EFFECTS OF BIOFERTILIZER AND MACRONUTRIENTS ON THE YIELD AND YIELD COMPONENTS OF FENUGREEK SEED

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECTS OF BIOFERTILIZER AND MACRONUTRIENTS ON THE YIELD AND YIELD COMPONENTS OF FENUGREEK SEED"** submitted to the **INSTITUTE OF SEED TECHNOLOGY**, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **SEED TECHNOLOGY**, embodies the results of a piece of bona fide research work carried out by **Mst. Sadia Akther, Registration. No. 15-06711,** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

I further certify that any help or sources of information received during the course of this investigation have been duly acknowledged.

Dated: June 2022
Place: Dhaka, Bangladesh

Prof. Dr. Khaleda Khatun
Supervisor
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DEDICATED
TO MY
BELOVED
PARENTS

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ABSTRACT

The experiment was conducted at “Central Research Farm” of Sher-e-Bangla Agricultural University, Dhaka, during November 2021 to April 2022 to study the effects of biofertilizer and macronutrients on the yield and yield components of fenugreek seed. The experimental material for the study was BARI Methi-1. The experiment consisted of single factor with total 13 number of treatments, T_0 = Biofertilizer 3 kg ha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg + 40 kg P ha^{-1}, T_3 = Biofertilizer 3 kg + 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg + 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg + 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg + 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg + 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg + 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg + 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg + 100 kg N + 40 kg P + 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg + 75 kg N + 30 kg P + 45 kg K ha^{-1}, T_{12} = Biofertilizer 3 kg + 50 kg N + 20 kg P+ 30 kg K ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data were recorded on yield and yield component of fenugreek seed and significant variation was observed for most of the studied characters, T_{10} = Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1} treatment showed the best in seed yield. Under this investigation it was revealed that the maximum plant height (54.24 cm), number of primary branches plant^{-1} (7.68), number of secondary branches plant^{-1} (5.21), minimum days required to first flowering (36.89 days), days required to 50% flowering (57.02 days), longest pod length (12.16 cm), maximum number of seed pod^{-1} (15.22), weight of seed pod^{-1} (147.11 mg), seed weight plant^{-1} (12.33 g), weight of 1000 seed (13.58 g), seed weight plot^{-1} (429.67 g), seed weight ha^{-1} (1790.30 kg), highest harvest index (41.68 %), vigor index (590.33) and benefit cost ratio (3.51) was obtained from T_{10} treatment . It was therefore concluded that that treatment T_{10} = Biofertilizer 3 kg + 100 kg N + 40 kg P + 60 kg K ha^{-1} performed positively to provide better yield and yield component of fenugreek seed.

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LIST OF ABBREVIATIONS

AEZ	: Agro-Ecological Zone
BARI	: Bangladesh Agricultural Research Institute
BBS	: Bangladesh Bureau of Statistics
CV%	: Percentage of Coefficient of Variance
DAS	: Days after sowing
et al.	: And others
FAO	: Food and Agricultural Organization of The United Nations
g	: gram (s)
ha^{-1}	: Per hectare
HRC	: Horticulture Research Centre
kg	: Kilogram
LSD	: Least Significant Difference
$mScm^{-1}$	: Mili Siemens per cm
Max	: Maximum
Min	: Minimum
MOP	: Muriate of Potash
N	: Nitrogen
NPK	: Nitrogen, Phosphorous and Potassium
NS	: Not significant
PSB	: Phosphate Solubilizing Biofertilizer
RCBD	: Randomized Complete Block Design
SAU	: Sher-e-Bangla Agricultural University
SRDI	: Soil Resources and Development Institute
TSP	: Triple Super Phosphate
wt.	: Weight
%	: Percent

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is a diploid, annual, self-pollinating plant that is strongly scented (Acharya *et al.,* 2008). It is locally known as "methi" and belongs to the family Leguminosae and sub family Papilionaceae. Some of the names given to it are Methi (Hindi, Urdu, Punjabi, and Marathi), Hulba (Arabic), Moshoseitaro (Greek), Uluva (Malayalam), Shoot (Hebrew), Dari (Persian), and Hey seed (English). It is widely used as a spice and condiment to add flavor in various foods (Dwivedi *et al.*, 2006).

It has important position amongst leafy vegetables, condiment, seed spices and medicine. Its grains are used to form a concentrate feed for animals. Besides this, it has immense medicinal utility. It is a source for preparing raw materials of pharmaceutical industry, like in steroidal hormones (Helambe and Dande, 2012).

The seeds are bitter in taste due to the presence of alkaloid "Trigonelline". Fenugreek seeds have high nutritive value containing protein (9.5%), fat (10%), crude fiber (18.5%), carbohydrates (42.3%) and many other nutrients and vitamins. It also contains a good percentage of gums (23.06%), mucilage (28%), trigonelline (0.13-0.35%) and saponins (1.7%), having calorific value 370 calories 100g seed^{-1}. Its fresh tender leaves and pods are rich in iron, calcium, ascorbic acid and protein, are eaten as fried vegetables (Das, 2007).

Fenugreek is now cultivated in all habitable continents of the world. Some of these continents have a long history of use, while other continents only started cultivating the crop during the past 2-3 decades (Prasad, 2011). Asia is positioned in 1st place among continents in terms of fenugreek production and acreage. India is leading in fenugreek seed production, producing about 90% of the world fenugreek production (Acharya *et al.,* 2008). It is commercially farmed in India, Pakistan, Afghanistan, Iran, Nepal, Egypt, France, Spain, Turkey, Morocco, North Africa, the Middle East, and Argentina (Altuntaş *et al.,* 2005). Spice Division of BARI has developed some potential high yielding varieties of fenugreek (BARI, 2011). Farmers cultivate their local variety with low yield potentiality. A wide range of medicinal properties has been attributed to fenugreek such as wound-healing, bust enhancement, enhanced lactation in weaning mothers, as an aphrodisiac, anti-diabetic, anti-hyperthyroidism, anticancer, gastro-protective, antioxidant, antipyretic, antimicrobial, anthelmintic, anti-sterility, antiallergy and anti-inflammatory effects (Acharya *et al.*, 2008; Krishnaswamy, 2008).

Currently, it is a cultivated crop in most parts of the world, focusing on isolating its important secondary metabolites rather than using it as an edible plant. Fenugreek seeds and leaves are of great importance as they contain medicinally important phytochemicals such as alkaloids, carbohydrates, steroid saponins, amino acids and organic and inorganic compounds and minerals. Fenugreek seeds and leaves can be used as a seasoning, food additive, flavor enhancer, preservative or directly as a vegetable. Despite its high medicinal value, it is still considered an underutilized herb. It is very necessary to focus on developing new plant varieties to exploit the full potential of fruit trees as well as their medicinal values.

Biofertilizers are low cost, renewable resource of plant nutrients and their usage in agriculture assumed a special significance particularly in the present-day context of organic farming, integrated farming and in nutrient management practices. Adesemoye and Kloepper (2009) reported that biofertilizers can be used in conjunction with chemical fertilizers as an economic input to increase crop productivity. Different biofertilizers and organic manures applied alone as well as in had a significant impact on various growth and yield parameters. Improper nutrient management is one of the factors responsible for the low productivity. Use of organic manures along with inorganic fertilizers not only improve physio-chemical and biological properties of soil but also provides all the nutrients in available form to crop plants, which in turn enhance better growth and finally the yield and quality parameters of *Trigonella foenum-graecum*. Thus, there is an urgent need to formulate integrated nutrient management practices for increasing the productivity and production of *Trigonella foenum-graecum*.

Macronutrients (N, P and K) play a significant role in plants proper growth, development and reproduction. Nitrogen (N) is an integral constitute of chlorophyll, amino acids, nucleic acid and ATP. Now, it is well documented that nitrogen is one of the most abundant elements on earth. Phosphorus (P) is second most major nutrient after nitrogen which is essential for root initiation and their development. Potassium (K) is also a foundation element involved in various functions in growth and metabolism of plants. It is identified as a major nutrient, meaning that it is frequently deficient for crop production and required by crops in relatively large amounts. Pulse crops showed up yield benefits from potassium application. Advanced potassium supply also enhances biological nitrogen fixation and protein content of pulse grains (Srinivasarao *et al.,* 2003). Moreover, Potassium improves plant ability to resist diseases, aids in production of carbon and flower formation. The reservoir of phosphorus and potassium to leguminous crops is necessary especially at the flowering and pod setting stages (Zahran *et al.,* 1998). Besides, recommended dose of fertilizers, use of low-cost nutritional inputs is an hourly requirement. The foremost organic manures like farmyard manure (FYM), vermicompost and biofertilizers that can largely supplement or replace fertilizers. Application of organic manures not only improves the soil organic carbon for sustaining the soil physical health but also increases plant nutrients. Biofertilizers enhances soil fertility, crop productivity and production in agriculture as they are eco-friendly.

Keeping the above facts in view the present experiment was undertaken with following objectives:

- To find out the effects of biofertilizer application on the yield and yield components of fenugreek seed;
- To determine the effects of different levels of macronutrient application on the yield and yield components of fenugreek seed; and
- To identify the combined effects of biofertilizer and macronutrients (N, P and K) on the yield and yield components of fenugreek seed.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Fenugreek (Trigonella foenum-graecum) cultivation is not being greatly improved in Bangladesh. However, the agro-climatic conditions in Bangladesh and other nations were the subject of numerous investigations of the earlier studies. A few of them been reviewed and explained below in the following paragraphs.

2.1 Effects of biofertilizer

According to Singh *et al.* (1990), biofertilizer have recently emerged as a promising element of integrated phytonutrient systems in agriculture. By enhancing the physio-chemical and biological qualities of the soil and reducing the use of pricey inorganic fertilizers, integrated use of organic, inorganic materials, and bio-fertilizers supports yield.

Ram *et al.* (1992) studied the application of beneficial microbial inoculants to soil or seeds aids in enhancing crop productivity by enhancing crop vigor, plant growth, and seed germination. Due to the release of hormones and vitamins that promote plant growth, it aids in the production of high-quality produce. In order to lower input costs and maintain soil health, emphasized the importance of employing biofertilizers in addition to chemical fertilizers.

Subba (1993) stated that by increasing the quantity and biological activity of desired microorganisms in the root environment, microbial inoculants, also known as "biofertilizer" are carrier-based preparations with beneficial microorganisms that are in a healthy state and intended for soil or seed application. They improve soil fertility and aid plant growth. The most commonly used biofertilizers in crop cultivation are Rhizobium, *Azotobacter* and *Azospirillum* (Sethi and Subba Rao, 1968), phosphate solubilizing bacteria and fungi (Sperber, 1957). Arbuscular Mycorrhizal (AM) fungi, Trichoderma sp. And *Pseudomonas* sp. Are considered as plant growth promoters and as potential biocontrol agents (Smitha, 2005).

Ghosh (2000) carried out a field experiment to study the effect of biofertilizer (buckup) and growth-regulator (electra, micrin and protein hydrolysate) on sesame (*Sesamum indicum* L.) on sandy-loam lateritic soil. Use of biofertilizer or growth-regulator alone did not influence the growth and yield attributes and yield of sesame over control, significantly. But combined application of biofertilizer and growth-regulator improved all the growth attributes and yield components and thus markedly increased grain and stick yields. The maximum grain (1,094 kg ha^{-1}) and stick (2,392 kg ha^{-1}) yields of sesame were obtained with integrated usage of buckup, electra, and protein hydrolysate, which outperformed no or single application of biofertilizer or growth-regulator.

Vimala and Natarajan (2000) conducted a field experiment with pea cv. Bonneville, 32 combinations involving four levels each of Nitrogen (30, 60, 90 and 120 kg ha^{-1}) and phosphorus (40, 80, 120 and 160 kg ha^{-1}), with and without biofertilizers (*Rhizobium* and phosphobacteria) were examined for their effects on pod characters, yield and quality. The pod characters and number of pods per plant were significantly influenced by the treatments. The effects of nitrogen, phosphorus, biofertilizers and the interactions N P and N x B on yield were significant and application of 120 kg N, 80 kg P and biofertilizers registered the highest yield of 3.98 kg $plot^{-1}$ (44.0 q ha^{-1}), which also showed the highest values for pod length, pod width, pod weight and shelling percentage. The treatments failed to significantly influence the TSS, while seed protein and crude fibre exhibited significant differences. Considering the pod characters, yield and quality, a combination of 120 kg N, 80 kg P, 2 kg Rhizobium and 2 kg phosphobacteria ha^{-1} was optimum.

Hamaoui and Sheikh (2001) examined the results of faba beans (*Vicia faba* L.) and chickpeas (*Cicer arietinum* L.) inoculated with *Azospirillum brasilense* under various growing circumstances. *A. brasilense* inoculation has dramatically boosted root and shoot development in greenhouse trials with both legumes when compared to non-inoculated controls. This is due to native rhizobia's increased ability to nodulate the plants. Additionally, irrigation with saline water had detrimental effects on plant growth that were greatly mitigated by the bacterial treatment. When chickpea plants were infected with peat-based *A. brasilense* inoculants in field studies, the plants' nodulation, root and shoot growth, and crop production significantly increased in comparison to non-inoculated control plants.

Khiriya *et al.* (2001) stated that application of 15 t ha^{-1} of FYM and 40 kg P_2O_5 ha^{-1} increased fenugreek's growth and yield. It was suggested to apply 15 t of FYM ha^{-1} as well as 25 kg N, 25 kg P_2O_5, and 50 kg K_2O ha^{-1} for the best possible yield of fenugreek.

El-Latif (2002) conducted an investigation to examine the effects of organic manure combined with biofertilizers on the growth, fruit yield, and essential oil content of

Caraway plants. During the soil preparation, three amounts of cattle manure 6 m^3, 9 m^3, and 12 m^3 were added. Caraway seeds were mixed with biofertilizer a mixture of 1 kg fed^{-1} Nitrobein and 1 kg fed^{-1} Phosphorrein before being sown right away. Plant growth, fruit yield, and oil content were all markedly enhanced by the use of cattle manure and biofertilizer. The highest values were seen at an application of 12 m^3 cattle manure. Cattle manure (9 m^3) combined with biofertilizer led to superior growth, fruit yield, and essential oil content. Additionally, it was discovered that using cattle manure alone or in combination with biofertilizer increased both the oil content and carvone percentages of the essential oils as well as their overall main components (limonene and carvone). At 9 m^3 of cattle manure plus biofertilizer, the best results were observed. In general, organic manure and biofertilizer increased plant production without negatively affecting the environment.

