conductivity (ds m^{-1})	0.025	Conductivity bridge (Jackson, 1967)
3	Organic matter (%)	1.43	Walkey and Black Wet Oxidation method (Jackson, 1967)
4	Available Nitrogen (kg ha^{-1})	246	Modified Kjeldhal method (Jackson, 1967)
5	Available Phosphorus (kg ha^{-1})	87	Olsen's method (Jackson, 1967)
6	Available Potassium (kg ha^{-1})	190	Flame photometer (Jackson, 1967)

APPENDIX-II

Influence of different sources of organic manures on p^H, EC and organic carbon content of soil after crop harvest

Treatments	p^H	Electrical conductivity	Organic matter (%)
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	6.76	0.30	1.60
T_2-100 % N through VC without *Rhizobium* seed treatment	6.68	0.29	1.47
T_3-150 % N through VC without *Rhizobium* seed treatment	6.63	0.28	1.53
T_4-100 % N through PM without *Rhizobium* seed treatment	6.79	0.20	1.23
T_5-150 % N through PM without *Rhizobium* seed treatment	6.74	0.58	1.57
T_6-100 % N through FYM without *Rhizobium* seed treatment	6.76	0.27	1.50
T_7-150 % N through FYM without *Rhizobium* seed treatment	6.76	0.27	1.33
T_8-100 % N through VC with *Rhizobium* seed treatment	6.75	0.20	1.50
T_9-150 % N through VC with *Rhizobium* seed treatment	6.77	0.27	1.02
T_{10}-100 % N through PM with *Rhizobium* seed treatment	6.78	0.26	1.63
T_{11}-150 % N through PM with *Rhizobium* seed treatment	6.66	0.25	1.70
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	6.81	0.28	1.47
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	6.84	0.24	1.23
Mean	**6.75**	**0.28**	**1.48**
S.Em±	**0.07**	**0.09**	**0.11**
C.D. @ 5%	**0.20**	**0.27**	**0.33**
	NS	**NS**	**NS**

NS- Non significant

APPENDIX-III

Influence of different sources of organic manures on nutrient status of soil after harvest of fenugreek

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	186.47	74.50	114.13
T_2-100 % N through VC without *Rhizobium* seed treatment	165.40	66.92	118.23
T_3-150 % N through VC without *Rhizobium* seed treatment	159.24	78.07	144.35
T_4-100 % N through PM without *Rhizobium* seed treatment	123.70	74.72	142.51
T_5-150 % N through PM without *Rhizobium* seed treatment	141.76	71.33	160.61
T_6-100 % N through FYM without *Rhizobium* seed treatment	184.21	78.90	130.94
T_7-150 % N through FYM without *Rhizobium* seed treatment	169.72	81.90	120.34
T_8-100 % N through VC with *Rhizobium* seed treatment	192.46	75.90	125.87
T_9-150 % N through VC with *Rhizobium* seed treatment	190.48	65.69	139.43
T_{10}-100 % N through PM with *Rhizobium* seed treatment	164.31	71.13	116.42
T_{11}-150 % N through PM with *Rhizobium* seed treatment	127.91	74.50	114.13
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	175.62	77.13	115.10
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	175.30	70.80	110.43
Mean	**165.89**	**78.41**	**128.48**
S.Em±	**21.04**	**3.84**	**13.53**
C.D. @ 5%	**61.42**	**11.21**	**39.49**
	NS	**NS**	**NS**

NS- Non significant

APPENDIX-IV

Meteorological observations recorded during the experimental period (October 2015 to February 2016) at University of agricultural sciences, GKVK, Bangalore

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Bright sunshine (h)
	Max	Min	I h	II h		
Oct 15	29.3	19.1	89	52	80.8	6.6
Nov 15	25.3	17.9	94	65	180.4	3.3
Dec 15	27.6	19.9	91	52	4.2	6.5
Jan 16	27.5	14.7	90	47	2.4	7.6
Feb 16	31.2	16.2	85	38	0.0	9.0
Mar 16	34.0	19.9	86	37	4.2	8.2
Apr 16	35.8	23.1	84	37	1.2	9.1
May 16	33.1	21.4	88	42	115.0	7.8

APPENDIX-V

Cost of cultivation for fenugreek (*Trigonella foenum–graecum* L.) as influenced by different sources of organic manures

Particulars	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**	**T_{10}**	**T_{11}**	**T_{12}**	**T_{13}**
Land preparation	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Seed cost (15Kg @ Rs. 80/Kg)	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
FYM(10t ha^{-1})	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Manures	2750	28000	40000	4500	6750	5500	8000	28000	40000	4500	6750	5500	8000
Rhizobium (Rs. 80/kg)	--	--	--	--	--	--	--	12	12	12	12	12	12
Irrigation	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Thinning (10 labours @ Rs. 200/l)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Hoeing	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Weeding (10 labours @ Rs. 200/l)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Plant protection (Wettable sulphur+ Carbendazime)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Harvesting (10 labours @ Rs. 200/l)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Threshing, cleaning	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Miscellaneous	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Total	31950	57200	69200	33700	35950	34700	37200	57212	69212	33712	35962	34712	37212

APPENDIX-VI

Nutrient status of different organic manures considered in this experiment

Manure	Nitrogen (%)	Phosphorous (%)	Potassium (%)
Vermicompost	1.7	0.042	0.59
Poultry manure	2.1	0.23	0.66
Farm yard manure	1.1	0.022	0.30

APPENDIX-VII

Quantity and cost of different organic manures considered under this experiment

Treatments	Manures and fertilizers	Quantity plot^{-1} (3.6 m^2)	Quantity ha^{-1}	Cost in Rs.
T_1- 60:90:50 Kg NPK ha^{-1} (RDF)	RDF (NPK)	21.6:202.5:30.6 g	60:90:50 kg	2750
T_2-100 % N through VC without *Rhizobium* seed treatment	Vermicompost	1.2 kg	3.5 t	28000
T_3-150 % N through VC without *Rhizobium* seed treatment	Vermicompost	1.8 kg	5.0 t	40000
T_4-100 % N through PM without *Rhizobium* seed treatment	Poultry manure	1.03 kg	3.0 t	4500
T_5-150 % N through PM without *Rhizobium* seed treatment	Poultry manure	1.54 kg	4.5 t	6750
T_6-100 % N through FYM without *Rhizobium* seed treatment	FYM	1.96 kg	5.5 t	5500
T_7-150 % N through FYM without *Rhizobium* seed treatment	FYM	2.94 kg	8.0 t	8000
T_8-100 % N through VC with *Rhizobium* seed treatment	Vermicompost	1.2 kg	3.5 t	28000
T_9-150 % N through VC with *Rhizobium* seed treatment	Vermicompost	1.8 kg	5.0 t	40000
T_{10}-100 % N through PM with *Rhizobium* seed treatment	Poultry manure	1.03 kg	3.0 t	4500
T_{11}-150 % N through PM with *Rhizobium* seed treatment	Poultry manure	1.54 kg	4.5 t	6750
T_{12}-100 % N through FYM with *Rhizobium* seed treatment	FYM	1.96 kg	5.5 t	5500
T_{13}-150 % N through FYM with *Rhizobium* seed treatment	FYM	2.94 kg	8.0 t	8000

Note:
Vermicompost- 8 Rs. kg^{-1}
Poultry manure- 1.5 Rs. kg^{-1}
FYM- 1 Rs. kg^{-1}
Urea- 6 Rs. kg^{-1}, DAP- 16 Rs. kg^{-1}, MOP- 19 Rs. kg^{-1}