Purbey and Sen (2005) recorded that combining the application of 25 to 50 percent of organics with 50 to 75 percent of the recommended fertilizer doses results in a higher yield and better quality of seed spices than using only organics.

Wu *et al.* (2005) reported that biofertilizers not only supplements nitrogen, but also produces a variety of growth-promoting substances viz., indole acetic acid, gibberellins and B vitamins.

Jat *et al.* (2006) stated that the highest yield of fenugreek seeds (1.26 t ha^{-1}), net returns (INR 9,761 ha^{-1}), and B:C ratio (6:1) were obtained with 100% inorganic N applied alone at a rate of 1 point 5 kg ha^{-1} and 5 t FYM ha^{-1}.

Mahfouz and Sharaf-Eldin (2007) research on coriander's growth, production, and essential oil content to determine how nitrogen and biofertilizers affect those factors (*Coriandrum sativum L.*). Treatments were control (T_1), biofertilizer (*Azotobacter* + *Azospirillum*) (T_3), biofertilizer + 37.5 kg N (T_3), and 75 kg N without inoculation (T_4). When compared to the control, the application of T_4 and T_3 significantly increased plant height, branch count $plant^{-1}$, total dry weights, fruit yield, essential oil (EO) yield $plant^{-1}$, EO yield percentage, EO yield $plant^{-1}$, linalool content in EO, and linalool yield. For all qualities, T_3 consistently produced the highest scores, followed by T_4, however most of the time there were no appreciable differences. The control group had the lowest values.

Basu and Bhadoria (2008) found that compared to a single application of either inoculants or cobalt, the combination of Rhizobium and phosphor bacterium (*Bacillus* *polymyxa*) inoculants and cobalt administered at the rate of 0.21 kg ha^{-1} considerably enhanced the yield and uptake of N, P, and K in groundnut. The soil fertility condition was also affected favorably by the use of cobalt and microbial inoculants.

According to Adesemoye and Kloepper (2009), microbial inoculants can be utilized as a cost-effective input to boost crop output when combined with chemical fertilizers.

Rajesh *et al.* (2009) conducted a field experiment was conducted to evaluate the beneficial effect of different biofertilizers and organic manures alone as well as their combinations on fenugreek. The application of different biofertilizers, organic manures alone and as well as their combinations affected different growth and yield parameters significantly except days taken for 50% flowering. Maximum number of branches plant^{-1} (6.6), pods plant^{-1} (88.6) and seed yield (2077 kg ha^{-1}) were recorded with application of recommended dose of NPK (25:40:20 kg ha^{-1}) being at par with seed inoculation with Rhizobium and application of nitrogen supplemented with farm yard manure (1975 kg ha^{-1}) and seed inoculation with Rhizobium and PSB and application of nitrogen supplemented with farm yard manure (1995 kg ha^{-1}).

Rokhzadi and Toashih (2011) investigated the effects of single and simultaneous inoculation of on the nutrient uptake, growth, and yield of chickpea plants in the field by using growth-promoting rhizobacteria *Azospirillum*, *Azotobacter*, *Mesorhizobium*, and *Pseudomonas*. At the start of the flowering stage, the treatments had a substantial impact on nodulation and the concentration of nutrients in the shoots. The combination inoculation of *Azospirillum spp.* + *Azotobacter* chroococcum 5 + *Mesorhizobium spp.* + *Pseudomonas fluorescens* resulted in the greatest dry weight of root nodules being measured.

Dutta *et al.* (2011) investigated the impact of biofertilizer and nitrogen levels on growth, yield, and quality of fenugreek (*Trigonella foenum-graecum*). Bengal, India. Rhizobium was used to treat the fenugreek seeds before they were sown with various amounts of inorganic nitrogen, fall doses of P and K, and FYM@5 tons ha^{-1}. The findings showed that growth factors, such as. When nitrogen-based fertilizer was replaced with biofertilizer in a 15–20% ratio, plant height and branch count improved noticeably. The highest seed yield was also achieved (12.8 q ha^{-1}) with a 15% substitution of inorganic nitrogen with Rhizobium which followed by 20% and 25% N substitution. But there was no difference in the essential oil content between the treatments. The results showed that there is potential for replacing 25% of the nitrogen-containing organic fertilizer fenugreek with biofertilizer and maintaining the soil.

Valadabadi and Farahani (2011) carried out research to reduce farmers' dependency on mineral fertilizers, to increase water use efficiency, and to increase households' incomes, participatory on-farm research trials to test the beneficial impact of biological fertilizers application on black cumin (*Nigella sativa* L.) some yield characters were investigated. The interaction between the application of biofertilizer and yield quality and quantity were the focus of this investigation. Certain factors including four level of animal manures (0,10,20 and 30 tons ha^{-1} respectively) and two levels of azotobacter (non-application and application) were studied. The final statistical analysis showed that the yield components were significantly greater in the 20 tons ha^{-1} animal manure and azotobacter application. Biological yield, seed yield, essential oil yield, stem dry weight, capsule dry weight, leaf dry weight, and plant height were all increased in units by the application of *Azotobacter* and 20 tons of animal manure per acre. The results may provide farmers with useful guidance for management of their fertilizer strategy and for careful estimation of the supply of chemical fertilizer through the use of biofertilizers.

Acimovic *et al.* (2011) conducted an experiment using the microbiological fertilizers: Bacillus subtilis FZB24 and Rhizovital 42I to examine the influence of the preparation on germination energy and overall germination of cumin, anise and coriander seeds. The standard germination of the mentioned plants was determined according to the ISTA rules, in four repetitions in plastic boxes at an alternating temperature of 20-30°C, and the readings were after 7 and 21 days. Application of the preparation did not have a statistically significant effect on the increase in the germination energy of the tested plants, as well as the overall germination rate of cumin and anise, while the total germination rate of coriander increased statistically significantly by the application of the preparation RhizoVital 42I by 4.5%. The Polish experiment was set up according to the method of a randomized block system with three replications. Different times of application of the tested preparations and their influence on seed yield were tested. The results show that the preparation RhizoVital 42I was more effective in all three tested plants. The most effective time for the application of the investigated preparations for coriander is in the 2-3 leaf phase, anise when the plants are in the leaf rosette phase, and cumin when 10% of the plants have started to flower.

Pramod *et al.* (2011) carried out an experiment to investigate the effects of phosphorus management treatments, sulphur and biofertilizers on the growth and yield of fenugreek (*Trigonella foenum-graecum* L.) and their long-term impact on the pearl millet crop that comes after them. With the exception of the dry weight of nodules plant^{-1}, which had statistical equivalence with 20 kg P_2O_5 ha^{-1} alone, the maximum values of the growth attributes, namely the plant height at harvest, the number of branches plant^{-1}, the number of nodules plant^{-1}, and the dry weight of nodules at 40 DAS, were all obtained on a pooled basis with the combined application of 20 kg P_2O_5 ha^{-1}. Additionally, the combined application of 5 t FYM ha^{-1} and 20 kg P_2O_5 ha^{-1} significantly increased the yield component values, *viz*. Except for the number of pods plant^{-1}, grains pod^{-1}, seed weight plant^{-1}, and fenugreek test weight, it was comparable to applying 20 kg P_2O_5 ha^{-1} alone. When 20 kg P_2O_5 and 5 t FYM were applied concurrently, the fenugreek seed yield (2,558 kg ha^{-1}) and straw yield (3,822 kg ha^{-1}) were found to be significantly higher than when 20 kg P_2O_5 was applied alone. There was a significant increase in the number of branches plant^{-1}, nodules plant^{-1} at 40 DAS, and fenugreek test weight when a higher level of 40 kg S ha^{-1} was applied in comparison to 20 kg S ha^{-1}. The growth attributes, yield, and yield attributes were significantly impacted by the dual inoculation of PSB and Rhizobium treatments, with the exception of the quantity of branches plant^{-1}, the weight of the seeds plant^{-1}, and the yield of fenugreek straw. After harvesting fenugreek, the application of 20 kg P_2O_5 ha^{-1}, 5 t FYM ha^{-1}, 40 kg sulfur ha^{-1}, and dual inoculation with PSB and Rhizobium significantly improved the soil’s status in terms of available nitrogen, phosphorus, and sulfur. The application of 20 kg P_2O_5 ha^{-1} and 5 t FYM ha^{-1} resulted in the highest grain and straw yields for the subsequent pearl millet crop. The dual inoculation of PSB and Rhizobium as well as the application of 40 kg sulphur per ha also demonstrated positive residual effects on the pearl millet grain yield and straw yield, respectively.

Moradi *et al.* (2011) conducted an experiment in order to evaluate the effects of different organic and biological fertilizers on quantity and quality of fennel essential oil in a completely randomized block design with three replications. The experimental treatments included two organic (compost and vermicompost) and two biological (*Pseudomonas putida* and *Azotobacter chroococcum*) fertilizers, their twin combinations (*Ps. putida* + *A. chroococcum, Ps. putida* + compost, *Ps. putida* + vermicompost, *A. chroococcum* + compost, *A. chroococcum* + vermicompost and compost + vermicompost) and control (non-fertilized). There were significant differences between treatments in terms of seed essential oil percentage, essential oil yield; anethole, fenchone, limonene and estragole content in seed essential oil. Results showed that the highest and the lowest percentages of essential oil were obtained in control (2.9%) and *A. chroococcum* + vermicompost (2.2%) treatments, respectively. The highest essential oil yield (29.9 L ha^{-1}) and anethole content of essential oil (69.7%) and the lowest contents of fenchone (6.14%), limonene (4.84%) and estragole (2.78%) in essential oil were obtained in compost + vermicompost treatment. It seems that compost + vermicompost treatment compared to other treatments supplied the highest equilibrium of nutrients and water in the root zone of sweet fennel which is led to increasing the anethole content, there upon, decreasing other compounds. Essential oil yield and percentage of anethole content in essential oil were significantly higher in all organic and biological treatments compared with control.

Bairva *et al.* (2012) conducted a field study to examine the effects of bio-fertilizers and plant growth regulators on the growth and yield of fenugreek. The experiment, which included five levels of plant growth regulators (GA_3 50 and 100 ppm and NAA 10 and 20 ppm and water) and four levels of bio-fertilizers (no inoculation, Rhizobium, PSB, and Rhizobium PSB), was carried out in a factorial randomized block design with three replications. The results showed that Rhizobium PSB dual inoculation of seed produced superior plant height, number of branches $plant^{-1}$, number of nodules $plant^{-1}$, and dry weight of nodules $plant^{-1}$ at 45 DAS and harvest stage compared to rest treatment. Additionally, significantly higher yield components (i.e., Increases in seed and biological yield (i.e., e. control (15.62 and 57.55 q ha^{-1}), respectively, by 18.02 and 63.96 q ha^{-1}. The foliar application of plant growth regulators resulted in favorable responses from the growth parameters, yield components, and seed yield. The maximum dry matter accumulation, number of pods $plant^{-1}$, number of seeds pod^{-1}, pod length, pod weight, and pod shelling percentage were noted in the 20 ppm NAA treatment followed by the 10 ppm NAA application. In a 20 PPM foliar spray of NAA, the productivity of the fenugreek crop was highest in terms of seed production, biological yield, and harvest index (17.62, 65.65 q ha^{-1}, and 27.45%).

Darzi and Hadi (2012) carried out a field experiment to find out how organic manure and biofertilizer affected the fruit yield and yield components in the dill plant height, umbel number $plant^{-1}$, weight of 1000 seeds, biologicals, and fruit yield. Vermicompost (0,4,8 and 12 $tonha^{-1}$) and biofertilizer, mixture of *Azotobacter chroococcum* and *Azospirillum lipoferum* (non-inoculated, inoculated seeds and inoculated seeds + spray on the plant base at stem elongation stage) were used as the effecting parameters. The current findings indicate that the application of 8 tons ha-1 of vermicompost resulted in the largest umbel number plant $^{-1}$, weight of 1000 seeds, and fruit production. Following the application of 4 and 12 tons ha^{-1} of vermicompost, respectively, the maximum plant height and biomass yield were attained. Additionally, biofertilizer had a large impact on plant height, biomass yield, and fruit yield. By applying the biofertilizer twice, the maximum plant height, biomass yield, and fruit yield were achieved.

Mehta *et al.* (2012) carried out a field experiment with the aim to study the effect of nitrogen, phosphorus and biofertilizer on growth dynamics, productivity and nutrient uptake of fenugreek. The experiment consisting of sixteen treatment combinations with two levels each of nitrogen (N) (10 and 20 kg ha^{-1}) and P_2O_5 (20 and 40 kg ha^{-1}) and four levels of seed inoculation with bio-fertilizers (no seed inoculation (control), seed inoculation with *Rhizobium* alone, seed inoculation with phosphate solubilizing bacteria (PSB) alone and seed inoculation with both *Rhizobium* + PSB). Significant increase of dry matter accumulation per plant (DMA), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) at all the growth stages as well as seed yield, straw yield, net return, benefit cost ratio (BCR) were reported when treated with 20 kg N and 40 kg P_2O_5 ha^{-1}. Inoculation of seed with both *Rhizobium* and PSB gave the highest DMA, CGR, RGR and NAR over their sole application as well as control.

Soyam *et al.* (2012) conducted a study titled effect of different biofertilizers on growth, yield, and quality of fenugreek to investigate how biofertilizers affected the vegetative growth, yield, and quality parameters in the fenugreek variety Rmt-303, 11 treatments were tested. Rhizobium and PSB were used to treat the fenugreek seeds, and these treatments were also applied to the soil before planting. The maximum vegetative growths in terms of plant height, branch count, leaf area, and traits influencing yield, namely. Green leaf yield ha^{-1} (74.57 q) and fresh weight of plants $plot^{-1}$ (14.06 g) were found to be significantly highest when seeds were treated with Rhizobium plus PSB and applied to the soil. With seed treatment and Rhizobium plus PSB application to the soil, it was discovered that the levels of chlorophyll, leaf moisture, and protein were significantly at their highest. Comparatively to individual inoculation and control treatments, combined inoculation of Rhizobium and PSB significantly increased the number of nodules $plant^{-1}$, plant height, and dry matter accumulation.

Abdullahi *et al.* (2013) carried out an investigation into the combined effects of biofertilizer (*Azospirillum* and arbuscular mycorrhiza fungi, AMF; *Glomusmossea*) and chicken manure (PM) on nutrient uptake, plant growth, and the population of soil microbes linked to sesame in a field. The experiment comprised of four treatments; T_1 (*Azospirillum* + AMF), T_2 (*Azospirillum* + AMF + 5 tons ha^{-1} poultry manure), T_3 (10 tons ha^{-1} poultry manure), and T_0 (Control) laid out in randomized complete block design with three replications. By applying bio-fertilizer and chicken manure separately or in combination, plant growth parameters such as plant height, number of leaves per plant, number of branches per plant, leaf area, shoots, and root dry biomass considerably increased over control. Combined application of bio-fertilizer and poultry manure @ 5 tons ha^{-1} (bio-organic) significantly produced the plants with desirable growth parameters, nutrients content and uptakes for N, P, and K. Root colonization by AM fungi was recorded in inoculated and un-inoculated plants. Colonization % ranges from 6% in control to 62.8% in Bio-organic. There was no significant difference in % root colonization of inoculated plants. Populations of *Azospirillum* and AM spores have increased in all treatments over the initial population prior to experiment in all treatments. Bio-organic recorded the highest *Azospirillum* population (28.56 × 10-6 CFU g^{-1} soil) and 69.3 AM spores g^{-1} soil and values were significantly higher to all the treatments. The overall results of this study showed that bio-organic (bio-fertilizer and poultry manure at 5 tons ha^{-1}) produced plants with the highest growth parameters, nutrient uptake, increased soil *Azospirillum* population, AM spore density, and mycorrhization compared to exclusively applying bio-fertilizer or poultry manure at 10 tons per hectare. Combining bio-fertilizer with organic amendments could be advised for successful sesame production.

Acimovic (2013) conducted a study to examine the effects of applying various fertilizers on the yield of the plant species under study. Different treatments (control, "Slavol," "Bactofil B-10," "Royal Ofert," vermicompost, and NPK) were used in the field trial. The biofertilizer "Bactofil B-10" application produced the highest caraway yield. The highest yield for anise and coriander was obtained by using chemical fertilizer. Vermicompost for anise and particular poultry manure 'Royal Ofert' granules for coriander were the most productive organic fertilizers.

Hosein *et al.* (2014) studied the effect of bio-fertilizers and chemical fertilizers on yield and yield components of fennel (*Foeniculum vulgare* Mill) with eight treatments and three replications. Treatments included: control (N_1), nitroxin (free-living nitrogen fixing bacteria) (N_2), phosphate solubilizing bacteria (N_3), nitroxin + phosphate solubilizing bacteria (N_4), chemical fertilizer (urea 100 kg ha^{-1} + mono super phosphate 120 kg ha^{-1}) (N_5), 50% chemical fertilizer + nitroxin (N_6), 50% chemical fertilizer + phosphate solubilizing bacteria (N_7), 50% chemical fertilizer + nitroxin + phosphate solubilizing bacteria (N_8). Results showed that fennel plant height, seed production, biological yield, and harvest index were significantly impacted by fertilizer treatments. Maximum seed yield (1017 $kgha^{-1}$) was obtained from (N_8) treatment and the highest plant height (107 cm), biological yield (3875 $kgha^{-1}$) and harvest index (26%) were obtained from (N_8) and (N_6) treatments respectively. The 1000 seed weight did not significantly change as a result of the fertilizer treatments. According to the results, it is concluded that application of biofertilizers with 50% chemical fertilizer could reduce the need for chemical fertilizers and the highest seed and fruit yield would be obtained.

Kumar *et al.* (2015) analyzed the impact of chemical and bio-fertilizers on fenugreek's growth, yield and quality from 2012 to 2013. There are three different types of biofertilizers: *Azospirillum*, PSB, and Rhizobium were used in the fenugreek at two levels of N, P, and K in comparison to the control (recommended dose of NPK through chemical fertilizers). The results of all experiments showed that under 50 percent RDF 50 percent Rhizobium, the maximum plant height (36.84 cm), number of branches (3.33), number of pods (7.20), days to 50 percent flowering (66.33), days to 50% germination (13.00), length of pods (8.53 cm), yield (15.57 q ha^{-1}), yield $plant^{-1}$ (5.85 g), and days to maturity (145.26) were recorded, while the minimum was under control.

Fallah (2015) carried out an experiment using a randomized complete block design with three replications to examine the effects of fertilizer source and intercropping ratios on the macronutrient concentration and uptake of fenugreek and black cumin. Three intercropping ratios (F:B 2:1, F:B 1:1, and F:B 1:2) and two fertilizer sources (chemical fertilizer, chemical fertilizer: broiler litter as 50:50, and broiler litter) were assessed as the first and second factors, respectively. Sole cropping of fenugreek (F) and black cumin (B) was also evaluated. The results showed that, when compared to monocropping treated with inorganic fertilizers, intercropping treated with integrated fertilizer increased nitrogen and phosphorus concentration of black cumin by 79 percent, 70 percent, and 4 percent, respectively, and nitrogen uptake of fenugreek by 4 percent. Only black cumin treated with integrated fertilizer showed the highest uptake of nitrogen and phosphorus. The B:F is (1:1) treated with inorganic fertilizer and the monocropping treated with integrated fertilizer, respectively, had the highest fenugreek nitrogen concentrations and phosphorus concentrations and uptake. The monocropping of fenugreek treated with integrated fertilizer and B:F (1:1) treatment both achieved the highest potassium concentration and uptake of potassium, whereas sole fenugreek treated with inorganic fertilizer had the lowest potassium concentration and uptake. These findings imply that integrated nutrient management for intercropping systems can reduce nitrogen losses and thereby may aid in environmental protection.

Subash and Rafath (2016) studied the effect of plant growth regulators (IAA and GA_3) and living bacteria containing (*Azospirillam*) biofertilizer were investigated on the germination, root length and shoot length. The seeds of sesame variety TMV – 7 were treated with different concentration GA3 (1.0 mg L^{-1}, 1.5 mg L^{-1}, 2.0 mg L^{-1} and 2.5 mg L^{-1}) and indole acetic acid (1.0 mg L^{-1}, 1.5 mg L^{-1}, 2.0 mg L^{-1} and 2.5 mg L^{-1}). In a container, rice starch and the biofertilizer *Azospirillam* were combined to create slurry. Germination, root length and shoot length were evaluated. According to the findings, the biofertilizer had a regulating influence on seed germination, root length, and shoot length compared to the control. In comparison to IAA, 2.0 mg L^{-1} of GA3 has the greatest effect on plants treated with plant growth hormones. The biofertilizer treatment, it can be concluded, promoted germination and growth by excreting phytohormones and improving the mobilization of nutrients from the seed.

Fernandes *et al.* (2015) studied the comparative effect of biofertilizers *Rhizobium japonicum* and *Azotobacter spp.* on the growth and yield of Mungbean (*Vigna radiata* L.) was studied. After 45 days, the results of the biofertilizer treatment on mungbean seeds were documented. Outcomes demonstrate that, when compared to control (undistributed) plants, plants treated with *Rhizobium japonicum* and *Azotobacter spp.* displayed good results in the morphological and biochemical parameters.

Vedpathak and Chavan (2016) carried out a field experiment to study the effects of organic and chemical fertilizer on growth and yield of Fenugreek. Fenugreek local seeds were treated with different fertilizer treatments in field including vermicompost (T_1) @ 0.6 kg/plot (@ 0.3 kg/sq. m), NADEP compost (T_2) @1.25 kg/plot (@ 0.625 kg/sq. m), pit compost (T_3) @ 1.25 kg/plot (@ 0.625 kg/sq. m), chemical fertilizer (T_4) @ 80:40:40 Kg of NPK/ha according to RDF and control (T_5). The results showed that the growth parameters viz., plant height (28.75cm), fresh and dry weight per plant were improved after 60th day with application of vermicompost treatment (T_1). Number of pods per plant (2.66) were higher in control treatment (T_5). Total weight of pods per plant (0.78 gm/plant) and mean weight per pods per plant (0.30gm/pod/plant) was more with application of straight chemical fertilizers (T_4). Application of chemical fertilizer is better and sustainable for higher yield of Fenugreek vegetable per plot than the other remaining fertilizer treatments.

El-Banna and Fouda (2018) investigated the effects of various fertilizer types on the vegetative growth, yield, and some nutrient contents of the caraway plant (*Carum carvi* L.), including mineral fertilizers (100% as a control) or 30% combined with organic fertilizers (farmyard manure at 20 or 30 m^3 fed^{-1}) and bio-fertilizers. The results indicated that the highest mean values of the vegetative growth and fruit yield parameters of caraway plant were significantly increased when plants received 30 % of the recommended mineral fertilizer combined with farmyard manure at 30 m^3 fed^{-1} in the presence of bio-fertilizer and sprayed with humic acid as compared with control (NPK at 300, 200 and 50 kg fed^{-1}, respectively). In addition; N, P and K percentage in herb and seeds recorded the highest values with the same previous treatment. While, the highest values of NO_3-N concentration in herb and seeds were obtained with full recommended dose of mineral fertilization (control treatment).

Ali *et al.* (2009) conducted an experiment to determine the effects of vermicompost and vermiwash biofertilizers on the traits of the fenugreek (*Trigonella foenum-graecum*) plant, a field experiment with an 8 treatment, 3 replications, randomized complete block design was conducted. Vermicompost applications of 5,10 and15 tons ha^{-1}, vermiwash applications of 3,000, 6,000, and 12,000 parts per million, and a combined application of 10 tons of vermicompost and 6,000 ppm vermiwash were among the treatments. A non-fertilized control was also included. Crop growth rate (CGR), pod length, pod width, grain yield, chlorophyll a and b, essential oil percentage, and essential oil yield were all evaluated in this study. The results showed that using vermicompost biofertilizer increased the quantitative traits that were measured when compared to using vermiwash. With the exception of pod length, each trait was most and least affected by 15 and 5 tons of vermicompost ha^{-1}, respectively. Most characteristics did not differ significantly between the 10 to 15 tons of vermicompost ha^{-1} treated with 6,000 ppm vermiwash. Application of vermicompost fertilizer was found to yield less-effective outcomes than vermiwash fertilizer. The findings of the application of 3,000 and 6,000 ppm vermiwash, however, had a statistically significant effect on the treatment with 5 tons of vermicompost ha^{-1} for the majority of the features. The effect of this fertilizer on the measured traits decreased as vermiwash concentration increased. Overall, the results of this experiment showed that all of the traits assessed in this study were positively impacted by the use of vermicompost and vermiwash biofertilizers. The fenugreek plant is also significantly more affected by the vermicompost fertilizer than by the vermiwash fertilizer.

Mafakheri and Asghari (2018) conducted a pot experiment with four replications was set up in the Research Greenhouse of the College of Agriculture, University of Tehran, Iran, to assess the impact of bio fertilizers on the growth, productivity, and element uptake of fenugreek. Treatments included a variety of biofertilizers (*Azotobacter chrococum* (A), *Bacillus subtilis* (B), *Rhizobium meliloti* I, *Pseudomonas fluorescence* (S), and their double (AB), triple (ABR), (ABS), and quaternary combinations (ABRS), as well as arbuscular mycorrhizal fungi (from Glomus sp. Genus), (M), and (C). The application of biofertilizers, both single and integrated, significantly enhanced fenugreek’s vegetative and generative growth as well as its uptake of nutrients, according to the results. When compared to the other treatments and the control, the application of the integrated AS (*Azetobacter chrococum*, *Pseudomonas fluorescence*) fertilizer treatment had the most favorable effects on the growth characteristics of fenugreek.

Tawfik *et al.* (2018) carried out a field experiment to study the effect of NPK as a chemical fertilizer versus the organic fertilizer El-Takamolia (sugar can industry waste) on *Nigella sativa* L. during two successive winter seasons. El-Takamolia was utilized at rate of 4 and 8 tons fed^{-1}. Both the recommended NPK mineral fertilizer and unfertilized plants were utilized as control treatments. The highest level of El Takamolia fertilizer (8 ton fed^{-1}) was the best one for improving vegetative growth parameters compared to the other treatments in both seasons. The data revealed a significantly enhanced seed yield plant^{-1} and per feddan in addition to increase the number of capsules as a result of using El-Takamolia at rate of 8 tons fed^{-1} comparing with the NPK treatments. In comparison to the untreated control, the application of any fertilizer treatment improved the yields and percentages of volatile and fixed oils. Also, Leaf content of both chlorophyll a and b were increased. An increase in leaf and seed contents of carbohydrates and leaf content of phosphorus and potassium were detected. It could be concluded that El-Takamolia organic fertilizer may be efficiently used in the production of *Nigella sativa* L.

Morya *et al.* (2018) carried out a field tests to investigate the impact of organic, inorganic manures, and biofertilizers on soybean growth, yield, and nutrient uptake, during the kharif season. Results showed that 50/50 RDF (10:30:20 kg NPK ha^{-1}) and 50/50 vermicompost (2:05 t ha^{-1}) applications significantly increased growth characteristics, i.e., plant height (55.88 cm), number of branches (4.72), production of dry matter plant^{-1} (19.21 g), no. of nodules (19.21 plant^{-1}) and dry weight of nodules (65.43 mg plant^{-1}). Similarly, with the application of 50% RDF and 50% vermicompost, the highest pods plant^{-1} (72.40), seeds pod^{-1} (3.25), and test weight (137.63 g) were also noted. Under 50 percent RDF, 50 percent vermicompost, and 100 percent RDF (20:60:40 kg NPK ha^{-1}), the highest seed and straw yields (20:60:40 kg ha^{-1} and 2262 and 2143 kg ha^{-1}, respectively) were produced. Higher N, P, and K uptake were also observed with the same treatment (190.21, 23.45, and 121.06 kg ha^{-1}, respectively), which was followed by 100 percent RDF. Therefore, in the rainfed environment, soybean should be fertilized with 50% RDF and 50% vermicompost for higher production and productivity.

Vikash *et al.* (2019) conducted a field study the effects of organic and inorganic fertilizer treatments on fennel crop seed quality parameters were significant. Maximum test weight (9.1 g), seed density (1.58 g cc^{-1}), standard germination (91 g cc^{-1}), seedling length (22 g cm^{-1}), seedling dry weight (4 g kg^{-1}), and vigor index I and II (2053) are some of the measurements that must be met. The control value, which was the lowest value found in treatment T_{16}, was 7.33, 1.14, 75.12, 15.75, 2.60, 1184, 222.2, 18.33, 1.127, 0.703, 6.43, and 66.67. Under T_9: 100% RDN through vermicompost *Azotobacter* PSB, the least electrical conductivity of 118.79 $mScm^{-1}$ was found, which was significantly lower than all of their treatments. The electrical conductivity of the seeds was highest (167.31) $mScm^{-1}$ under control conditions where no chemical, organic, or biofertilizer was applied.

Trivedi *et al.* (2019) studied the synergistic effect of NPK with biofertilizers. The experiment consisted of six treatments with four replications and it was laid out in Randomized Complete Block Design. The treatments were: T_1 – Control, T_2 – RDF (NPK @ 75:50:25 kg NPK ha^{-1}), T_3 – 50 % RDF + *Azotobacter* (5%) + PSB (5 %), T_4 – 75 % RDF + *Azotobacter* (5%) + PSB (5 %), T_5 - 100 % RDF + *Azotobacter* (5%) + PSB (5 %), T_6 – *Azotobacter* (5%) + PSB (5 %). The best treatment, T5, reported the highest plant height (74.07 cm), widest leaves (3.11 cm), heaviest leaves (15.88 g), longest leaves (6.17 cm), and highest yield (163.25 q ha^{-1}). However, in terms of yield T_5 was found to be significant with T_4 (130.5 q ha^{-1}). That demonstrates how biofertilizers can improve amaranth's yield and nutrient use efficiency.

Sahu *et al.* (2020) conducted an examined the Effect of Integrated Nutrient Management on Fenugreek (*Trigonella foenum-graecum* L.) between October 2016 and March 2017. The experiment had three replications and a randomized block design layout. The experiment used the fenugreek cultivar AFG-3. There are twelve different treatments, including integrated nutrient management using organic, inorganic, and biofertilizers as well as control. The observations on various growth and yield parameters were noted, and the outcomes are outlined below. Based on a one-year research trial, it was possible to draw the conclusion that the treatment (T_{11}) i.e. Rhizobium PSB (Phosphate Solubilizing Bacteria) was the best at all stages of growth parameters like plant height 30, 60, 90 DAS (cm), number of primary branches $plant^{-1}$ at 30, 60, and 90 DAS, length of internode, days to 50% flowering, fresh and dry weight of the plants, and yield parameters like days to first pod formation, days to 50% pod formation, number of pods $plant^{-1}$, weight of pods, etc. 50 percent RDF Neem cake @ 1 ton ha^{-1}.

Youssef *et al.* (2020) performed a field experiment on caraway plants to evaluate the effect of biofertilizer applications as partial replacement for chemical fertilization on vegetative growth, seeds yield, essential oil productivity and its main components as well as chemical constituents of caraway under Sinai conditions. Treatments were the combination of five fertilization levels (full recommended dose of NPK only, 75, 50, 25% of the recommended NPK plus bio-fertilizers and bio-fertilizers only). The results showed that application of T_2 (75% of the recommended NPK plus bio-fertilizers) increased vegetative growth, yield, maximized essential oil percentage and yield compared to other treatments. The bare minimums for vegetative growth, yield, and essential oil productivity, however, were only attained with plants that had been fertilized with T_5 biofertilizers. Finally, carvone and limonene were the main chemical constituents of essential oil for caraway.

Awaad *et al.* (2020) carried out an experiment to evaluate the effects of bio-fertilizers (*Azospirillum* and *Azotobacter*) and different nitrogen fertilizer sources i.e., ammonium nitrate (AN), slow release nitrogen fertilizer urea-form aldehyde (SRF) and organic fertilizer (OF) at rate of 100% in absence of bio fertilizer and at rate of 75% nitrogen from recommend dose for both canola as winter season crop and sesame as summer season crop on the growth, chemical composition as well as concentration and yields of protein and oil in both canola and sesame crops. The results of the analyzes showed that the use of bio-fertilizer with mineral nitrogen fertilizer increased plant growth rates, (number of pods plant^{-1}, height plant, weight of 1000 Seeds (g), number of seeds/ capsule, seeds and straw yields, biological yield as well as the harvest index of both canola and sesame plants compared with mineral fertilizer AN and SRF alone. By applying nitrogen fertilizer with bio-fertilizer, the maximum values of concentration and uptake of N, P, and K in both straw and seeds were achieved. The interaction of nitrogen fertilizer and bio-fertilizer produced adequate protein and oil percentages and may have improved the quality of canola and sesame seeds. On the other side, the application of mineral nitrogen along with bio-fertilizer improved various soil chemical parameters (EC, pH, and O.M).

Ngosong *et al.* (2020) reported that grain legumes have two advantages: they can be used as a food source and can improve plant nutrition or soil fertility, but the latter benefit may depend on fertilization practices. A controlled study was conducted to evaluate the impact of four fertilizer treatments (control–no input, single dose NPK, split dose NPK, and poultry manure) on earthworm's soil fertility and the implication on the performance of climbing bean (*Phaseolus vulgaris*). Poultry dung had the biggest impact on the soil's pH, organic C, N, P, K, calcium, magnesium content, and ECEC after the fertilizer applications. The control treatment had the highest amount of bean root nodule mass, followed by inorganic fertilizers and chicken manure. Significantly negative associations between the soil organic C, N, P, Mg, Ca, and ECEC and the root nodule mass were observed. The amount of earthworms per square meter varied significantly between treatments, with poultry manure having the highest density when compared to the control and both single and split-dose inorganic fertilizers. Earthworms had positive correlations with soil pH, K, Mg, Ca, and ECEC and negative correlations with soil acidity. The number of bean pods varied considerably among fertilizer applications, with poultry manure having the largest number, followed by split-dose NPK, which was different from the control and single-dose NPK. Additionally, there was a favorable correlation between the quantity of bean pods and the soil's organic C, P, Mg, and Ca content as well as ECEC. These results show how important chicken manure is for the health of the soil's fertility and earthworm population, as well as how climbing beans respond to it. However, the findings reveal potential restrictions of poultry manure on climbing bean root nodulation and nitrogen fixing capacities, which should be taken into account when developing integrated soil fertility management strategies.

Moradzadeh *et al.* (2021) studied the combined effect of urea and biofertilizers on the quantitative and qualitative traits of *N. sativa* L. in a randomized complete block design with 10 treatments and three replications. The treatments included control (no fertilization), U (100% chemical fertilizer as urea at 53.3 kg ha^{-1}, Nb (Biofertilizer, *Azotobacter vinelandii*), Pb (Biofertilizer, *Pantoea agglomerans* and *Pseudomonas putida*), Kb (Biofertilizer, *Bacillus spp*.), NPKb (NPK, biofertilizer), Nb + 50% U, Pb + 50% U, Kb + 50%U and NPKb + 50% U. The NPK(b) + U50% was related to the highest quantity of plant height, branch diameter, capsule (follicle) number $plant^{-1}$, auxiliary branches, seed yield $plant^{-1}$, thousand-seed weight, essential oil content, total phenolic compounds, flavonoid content, DPPH free radical scavenging, nitric oxide (NO) radical scavenging, superoxide radical scavenging, chain-breaking activity, phosphorus content, and potassium content, along with U for the highest biological yield and (Pb) + U50% for the highest essential oil percentage which is close to (NPKb) + U50%. The lowest value was observed in all traits related to the control treatment except for branch diameter that was related to (NPKb). Hence, the application of

(NPKb) + U50% as bio-chemical fertilizers improved *N. sativa* L. Traits, so it can be recommended.

Jamir *et al.* (2021) conducted a study to promote sustainable agriculture using less inorganic fertilizer by using biofertilizers. The experiment included 14 treatments with three replications each, including three inorganic fertilizer concentrations (50, 75, and 100 percent) of the recommended NPK and three biofertilizers (i.e., As part of a soil application, *Azospirillum lipoferum* (a N fixer), *Bacillus megaterium* (a potash mobilizer), and *Fraturia aurantia* (a K mobilizer) were used. The results revealed that the 100% RDF *Azospirillum* PSB KS had the highest plant height (86.06 cm) at 100 DAS, the most primary branches (10.66) and secondary branches (17.33), the most capsule plant^{-1} (12.33) and the most seeds capsule^{-1} (14.66), the lowest test weight (3.54 g), and the highest projected yield (538.50 kg ha^{-1}). The yield (536.74 kg ha^{-1}), which was 75% RDF, was comparable to *Azospirillum* PSB KS's yield. The maximum net return (Rs. 1,08,083.74 ha^{-1}) and B: C ratio (4.14: 1) were derived from *Azospirillum* PSB KS that was 75% RDF. These results indicated that the best combination for optimum production of black cumin without yield loss and reduction of 25% of inorganic fertilizers by use of biofertilizers and environmental pollution to some level was *Azospirillum* PSB KS with 75% RDF.

Patel and Prasad (2022) studied the growth, number of leaves plant^{-1}, and production of green leaves of fenugreek were the focus of a field experiment to compare the effects of various organic manures and biofertilizers. The maximum plant heights (15, 35, and 60 cm) was observed with the application of 3.5 t ha^{-1} Vermicompost Rhizobium PSB at 30 DAS, 60 DAS, and at harvest, respectively. This value was found to be significantly higher than the control treatment. The data also shows that at 30 DAS and 60 DAS, respectively, the number of leaves plant^{-1} was recorded (20.60, 69.50), which was found to be significantly higher than rest treatment. The data clearly showed that various organic manures and biofertilizers had a significant impact on green leaf production as measured by yield plot^{-1} (g) and kg ha^{-1}. The application of 3.5 t ha^{-1} Vermicompost Rhizobium PSB was found to be significantly higher than the rest treatment, and the maximum yield plot^{-1} (716.66 g) and yield kg ha^{-1} (1990.72 kg) were recorded.

Delfieh *et al*. (2022) conducted an investigation to examine the effects of various nitrogen nutritional systems (biologic, organic, and chemical fertilizers) on fennel in two crop years (2013-2014 and 2014-2015). Treatments included cow manure (N_3), inoculating fennel seeds with *Azotobacter* and *Azospirillum* (N_4), uniformly spreading urea at stem elongation (Na), Ns or Integrated-1 (N_3 N_4), and N. or Integrated-2 (N; N_4). The control treatment was uniformly spreading urea at planting time and at stem elongation (N_1). Results showed that for the first and second years, respectively, N_2 has resulted in 13.4% and 14% higher seed yield production than N_1. Additionally, the results showed that for the first and second years of study, respectively, N_2 could yield an essential oil yield that was 14.3% and 13.6% higher than N_1. Anethole, methyl chavicol, pinene, limonene, and fenchone made up the majority of the essential oil's chemical composition. The findings of this study demonstrated that the application of biofertilizers (*Azotobacter* and *Azospirillum*) to fennel had no beneficial effects.

Singh *et al.* (2022) conducted a field experiment to evaluate the effect of biofertilizers with 75% recommended dose of fertilizers on growth, yield, nutrient uptake, nutrient use efficiency and B:C ratio of chickpea (*Cicer arietinum* L.).The result showed that among the seed treatment with *Rhizobium leguminosorum* @10 g kg^{-1} seed and soil application of PSB and KSB @ 5 as above along with application of 75% recommended dose of fertilizers have been significantly enhanced root nodule formation, fertilizer use efficiency, productivity and reduced wilt infestation under this treatment followed by recommended dose of NPK + seed inoculation by *Rhizobium* and PSB separately @ 10 g kg^{-1} seed as compared to control plot.

2.2 Effects of macronutrients

Verma and Saxena (1995) studied that effect of using *Rhizobium*, farm yard manure (FYM) and inorganic fertilizers on plant growth, yield attributes, yield of French bean and nutrient build up in soil was studied under field conditions. *Rhizobium* inoculation and application of FYM and chemical fertilizers had significantly increased the plant height, number of pods per plant, number of seeds per pod, yield and net returns over controls. Application of K @ 30 kg ha^{-1} along with recommended dose of fertilizers significantly increased the yield of French bean by 34.8% and the observed response in terms of seed yield was 21.6 kg per kg of K applied. Highest growth, yield attributes and seed yield were recorded with application of 40 kg N ha^{-1}, 60 kg P ha^{-1} and 30 kg K ha^{-1}, with an increase of 58.8% in yield over recommended dose of fertilizers. The yield of 3270 kg ha^{-1} was observed in the interaction treatment in which Rhizobium inoculated seeds were used in conjunction with 5 t FYM and 40 kg N, 60 kg P and 30 kg K ha^{-1} . Maximum soil organic carbon (13.5 g kg^{-1}) and the highest available N, P, K contents (380, 98, 230 kg ha^{-1} , respectively) were observed under the combined use of Rhizobium and FYM along with chemical fertilizers (40 kg N, 60 kg P and 30 kg K ha^{-1}) after completion of the experiment, which indicated the buildup of available soil nutrients over other treatments including recommended dose of fertilizers.

Deepak *et al.* (2000) reported that fenugreek cv. hisar sonal was treated with N at 20, 40 and 60 kg ha^{-1}, and P at 25, 50 and 75 kg ha^{-1}, and sown at rates of 15, 20, 25 and 30 kg seed ha^{-1} in a field experiment conducted in Haryana, India, during the winter season of 1995- 96. Harvest index was highest with N at 20 kg ha^{-1} + P at 75 kg ha^{-1}. Seed yield was highest (14.80 q ha^{-1}) at treatments with 20 kg N ha^{-1} + 75 kg P ha^{-1} + sowing rate of 25 kg seed ha^{-1}. The highest plant height was obtained in the treatment 40 kg N ha^{-1} + 75 kg P ha^{-1} + 20 kg seed ha^{-1}.

Jameel *et al.* (2009) conducted an experiment to evaluate how different quantities of balanced NPK fertilizer (20-20-20) normal and nano would affect the mineral and protein content of seeds in three species of apiaceae (cumin, anise, and sweet fennel). The results showed the superiority of sweet fennel plant in seeds content of total phosphorus and potassium versus the superiority of cumin plant in total seeds content of nitrogen and protein. The significant effect of soil-additive fertilizers from normal and nano compound fertilizer in the increase of the majority of the studied traits and recording the highest mean in the NPK mixture at the double recommended or recommended level. The interference between factors gave the same significant effect to the superiority of the individual factors, as well as the improvement traits of more than double in some of them and the difference of response between plants depending on the type of fertilizer.

Tunçturk *et al.* (2011) conducted a study to find out how applying nitrogen and sulfur affected the yield and quality of fenugreek with the exception of thousand seed weight, nitrogen fertilizer had a substantial impact on all growth and yield indices. The highest seed yields (853.0 and 815 kg ha^{-1}) were attained in 2006 and 2007, respectively, following applications of 90 kg N ha^{-1} and 20 kg S ha^{-1}. In both of the experimental years, applications of 90 kg N and 40 kg S had the maximum protein content (24.2%).

Kinji *et al.* (2012) investigated how a lack of macronutrient elements (nitrogen, phosphorous, potassium, magnesium, and calcium) affected the fenugreek plant's dry and fresh weight, root and shoot length, leaf relative water content, and chlorophyll content. It was found that this rise was significant at the 0.05 level of statistical significance in relation to the magnesium deficiency that led to an increase in root and shoot dry weight, root and shoot fresh weight, root and shoot length, and leaf relative water content. When there is a calcium deficiency, root and shoot length, root and shoot dry weight, and shoot fresh weight decrease; statistical level 0.05 showed a meaningful difference from the blank level in these variables; however, there was no meaningful difference from the control level in these variables with regard to leaf relative water content. Shoot length, root and shoot fresh weight, and leaf relative water content all significantly increased in potassium deficiency, but root and shoot dry weight decreased at a statistical level of 0.05, which was significantly more significant than the blank level. When examining the effects of phosphorus deficiency, shoot length significantly increased compared to the blank level, although noteworthy decreases were seen in root dry weight, shoot fresh weight, and leaf relative water content compared to the blank level (P 0.05).Root length, fresh weight, and relative water content of leaves all significantly increased in nitrogen deficiency, however shoot fresh weight, root, and shoot dry weight all significantly decreased at statistical levels of 0.05 in comparison to blank. Chlorophyll levels in fenugreek leaves decreased due to nutrient deficiencies, with nitrogen, potassium, and phosphorus levels being lower than the control level. Chlorophyll levels increased in plants lacking in calcium and magnesium. Chlorophyll b and total chlorophyll concentration in fenugreek leaves significantly decreased as a result of a lack of macronutrient elements (P 0.05). Additionally, a lack of macronutrients led to a decrease in the activity of malondialdehyde in the fenugreek plant's root and shoot.

Mousa *et al.* (2012) conducted a field experiment to investigate the effects of plant spacing (15 and 30 cm) and various fertilizer treatments; cattle manure ($15m^3$ fed^{-1}), NPK fertilization [ammonium nitrate (33.5% N) 60, calcium superphosphate (15.5% P_2O_5) 45, and potassium sulphate (48% K_2O) 48 kg fed^{-1} and bio-fertilizers [Biogen (500g) and phosphorein (300g Kg^{-1} seeds) were added either individually or in combination]. Data obtained showed that significant increases were found in branch number, seed production, yields of volatile and fixed oil in seeds in relation to plant spacing of 30 cm comparison to that of 15 cm. Moreover, leaf contents of carbohydrates, nitrogen, phosphorous and potassium recorded similar trend. All fertilizer treatments significantly increased plant height and branch number plant^{-1} compared to unfertilized plants. Cattle dung, however, was more successful in this regard. Compared to other treatments, cattle manure produced higher yields of seeds and volatile oil. Additionally, it markedly boosted the amount of carbohydrates, N, P, and K in the leaves. The interaction of the various treatments showed that the best outcomes were obtained with a 30 cm gap and animal manure.

Mahmowd *et al.* (2014) carried out an experiment during summer growing seasons to investigate the effects of applied N, P and K on peanut yield, quality and some macronutrients (N, P and K) uptake in sandy soils. Increasing N, P and K rates from (30-30-24 to 60-45-48 kg NPK fed^{-1}) significantly increased plant height, number of branches plant^{-1}, seed weightplant^{-1}, pod yield fed.$^{-1}$, 100-pod weight, 100-seed weight, shelling% and N, P and K-uptake. The interaction between genotypes and nitrogen, phosphorus, and potassium fertilization had a significant impact on all examined attributes in both seasons, according to the results. Additionally, all the investigated features had a positive correlation with pod yield (kg). In both seasons, (60,45, and 48 kg NPK fed^{-1}) generally produced the greatest values of the majority of examined attributes.

Udit (2014) conducted an experiment to study the production potential of fennel as affected by biofertilizer (*Azotobacter*) and levels of nitrogen. Altogether four levels of nitrogen and biofertilizer (*Azotobacter*) with or without including control were replicated three times. The fennel yield was significantly higher in the treatment *Azotobacter* application combined with 75% of the recommended dose of nitrogen on both the year. In comparison to other treatments, the yield that was observed in the control was quite low. Biofertilizer (*Azotobacter*) without nitrogen also showed yield reduction.

Nilanthi *et al.* (2015) carried out a field experiment to study the effect of foliar application of Ca Zn, B, N, P, k Amino acid and water on growth, yield and quality of two soybean cultivars under normal and water stress conditions. Result showed the effect of foliar application year on plant height, pod number plant^{-1}, seed number pod^{-1} and grain yield were significant. The highest grain yield (4021.91 kg ha^{-1}) achieved B application in 2017. The lowest grain yield (237.41 kg ha^{-1}) was obtained in 2016 and control treatment, also there was no significant difference between control treatment and water application in two year of experiment. The result showed in 2017 there was no significant difference in treatment in seed protein content. Also, there was no significant difference between foliar application and control in seed oil content in 2016. Also, two cultivars have significant different in grain yield in 2017. But there was no significant difference in two cultivars in 2016. In general, results showed that spray application of nutrients, especially B application, improves the yield and yield component.

Khalid and Shedeed (2015) caried an experiment to study the effect of different levels of NPK fertilizers, foliar nutrition and their interactions on the morphological and biochemical contents of *Nigella sativa* L. The most effective rate was $N_3P_3K_3$ x foliar nutrition interaction, resulting in a positive increase in vegetative growth. The highest values of vegetative growth characters were 27.7, 41.4 cm (plant height); 55.4, 51.9 (leaf number); 10.2, 11.7 plant^{-1} (branch number); 15.5, 20.8 plant^{-1} (capsule number); 47.1, 49.4 g plant^{-1} (herb dry weight); 4.3, 4, 7 g plant^{-1} (seed yield) during the first and second seasons respectively. As well as $N_3P_3K_3$ x foliar nutrition led to higher biochemical contents than the control. The highest values of chemical contents were 22.9 and 25.1% (fixed oil); 33.0, 30.1 % (total carbohydrate); 16.9, 8% (soluble sugars); 23.7 and 24.8 % (protein); 3.8 and 4 % (N); 0.4 and 0.4 % (P); 1.2 and 1.8 % (K) during the first and second seasons respectively.

Valiki *et al.* (2015) carried out a study to examine the effects of various vermicompost and NPK fertilizer levels on fennel (*Foeniculum vulgare* Mill.) production, growth metrics, and essential oil. The study used a complete randomized blocks design with six treatments and three replications. Treatments included NPK fertilizer, vermicompost (5, 10, 15 and 20 t ha^{-1}) and control. Plant height, number of main and lateral branches, number of umbrella plants, number of umbelets per umbrella, seed yield, biological yield, harvest index, and quantity of oil produced at various vermicompost and NPK fertilizer levels were all statistically significant, according to analysis of variance. Generally, results indicated that using 15 t ha^{-1} vermicompost showed more positive effect on recorded traits of fennel (*Foeniculum vulgare*) than other treatments.

Nkiruka *et al.* (2016) stated that for soybean to achieve the dual goals of fixing atmospheric nitrogen and high producing, same as other grain legumes, it needs several key nutrients. Then, a screen house experiment was set up to examine the impact of N, P, K, Zn, and Mo on soybean nodulation and growth. Soils test revealed variation of soils' chemical contents among farmers field, especially for P with 51.7 mg kg^{-1} in soil to 2.7 mg kg^{-1}. Significant effects from soils and fertilizers were observed on biomass yield, nodulation and nutrient uptake. Nitrogen fixation potential of TGX 1448–2e, however, was not increased by soils or fertilizer treatments. The effects were significant on P-uptake, shoot and nodule dry weight. K treatment was found to decrease soil P absorption and shoot dry weight. These results in response to fertilizer treatments indicate that soybean fertilization should be advised in accordance with the fertility of the soil.

Jasim *et al.* (2016) did an experiment in Babylon during the growing season 2013 – 2014 to study the effect of 5 soil fertilization treatments [control, 200 kg ha^{-1} of NPK (18-18- 0), 4 and 8 t ha^{-1} of compost of poultry], and its impact on the development and yield of fenugreek when exposed to 4 applications of foliar fertilizers (control, spray urea 1 g L^{-1}, spray humic acid 2 ml L^{-1}, and spray polimet 2 ml L^{-1}). Foliar fertilizers were added twice, and soil fertilizers were added as a side dressing. The findings revealed that poultry (8 t ha^{-1}) was superior to control in terms of branches number and wet weight, while chemical fertilizer was significantly superior to other treatments in terms of plant height, number of leaves, leaf area, and wet and dry weight. In terms of plant height, leaf count, and soft weight, urea spray was superior. Polimet spray was superior compared to control in branches $plant^{-1}$. Plant height, branch and leaf number, leaf area, and wet and dry weight all increased as a result of the soil's interaction with fertilizer spraying.

Nilanjana *et al.* (2017) investigated the performance of fenugreek under different levels of NPK for maximization of yield. Three levels of each nitrogen (40, 60, 80 kg ha^{-1}), phosphorus (60, 80 and 100 kg ha^{-1}) and two levels of potassium (20 and 40 kg ha^{-1}) were included in this investigation. There were altogether 18 treatments. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications. Among different treatment combination maximum plant height of 44.28 cm at 45 DAS with $N_{80}P_{80}K_{40}$ but at 105 DAS maximum plant height was observed with $N_{60}P_{100}K_{40}$ (108.17 cm). Plants grown under $N_{60}P_{80}K_{40}$ combination, exhibited the maximum number of secondary branches (15.94) $plant^{-1}$. In $N_{60}P_{80}K_{40}$, yield-related metrics like maximum pod length (10.96 cm), number of seed pods per pod (15.32), and maximum predicted yield (17.20 q ha^{-1}) were noted. Under West Bengal's alluvial plains, NPK @ 60:80:40 kg ha^{-1}, NPK @ 40:80:40 kg ha^{-1}, and NPK @ 60:100:40 kg ha^{-1} were the most successful treatments from the perspective of yield maximization.

Mazid and Naj (2017) conducted an experiment to see whether spraying a little quantity of phosphorus (P) and/or sulphur (S) would increase chickpea performance, with or without the GA (Giberallic acid) soaking treatment (10^{-6} M GA for 8h) and/or the GA spray treatment (10^{-6} M GA at 60-70 DAS). The combination of P and S together with GA at two sample stages led to higher responses and additional advancements in the following parameters: Stomatal conductance, net photosynthetic rate, leghemoglobin content (Lb), and carbonic anhydrase activity (90 and 100 DAS). This treatment also increased harvest index (HI), pod number plant^{-1}, seed yield plant^{-1}, seed protein and carbohydrate content at harvest. This combination resulted in a 21% increase in protein content and an 11% increase in carbohydrate content.

Datta and Hore (2017) carried out a field experiment to examine the effect of nitrogen, phosphorus and potassium application on growth and yield of variety 'Hissar Sonali' of fenugreek. Three levels of each nitrogen (40, 60 and 80 kg ha^{-1}), phosphorus (60, 80 and 100 kg ha^{-1}) and two levels of potassium (20 and 40 kg ha^{-1}) were included in the investigation. There were altogether 18 treatments. Three replications of a factorial randomized block design were used to set up the experiment. Among different treatment combination maximum plant height was observed with $N_{60}P_{100}K_{40}$ (108.17 cm) at 105 DAS. Plants grown under $N_{60}P_{80}K_{40}$ combination, exhibited maximum number of primary branch (8.72) plant^{-1}. In, $N_{40}P_{60}K_{40}$, the minimum number of days needed for 50% pod development was observed (68.12 days). Thus, $N_{60}P_{80}K_{40}$ combination showed the yield characteristics of greatest number of pods plant^{-1} (76.48) and seed yield plant^{-1} (14.36 g). Maximum projected yield (17.20 q ha^{-1}) was recorded in $N_{60}P_{80}K_{40}$ followed by $N_{40}P_{80}K_{40}$ (16.31 q ha^{-1}) and $N_{60}P_{100}K_{40}$ (15.80 q ha^{-1}) as compared to lowest yield of 11.70 q ha^{-1} under $N_{40}P_{60}K_{20}$ combination. The majority of metrics showed a rising tendency with medium levels of nitrogen (N_{60}) and phosphorus (P_{80}), whereas greater levels of potassium showed a favorable reaction. From the perspective of maximizing yield, NPK @ 60:80:40 kg ha^{-1}, NPK @ 40:80:40 kg ha^{-1}, and NPK @ 60:100:40 kg ha^{-1} were the most successful treatments.

Mitoo *et al.* (2017) conducted an experiment to investigate the effect of four levels of phosphorous (0, 20, 30, 40 kg P kg ha^{-1}), as well as three levels of sulphur (0, 10, and 20 kg S kg ha^{-1}), on the vegetative growth of fenugreek (cv. BARI Methi-1). The highest plant height (26.73 cm) was achieved with a dose of 40 kg P ha^{-1} and 10 kg S ha^{-1} applied 30 days after sowing (DAS), whereas the highest plant height (32.47 cm) was achieved with a dose of 40 kg P ha^{-1} and 20 kg S ha^{-1} applied 60 days after sowing (DAS). The application of 40 kg P ha^{-1} and 20 kg S ha^{-1} resulted in the highest number of primary branches per plant 4.60 at 30 DAS and 5.73 at 60 DAS. The doses suggested above assist in achieving optimal seed yield. As a result, a fertilizer dose of P-S (40+10) kg ha^{-1} with a blanket dose of N-K (80+67) kg ha^{-1} + 5.0 tons of cow dung might be regarded as adequate for fenugreek production.

Amirnia *et al.* (2018) conducted an experiment to examine the effect of foliar application of 3 levels macro nutrients (nitrogen, phosphorus, potassium) in different 3 levels dosage of these elements (2, 3 and 4g 1000 seed weight) on yield and yield components of fenugreek herb. Results showed that foliar application of macro nutrients was significant in plant height, number of pods, number of seeds pod^{-1}, pod length, 1000 grain weight, seed yield and biomass, seed nitrogen and protein percentage of Fenugreek. The nitrogen treatment produced the maximum grain yield (1029.2 kg ha^{-1}) and seed protein content (12.4%). Also, the lowest 1000-seed weight was achieved in control. The dosage of macro nutrients (excluding number of seeds pod^{-1} and seed yield) had a significant effect on the observed traits. The maximum seed protein percentage (11.26 %) was detected by 2g per 1000 seed weight, whilst the highest biomass yield (1574.17 kg ha^{-1}) was achieved by 4g per 1000 seed weight. Therefore, foliar application method reduces utilization of chemical fertilizers, which can increase the efficiency of fertilizer application and decrease fertilizer nutrient losses.

Badran *et al.* (2018) carried a field trial to study the effect of mineral NPK and organic fertilization on growth, yield, essential oil and herb N, P and K % of *Coriandrum sativum*, L. plants. The acquired results showed that both low and high NPK fertilization rates, with the high one producing the highest values, considerably improved all evaluated characters of growth, yield, essential oil, and herb % of NPK. When it comes to organic fertilization, the various growth characteristics (plant height, stem diameter, and herb dry weight), yield and yield component characteristics (number of umbels $plant^{-1}$ and fruit yield $plant^{-1}$ and per fed), essential oil parameters (% and yield $plant^{-1}$ and per fed) and NPK % in the herb were gradually increased parallel to the gradually increasing compost level. The combined treatment between the low NPK rate (50 g kristalon/10.8 m^2 plot) and medium compost level (10 tons fed^{-1}) resulted in better fruit and essential oil yield than that obtained from the high NPK rate. So, the possibility of substituting one half of the mineral NPK dose by the medium compost level is justified.

Cavalcante *et al.* (2019) conducted a study to assess the impact of mineral fertilization on the development and production of castor bean (*Ricinus communis* L.) seeds and oil. Reference doses were 50:300:150 kg ha^{-1} of N, P_2O_5 and K_2O. An appropriate value of the growth and yield characteristics was achieved on average with a nitrogen dose of 150 kg ha^{-1}. Since the differences in the rise of growth factors between this dose and the greatest ones predicted by the equations were so tiny, 300 kg ha^{-1} of phosphorus should be applied for plant development; for castor bean production, the optimal applied dose was 600 kg ha^{-1} of phosphorus. The optimal potassium dose was 300 kg ha^{-1}, which increased leaf area, seed output, and oil production. The nutrient that encouraged the most oil $plant^{-1}$ production was phosphorus (92.40 g), followed by nitrogen (75.55 g) and potassium (72.10 g).

Khalil *et al.* (2019) used biofertilization with *Rhiobium radiobacter sp*. strain (fixed nitrogen), *Bacillus megatherium* as (dissolving phosphate bacteria), and *Bacillus circulans* (enhancing potassium availability) to evaluate the effect of partial substitution of 50 % and 25 % of NPK addition rates (40 kg N $fed.^{-1}$, 100 kg P_2O_5, and 70 kg K_2O fed^{-1}) on some soil properties and faba bean yield, yield attributes, and chemical composition content, i.e., Nubaria 1 and Misr 3. The Misr 3 plants treated with the maximum prescribed dose of NPK fertilizer and biofertilization produced the highest value (98.85 g) for 100-seed weight. Pod yield, N, P and K content as well as N, P and K-uptake by faba bean (Nubaria1) seeds gave the maximum values under Biofertilization + full NPK fertilizer recommended dose (full-RD). Seed yield and protein content were increased significantly and gave the highest values due to the treatment of Biofertilization + 75% of NPK fertilizer (¾RD) for Nubaria1 plants. Highest yield efficiency (97.25%) was obtained due to Biofertilization + 75% of NPK fertilizer (¾RD) for Misr 3 plants. When plants were treated with Biofertilization + full NPK-RD, which was superior to the other treatments and produced the highest yield with Misr 3 variety, fertilized treatments in combination with biofertilization decreased values of soil EC and pH and increased soil available N, P, and K content after harvest.

Patel *et al.* (2019) reported that fertilizer can be utilized as a biological control method for plant diseases and can boost plant resilience. The goal of the study was to ascertain how microorganisms affected the germination of seeds from various plant families, including the Solanaceae, Apiaceae, and Fabaceae. Three different types of studies were conducted: seeds without microbial consortia treatment, seeds treated with microbial consortium, and seeds treated with microbial consortium plus cow dung as biofertilizers. After the seeds were sawed, daily applications of sunlight and water were made to aid in seed germination. Different characteristics, including the number of plants, the length of the roots, and the length of the shoots, were measured after seed germination at regular intervals. The maximum plant growth was seen in the current study when cow manure was added to the microbial consortium.

Rohit *et al.* (2020) carried a field experiment consisted of 9 treatments combinations which were replicated thrice and laid out in a RBD of three levels of NPK (0 % NPK, 50 % NPK and 100 % NPK), three levels of Zn (0 % $ZnSO_4$, 50 % $ZnSO_4$ and 100 % $ZnSO_4$). The results demonstrated that the application of T_8 (NPK 100 %, $ZnSO_4$ 100%; 40:80:40 Kg NPK + 20 Kg Zn ha^{-1}) of Pea (*Pisum sativum* L.) were found to be the best treatment combinations for progressively increasing plant height (cm), number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and pod yield (q ha^{-1}).

Varun *et al.* (2020) conducted an experiment to find out the effect of nitrogen, phosphorus and Potassium (NPK) on growth, and yield of black cumin. On the basis of present investigation it is concluded that the application of treatment T_6 70:65:65 (Urea = 152.17 kg ha^{-1}, Single Super Phosphate = 406.25 kg ha^{-1}, MoP = 108.33 kg ha^{-1}) was superior in terms of growth and yield viz. plant height (60.23), number of primary branches $plant^{-1}$ (8.25), number of primary branches $plant^{-1}$ (14.96), days to flower bud appearance (63.48), days to 50% flowering (56.46), number of capsule $plant^{-1}$ (37.47), seed yield $plant^{-1}$ (8.59 g), seed yield $plot^{-1}$ (103.12 g) and seed yield (7.20 q ha^{-1}) of black cumin

Deshmukh *et al*. (2020) conducted an experiment during the rabi season of 2014-15, to study the effect of nitrogen and phosphorus on growth and seed yield of fenugreek. The experiment was laid out in Factorial Randomized Block Design with three replications. Twelve treatment combinations were formed with a view to integrate four nitrogen doses and three phosphorus doses. The allocation of treatments was made by random method. On the basis of results obtained in the present investigation, the yield para meters in respect to number of pods per plant, seeds per pod seed yield per hectare were observed significantly maximum in the treatment T_9 (N_3P_3) i.e., 80kg N+ 60kg P.

Considering the cost economics, nitrogen level N_3 (80 kg ha^{-1}) and phosphorus level P_3 (60 kg ha^{-1}) was found to be most remunerative as per the B:C ratio (2.51).

Debnath *et al.* (2020) conducted a field experiment to investigate the effect of primary nutrients (NPK) on growth, yield and yield attributes of mungbean. The experiment had four levels of primary nutrients (N:P:K), F_0 = no NPK supplied, F_1 = 8:10:12 kg ha^{-1}, F_2 = 16:20:24 kg ha^{-1}, and F_3 = 24:30:36 kg ha^{-1}. It was set up in a randomized full block design with three replications. With the exception of stover yield and harvest index, increasing the quantities of primary nutrients have a substantial impact on the growth, yield, and yield qualities of mung. The highest plant height, number of pod $plant^{-1}$, weight of seed $plant^{-1}$ and seed yield were obtained from 16:20:24 kg N:P:K ha^{-1} whereas 24:30:36 kg N:P:K ha^{-1} produced the highest number of leaf $plant^{-1}$, number of branch $plant^{-1}$, seed pod^{-1} , weight of seed pod^{-1} and 1000-seed weight. The pod $plant^{-1}$, seed weight pod^{-1} and seed yield grew with increased nutrient rate until N:P:K @ 16:20:24 kg ha^{-1} and subsequently decreased. According to the study's findings, it is best to apply primary nutrients (N,P and K) at a ratio of 16:20:24 kg ha^{-1}.

Reddy and Hore (2020) carried out an experiment in which foliar sprays at 30 and 60 days after sowing were applied with three concentrations of five growth substances: GA3 (50, 100, and 150 ppm), NAA (25, 50, and 75 ppm), ethrel (100, 150, and 200 ppm), maleic hydrazide (500, 1000, and 1500 ppm), thiourea (250, 500, and 750 ppm), and control (water spray). Three replications and a randomized block design were used to set up the experiment. With NAA 75 ppm, the shortest time for 50% pod formation (61.28 days), the highest yield $plot^{-1}$ (652.39g) and the yield ha^{-1} (16.31q) were all noted. GA3 100 ppm-treated plants recorded the highest number of seed $pods^{-1}$ (15.18) and test weight (14.75 g). With GA3 150 ppm, the maximum plant height (73.35 cm) and primary branches (6.84 cm) at 75 DAS were measured. Thiourea 500 ppm recorded longest pod (12.56 cm). The predicted yield for the control plants was 12.38 q ha^{-1}. Under alluvial plains for the production of fenugreek, the most successful treatment from the standpoint of yield maximization was NAA 75 ppm (16.31 q ha^{-1}), followed by thiourea 250 ppm (15.69 q ha^{-1}) and ethrel 200 ppm (15.46 q ha^{-1}).

Chichongue *et al.* (2020) conducted a study to assess the effects of cow manure and inorganic fertilizer on height, Stover yield, grain yield, yield quality for both maize and legumes of a maize/legume intercrop. A factorial design experiment with a split plot arrangement and replicated three times per site was used. The treatments comprised two intercropping systems of maize/bean and maize/soybean and five fertilizer application rates: Control, cow manure (5 tons ha^{-1}), cow manure 1.25 tons ha^{-1} + 100 kg NPK ha^{-1}, cow manure 2.5 tons ha^{-1} + 50 kg NPK ha^{-1} and 200 kg NPK ha^{-1}. The results showed that adding cow dung to NPK fertilizers caused significant variations in Stover weight, plant height, hundred grain weight, and grain yields ($P \leq 0.05$When compared to Lichinga, maize planted in Sussundenga produced higher values for stocker weight, plant height, hundred seed weight, and total grain yield. In fact, intercropping with common bean boosted maize growth metrics more than soybean did in both locations. This is because the maize/common bean intercrop made greater use of the available resources. Combination of 1.25 tons ha^{-1} of cow manure and NPK 100 kg ha^{-1} fertilizers significantly ($P \leq 0.05$) increased the yield of maize over application of cow manure or NPK alone and farmers are recommended to adopt this production system in the two sites.

Ugile *et al.* (2020) conducted a field study to evaluate the effect of macro nutrients and priming of micronutrient on growth parameter, yield and grain quality of linseed. The results showed that methods of micronutrient application through seed priming along with RDF treatment T_{10} proved its superiority over rest of treatments on growth and yield parameter characters. The results revealed that treatment T_{10} receiving Zn+ B + Mo + Fe+ S each @3g kg^{-1} seed application along with RDF recorded maximum germination percentage, plant height, leaf area, root density, number of pods, and final plant stand percentages as well as noticed highest grain yield, dry matter yield and total biological yield of linseed. Results also showed that applying therapy T_{10} considerably enhanced test weight, protein, and oil percentage. The control plot treatment produced the lowest values for all metrics.

Kumar *et al.* (2020) conducted three-year field experiment comprising of eight treatment combinations and replicated thrice. Seeds of French bean cv. Green Wonder were sown at a spacing of 45 × 15 cm in each plot of size 3.0 m × 1.8 m. Recommended dose of fertilizers (NPK 50:100:50 kg ha^{-1}) was followed as per different treatment details. Application of 75% NPK through inorganic and 25% N through vermicompost resulted in minimum days to first pod harvest (61.89 days), maximum pod width (7.67 mm), number of pods plant^{-1} (30.96), plant height (51.29 cm), average pod weight (5.70

g), marketable pod yield (130.53 q ha^{-1}) and highest benefit cost ratio (2.18) along with maximum net returns (Rs. 313061.43 ha^{-1}).

Aziz *et al.* (2021) conducted a field study to assess the impact of foliar applications of Nano- NPK fertilizer for one and two applications at different levels (0, 30, 60, 90, and 120 mg L^{-1}) on growth and yield of (*Vicia faba* L.). The study was implemented as foliar Nano-NPK application at various levels (0, 30, 60, 90 and 120 mg L^{-1}). Results indicated a significant impact on the majority of treatments examined. The findings showed that the number of foliar applications significantly impacted the majority of vegetative, yield, and yield component metrics. The best results were from twice foliar application of Nano-NPK, which also produced the best values for the number of branches per plant-1, the percentage of chlorophyll in the leaves, and the dry matter of the leaves (334.416, 5.381, 46.949 %, and 22.789 %, respectively).However, the highest results of plant height, number of branches $plant^{-1}$, number of leaves $plant^{-1}$, leaves chlorophyll content %, dry matter in leaves and TSS in seed (131.448 cm, 365.995, 6.120, 51.592%, 25.435% and 16.107% respectively) were recorded from (120 mg L^{-1}) of Nano- NPK. Additionally, two foliar applications of (120 mg L^{-1}) Nano-NPK had the greatest effects on yield, yield component, and vegetative development.

Bahar *et al.* (2021) reported that applying charcoal to agricultural soils improves crop yields and soil fertility all over the world, yet scholarly studies on the subject may be quite esoteric. In this study, nanotechnology was employed as a second factor in addition to various charcoal sources as the first factor to enhance the growth and yield parameters of *Vicia faba* L. The findings showed that each type of fertilizer—charcoal and Nano-NPK—had a distinct impact on the parameters under study. The plant height in the control treatment was 63.00 cm, but in the soil treated with local, China, and straw charcoals, the plant height grew considerably to 72.56, 72.64, and 75.48 cm, respectively. In addition, the number of pods $plant^{-1}$, pod length, and fresh yield $plant^{-1}$ were (30.92, 17.59 cm, and 141.84 g) for the control treatment; these values significantly increased to (37.81, 18.71 cm, and 246.34 g) for treatments involving the addition of straw charcoal or ash to the soil, respectively, at concentrations of 100 mg L^{-1} and 200 mg $^{-1}$ of Nano-NPK fertilizers. altered growth and yield factors significantly. In the control treatment (C_0N_0), the fresh yield, the number of pods, and the pod length were each (23.75, 16.35 cm, and 83.13 g), however in the interaction treatment between charcoal C_3 (Straw Charcoals) and Nano NPK N_2 (200 mg L^{-1}) produced a significant rise in their values to reach (47.75, 19.07 cm, 261.67 g).

Prabhat *et al.* (2022) investigated the impact of various organic manures and biofertilizers on plant development, yield-attributing traits, and fenugreek yield. The results showed that adding 3.5 t ha^{-1} of nitrogen improved several growth parameters, including plant height maximum (15.23, 35.50, and 60.50 cm) at 30 DAS, 60 DAS, and harvest, respectively, and number of primary branches $plant^{-1}$ (5.80 and 13.25) at 60 DAS and at harvest in (T_5) and DAS to 50% flowering (81.65 days) early flowering (T_4) where the application was 5.5 t ha^{-1} FYM + Rhizobium seed treatment + PSB. When 3.5 t ha^{-1} of vermicompost + rhizobium + PSB were applied, the seed and straw yield kg ha^{-1} (1566.79, 2332.53 kg) significantly increased as well as the yield-attributing characteristics included the number of pod $plant^{-1}$ (32.00), pod length (12.57 cm), number of seed pod^{-1} (12.00), and test weight of seed (12.70 g).

Verma *et al.* (2022) conducted an experiment to study the effect of Nitrogen, Phosphorus and potassium on morphological characters of *Nigella*. Among the yield and yield attributes application of different levels of NPK showed the significant variations expect harvest index (%), oil content in seed (%). However, T_8 - 70:70:55 kg ha^{-1} NPK was registered with highest value of number of capsules $plant^{-1}$ (77.13), number of seeds $capsules^{-1}$ (106.87), seed yield g $plant^{-1}$ (19.69), seed yield q ha^{-1} (10.24), biological yield q ha^{-1} (43.09), test weight (3.17 g), harvest index (27.91%) and oil content in seed (0.46%) compared to T_1 - 40:20:20 kg ha^{-1} NPK (recommended dose).

Sarkar *et al.* (2022) conducted a study on the impact of macronutrient combinations and plant spacing on the growth and yield of black cumin (*Nigella sativa* L.). In case of nutrient combination, the tallest plant (54.86 cm) was observed from T_3 ($N_{135}P_{75}K_{60}$ kg ha^{-1}) treatment. The highest primary branch $plant^{-1}$ (12.18), flower $plant^{-1}$ (22.20), capsules $plant^{-1}$ (8.62) and secondary branch $plant^{-1}$ (19.69), seeds capsules (76.18), 1000 seed weight (2.99 g), germination percentage (91.00%) was observed from T_2 (N_{90} P_{50} K_{40}) treatment. The highest seed yield $plant^{-1}$ (3.36 g), seed yield $plot^{-1}$ (170.4 g), seed yield ha^{-1} (1.18 t) and dry matter (11.29 g) were observed from T_2 (N_{90} $P_{50}K_{40}$ kg ha^{-1}) treatment.

Chapter III

Materials & Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2021 to April 2022 (6 months) to find out the effect of biofertilizer and macronutrients for maximum seed yield of BARI Methi-1. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout of the experimental design, intercultural operations, data recording and their analyses under the following headings and sub-headings.

3.1 Experimental period

The experiment was conducted from November 2021 – April 2022 (6 month).

3.2 Location of the experimental plot

The experiment was conducted at the "Central Research Farm" of Sher-e-Bangla Agricultural University, Dhaka-1207. The experimental field is located at $23^0$41' N latitude and 90^0 22' E longitude at height of 8.6m above the mean sea level. It belongs to the AEZ 28, Modhupur Tract (FAO, 1998).

3.3 Characteristics of soil

The experiment was conducted in the typical crop growing soil of the Madhupur Tract. Top soil was silty clay in texture, red brown terrace soil type, olive-gray with common fine to medium dark yellowish-brown mottles. The pH of the soil was 5.6 and the organic carbon was 0.45%. With good irrigation facilities, the experimental land was well drained. The experimental site was a medium-high land. It was above the level of the flood. During the experimental period, sufficient sunshine was available. Soil series: Tejgaon, General soil: Non-calcareous Dark Grey. The morphological characteristics of the soil of the experimental plots are as follows.

3.4 Climatic condition

The experimental site was under the sub-tropical monsoon climate, which is characterized by heavy rainfall during Kharif season and scanty in the Rabi season (October to March). There was no rainfall during the month of October, November, December and January. The average maximum temperature during the period of experiment was 26.82˚C and the average minimum temperature was 17.14˚C. Details of the meteorological data in respect of temperature, rainfall and relative humidity during the period of the experiment were collected from Weather Station of Agargaon, Dhaka.

3.5 Agro-ecological region

The experimental site belongs to the “Madhupur Tract” agro-ecological zone, AEZ- 28 (FAO, 1998). This was an area of complex relief and soils created above the Madhupur clay, where the analyzed edges of the Madhupur Tract were covered by floodplain sediments, leaving small hills of red soils as „islands‟ encompassed by floodplain. The experimental site is shown for better understanding in the AEZ Map of Bangladesh in Appendix I.

3.6 Experimental material

High yielding variety of fenugreek (cv. BARI Methi-1) developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur 20 was used as experimental material. The seed was collected from Regional Spices Research Centre, BARI, Joydebpur, Gazipur.

3.7 Experimental treatments

The experiment consists of single factor and 13 treatments will be tested in this experiment:

1. T_0 = Biofertilizer 3 kg ha^{-1}
2. T_1 = Biofertilizer 3 kg + 100 kg N ha^{-1}
3. T_2 = Biofertilizer 3 kg + 40 kg P ha^{-1}
4. T_3 = Biofertilizer 3 kg + 60 kg K ha^{-1}
5. T_4 = Biofertilizer 3 kg + 75 kg N ha^{-1}
6. T_5 = Biofertilizer 3 kg + 30 kg P ha^{-1}
7. T_6 = Biofertilizer 3 kg + 45 kg K ha^{-1}
8. T_7 = Biofertilizer 3 kg + 50 kg N ha^{-1}
9. T_8 = Biofertilizer 3 kg + 20 kg P ha^{-1}
10. T_9 = Biofertilizer 3 kg + 30 kg K ha^{-1}
11. T_{10} = Biofertilizer 3 kg + 100 kg N + 40 kg P + 60 kg K ha^{-1}
12. T_{11} = Biofertilizer 3 kg + 75 kg N + 30 kg P + 45 kg K ha^{-1}
13. T_{12}= Biofertilizer 3 kg + 50 kg N + 20 kg P + 30 kg K ha^{-1}

3.8 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with 13 treatments having three replications. First of all, the entire experimental plot was divided into three blocks, each of which was then divided into 39 units plots. The treatment s w assigned randomly to the unit plots of one block. The size of unit plot was 2.0 m × 1.2 m and number of replications 3. Two adjacent unit plots and blocks was separated by 20.0 cm and 15.0 cm, respectively. The treatments were assigned randomly to each block as per design of the experiment.

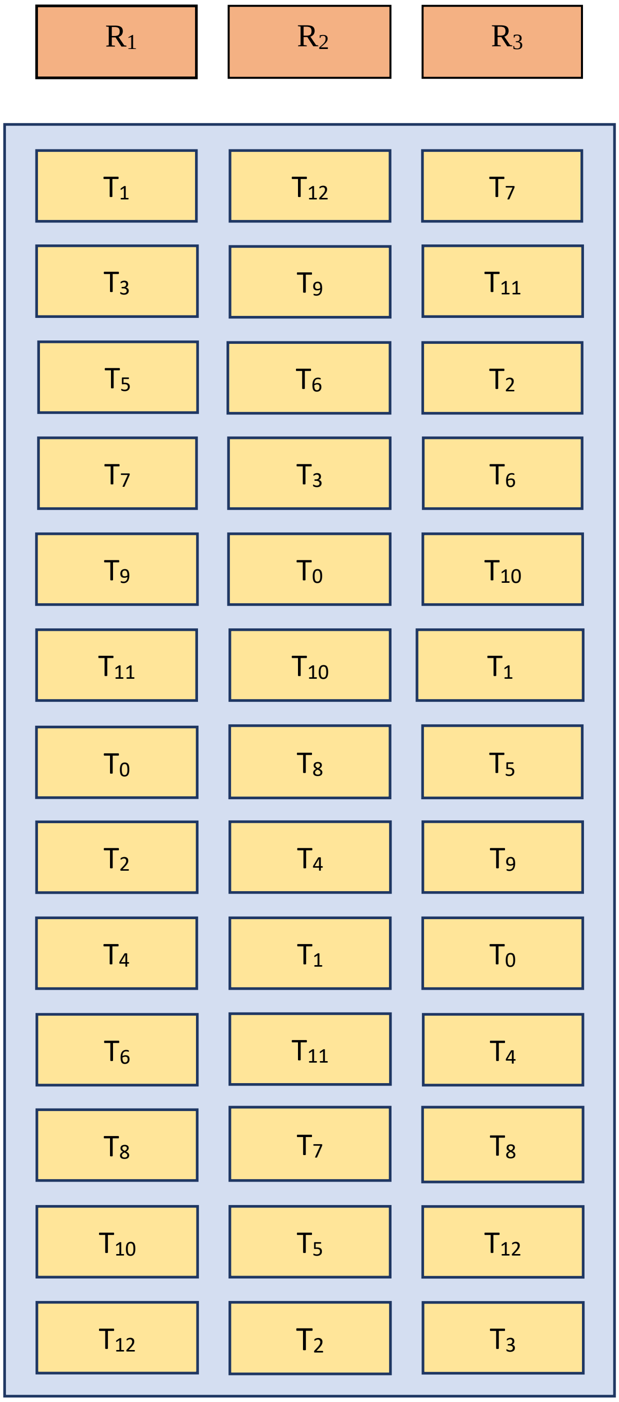
3.9 Application of fertilizers

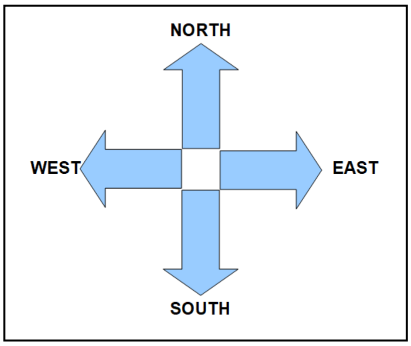
Manures and fertilizers that were applied to the experimental plot presented in table 3.1

Table 3.1: Doses and methods of application of fertilizer in fenugreek field

Nutrient/Fertilizer	**Rate (ha^{-1})**	**Fertilizer applied**
Vermicompost	4.3 t	Vermicompost
Nitrogen	As per treatment	Urea
Phosphorus	As per treatment	TSP
Potassium	As per treatment	MoP
Biofertilizer	3 kg	Biofertilizer

The entire amount of phosphorous, potassium and one-third of nitrogen fertilizer was applied during the final land preparation. The rest of the nitrogen fertilizer was top dressed in two equal splits during the vegetative growth stage and reproductive growth stage of plant.





Layout:
Plot size: 2.0m x 1.2m

Plot spacing: 40 cm x 10 cm

Between block: 0.15m

Treatments
1. T_0 = Biofertilizer 3 kgha^{-1}
2. T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}
3. T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1}
4. T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}
5. T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}
6. T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}
7. T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}
8. T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}
9. T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}
10. T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}
11. T_{10} = Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}
12. T_{11} = Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}
13. T_{12}= Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

Figure 3.1: Layout of the Experiment plots

3.10 Sowing

Fenugreek seeds were soaked in water for 6 hours to enhance germination. Seeds were also treated with Bavistin at the rate of 2 g kg^{-1} of seeds before sowing. The seeds were sown in rows 30 cm apart continuously by hand @ 15 kg ha^{-1}. To allow uniform sowing in rows seeds were mixed with some loose soil (about four to ten times of weight of seeds). The seeds were covered with good pulverized soil just after sowing and gently pressed by hands. The sowing was with slight watering just to supply sufficient moisture needed for quick germination. Seedlings of the plots were thinned later to maintain 10 cm intra spacing (plant to plant distance) 25 days after sowing (DAS).

3.11 Intercultural operations

The desired population density was maintained by thinning plants 25 DAS. Irrigation, mulching, weeding and plant protection measures etc. were performed for better crop establishment and proper plant growth.

3.11.1 Thinning

After 25 days of sowing thinning was done to maintain 10 cm intra-spacing (plant to plant distance).

3.11.2 Weeding

Several times hand weeding was done to keep field free from weeds. First weeding was done after 25 days of sowing followed by thinning. Second and third weeding was done after 35 and 50 DAS respectively.

3.11.3 Irrigation

For germination water was given to the plots by water cane with fine nozzle every two days till germination. After that, three irrigations were given at 30, 60 and 90 DAS.

3.12 Harvesting

Seeds were harvested on April, 2022 when pod color changed into yellowish brown in color. To avoid shattering of fruits, harvesting of seed plant was cut to the base by sickles in the early morning. Then the stalks with seeds were dried in the sun. Seeds (grains) were separated by beating with sticks and cleaned by winnowing and dried properly (10% moisture of seed).

3.13 Data collection

Ten (10) plants from each plot were selected randomly and were tagged for the data collection. Some data were collected from sowing to harvesting with 15 days interval and some data were collected at harvesting stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and straw yield plot^{-1} were recorded after cleaning and drying those properly in the sun.

3.13.1 Plant height

Plant height was measured four times at 15 days interval such as 30, 45, 60 and 75 days after sowing (DAS). The plant height was measured in centimeter by scale considering the distance from the soil surface to the tip of the randomly ten selected 20 plants and mean value was calculated for each treatment and expressed in centimeter (cm).

3.13.2 Number of primary branches plant^{-1}

Number of primary branches were counted from randomly ten selected plants at 15 days interval such as 30, 45, 60 and 75 days after sowing (DAS) from each plot. After that mean values were calculated and recorded.

3.13.3 Number of secondary branches plant^{-1}

Number of secondary branches were counted from randomly ten selected plants at 15 days interval at 60 and 75 days after sowing (DAS) from each plot. After that mean values were calculated and recorded.

3.13.4 Days required for first flowering

In each plot 5 plants were tagged and dates of first flowering was recorded by counting the days from planting to first visibility of flower bud from each tagged 5 plants.

3.13.5 Days required for 50% flowering

When five plants flowered, five dates of flowering were taken, added and the added values were divided by five. This parameter was treated as days to 50% flowering.

3.13.6 Pod length

For measuring pod length, pods of ten randomly selected plants of each replication were counted and the length of the individual pod was measured from the base to the tip of the pod and finally the measured lengths were recorded as per treatments and expressed in centimeter (cm).

3.13.7 Pod breadth

Pods of ten randomly selected plants of each replication were counted and the breadth of the individual pod was measured and recorded as per treatments and expressed in centimeter (cm).

3.13.8 Seeds pod^{-1}

Ten pods of each of randomly selected 10 plants were considered and then seeds pod^{-1} were counted from all the pods and the average data were taken as number of seeds pod^{-1}.

3.13.9 Seed weight pod^{-1}

Seed weight pod^{-1} (mg) was measured by Electric Balance in gram (mg). Seeds from ten selected plants from each unit plot were collected and divided by ten to calculate weight of seeds per plant.

3.13.10 Seed weight plant^{-1}

Seed weight plant^{-1} (g) was measured by Electric Balance in gram (mg). Seeds from ten selected plants from each unit plot were collected and divided by ten to calculate weight of seeds plant^{-1}.

3.13.11 Weight of 1000 seed

From each treatment 1000 seeds counted and then weighted them by electric balance.

3.13.12 Seed yield plot^{-1}

All seeds were collected from each replication of each treatment . Seed weight plot^{-1} was measured by an electric balance and then average was expressed as seed yield plot^{-1} in gram.

3.13.13 Seed yield

Seed yield plot^{-1} (g) was converted to ha^{-1} yield and it was expressed in kg.

3.13.14 Harvest Index

Harvest index was calculated using the following formula:

Harvest Index (%) = $\frac{\boldsymbol{Seed\ yield\ (t/ha)}}{\boldsymbol{Biological\ yield\ (t/ha)}} \times \mathbf{100}$

Where, Biological yield = Crop Dry Weight

3.13.15 Germination (%)

The number of sprouted and germinated seeds (Seedling emergence) was counted daily commencing. Germination was recorded at 24 hours interval and continued up to 10th. More than 2 mm long plumule and radicle was considered as germinated seed. The rate of germination (seedling emergence) was calculated using the following formula:

$$\text{Germination (\%)} = \frac{\boldsymbol{Number\ of\ seeds\ germinated}}{\boldsymbol{Number\ of\ seeds\ set\ for\ germination}} \times \mathbf{100}$$

3.13.16 Vigor index

The daily record of seed germination was kept starting from 24 hours up to 72 hours after placement of seeds for germination. Vigor index was calculated by the following formula (Agarwal, 1991).

$$\text{Vigor index} = \frac{\boldsymbol{No.\ of\ seeds\ germinated\ at\ first\ count}}{\boldsymbol{Days\ required\ for\ first\ count}} + \frac{\boldsymbol{No.\ of\ seeds\ germinated\ at\ last\ count}}{\boldsymbol{Days\ required\ to\ last\ count}}$$

3.14 Economic Analysis

The cost of production was analyzed in order to find out the most economics of biofertilizer and different macronutrients. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @14% in simple rate. The wholesale market price of fenugreek was considered for estimating the cost and return. The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost Ratio (BCR)} = \frac{\boldsymbol{Gross\ return\ per\ hectare(TK)}}{\boldsymbol{Total\ cost\ of\ production\ per\ hectare(Tk)}}$$

Net income = Gross income – Total cost of production

3.15 Statistical Analysis

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package program MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by Gomez and Gomez (1984).

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to investigate the effects of biofertilizers and macronutrients on yield and yield components of fenugreek seeds. The results obtained from the study have been presented, discussed and compared in this chapter through tables, figures and appendices. The analysis of the variances of the data for all parameters are presented in Appendix II-V. The results have been presented and discussed using tables and charts and possible interpretations in the following subtitles.

4.1 Plant height

Plant height was significantly influenced by different levels of nutrients application at different days after sowing (DAS) of fenugreek seed. Increasing level of all three macronutrients with same level of biofertilizers provided an improved result by increasing plant height to a significant level. It was observed that at 30, 45, 60 and 75 DAS the maximum plant height was 15.84 cm, 22.59 cm, 36.48 cm and 54.24 cm respectively from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment. On the other hands the lowest plant height 11.55 cm, 15.65 cm, 26.57 cm and 37.23 cm was observed at 30, 45, 60 and 75 DAS respectively from control T_0 treatment (Figure 4.1).

The findings of this investigation are in close conformity with those of (Halesh *et al.*, 2000 and Mavai *et al.*, 2000) who also recorded higher plant heights in fenugreek from judicious application of nutrient. Improved growth parameters with the application of biofertilizer might be due to biofertilizers which helps in nitrogen fixation and eventually plant obtains more nitrogen which is primary nutrient for growth and development as well as improve the availability of phosphorus which improve root proliferation and helped to increase nutrient absorption which was ultimately led to increase the growth of the plant. This result corroborated with the results obtained by Meena *et al.*, (2014); Ali *et al.* (2009). A positive response to nitrogen application was also reported by Tuncturk *et al*. (2011) and Mehta *et al*. (2012). Increasing height with the increasing levels of all three macronutrients (N,P,K) were observed. As per Datta and Hore (2017) among different treatment maximum plant height was observed with $N_{60}P_{100}K_{40}$ (108.17 cm) at 105 DAS.

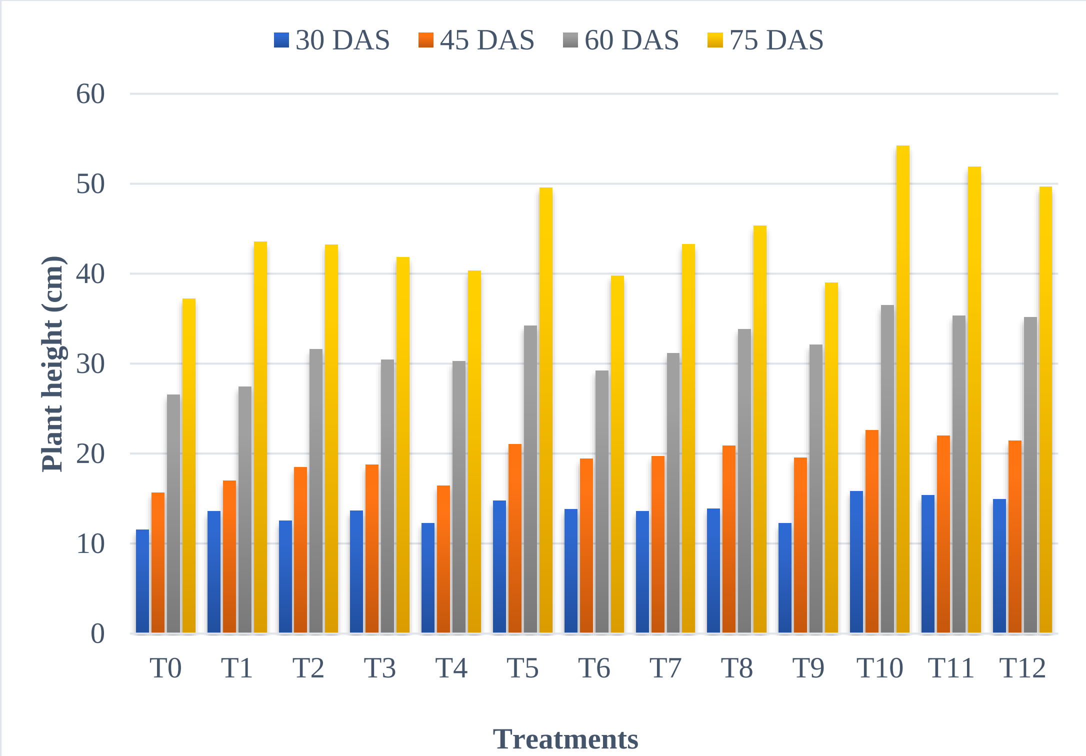


Figure 4.1: Effects of different levels of nutrient application on plant height of fenugreek at different data recording intervals. (Lsd = 0.578, 0.179, 0.076, 0.4173 at 30, 45, 60, 75 DAS) Note. T_0 = Biofertilizer 3 kgha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}, T_{12}= Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.2 Number of primary branches plant^{-1}

Application of different levels of nutrients had significant effect on the number of primary branches of fenugreek at 30, 45, 60 and 75 DAS different days after sowing (DAS) (Figure 4.2). At 30 DAS, the maximum number of primary branches (2.73) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment and the minimum (0.80) was observed from T_0 (control) treatment. At 45, 60 and 75 DAS, the maximum no. of primary branches plant^{-1} (6.48, 7.43 and 7.68) was also recorded from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment. At 45, 60 and 75 DAS, the minimum no. of primary branches plant^{-1} (3.21, 3.47, 4.13) was recorded from T_0 (Control) treatment (Figure 4.2). Increasing trend was noticed with increasing level of nitrogen application. The maximum response of phosphorus was noticed with its medium level of application but higher dose of potassium gave maximum number of primary branches. These results indicated that the different levels of biofertilizer with NPK fertilizers together supplied plant nutrients and provided better growing conditions which helped for getting proper vegetative growth as well as maximum no. of primary branches. Similar results have also been reported by Tuncturk *et al.* (2011).

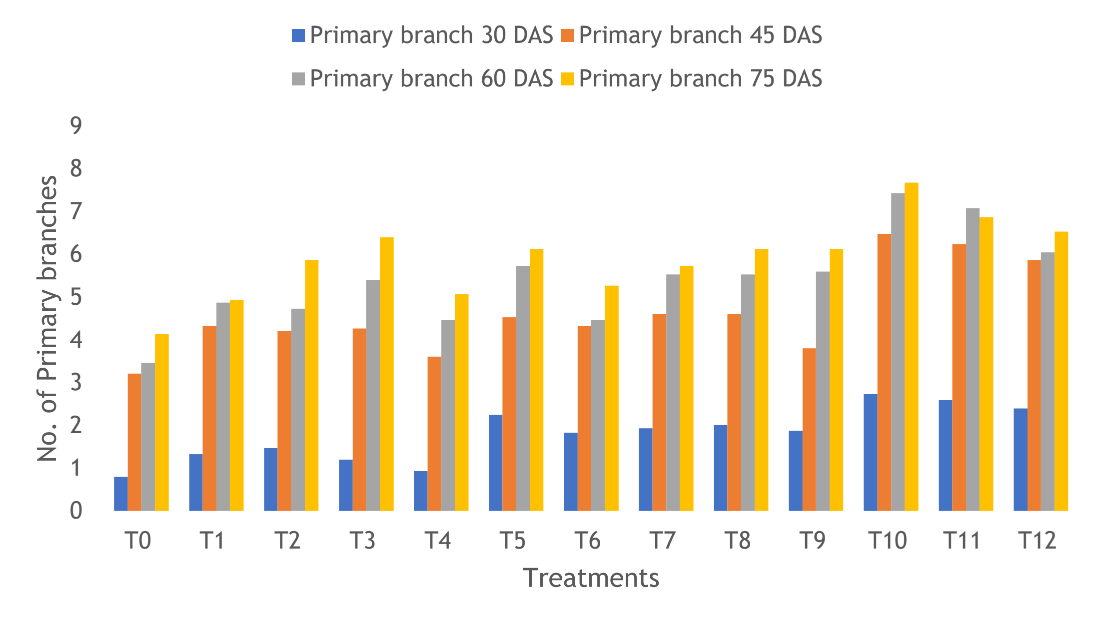


Figure 4.2: Effects of different levels of nutrient application on primary branches of fenugreek at different data recording interval. (LSD = 0.103, 0.084, 0.147, 0.254 at 30, 45, 60, 75 DAS). Note. T_0 = Biofertilizer 3 kgha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg + 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg + 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg + 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg + 50 kg N ha^{-1},T_8 =Biofertilizer 3 kg + 20 kg P ha^{-1},T_9=Biofertilizer 3 kg + 30 kg K ha^{-1},T_{10}= Biofertilizer 3 kg + 100 kg N + 40 kg P + 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg + 75 kg N + 30 kg P + 45 kg K ha^{-1}, T_{12}= Biofertilizer 3 kg + 50 kg N + 20 kg P + 30 kg K ha^{-1}

4.3 Number of secondary branches plant^{-1}

The application of different nutrients showed a significant effect on the number of secondary branches of fenugreek at different days after sowing (DAS). It was found that maximum number of secondary branches (4.20 and 5.21) was recorded from T-$_{10}$(Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment at 60 and 75 DAS which was followed by T_{11} and T_{12} treatments at same days after sowing (DAS) . On the other hands the minimum number of secondary branches at 60 and 75 days after sowing (DAS) were (0.53 and 1.13) respectively observed in case of T_0 (control) treatment (Table 4.1). Based on the results of this study, optimal levels of biofertilizers and macronutrients (NPK)s could result in better growing conditions for the plant possibly due to adequate nutrient supply to plants and facilitate the physiological metabolism of plant growth factors, which ultimately leads to the creation of more secondary branches per crop.

Table 4.1. Effects of different levels of nutrient application on number secondary branches of fenugreek plant at days after sowing (DAS)

Treatments	Secondary branch	
	60 DAS	**75 DAS**
T_0	0.53 i	1.13 h
T_1	2.27 e	2.53 g
T_2	1.27 g	3.20 f
T_3	1.80 f	2.65 g
T_4	2.13 e	3.61 e
T_5	2.93 c	4.53 c
T_6	1.00 h	3.80 e
T_7	2.13 e	3.21 f
T_8	2.73 d	4.20 d
T_9	2.67 d	3.20 f
T_{10}	4.20 a	5.21 a
T_{11}	3.93 b	4.80 b
T_{12}	3.80 b	4.67 bc
Lsd (0.05)	0.0918	0.1007
CV %	4.65	3.43

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability**.** Note.T_0 = Biofertilizer 3 kgha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}, T_{12}= Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.4 Days required for first flowering

Statistically significant influence was observed on days required to first flowering of fenugreek plant due to the different nutrient application under this present trial. From the results of the experiment, it was observed that the maximum days required for first flowering (36.89 days) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment which was statistically similar with T_{11} (Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}) treatment (36.21 days) and it was followed by T_{12} and T_5 treatment respectively. On the other hands from the minimum number of days required for first flowering (31.33 days) was revealed T_0 (control) treatment (Figure 4.3). Result from the experiment was in coincided with the findings of Ali *et al.* (2009). Similar result was observed by Jagdale and Dalve (2010) who reported that the maturity parameters like number of days required for first flower initiation, days required for

50% flowering, first pod formation, 50% pod formation and maturity of seed crop were found to be delayed with an increased level of nitrogen and phosphorus.

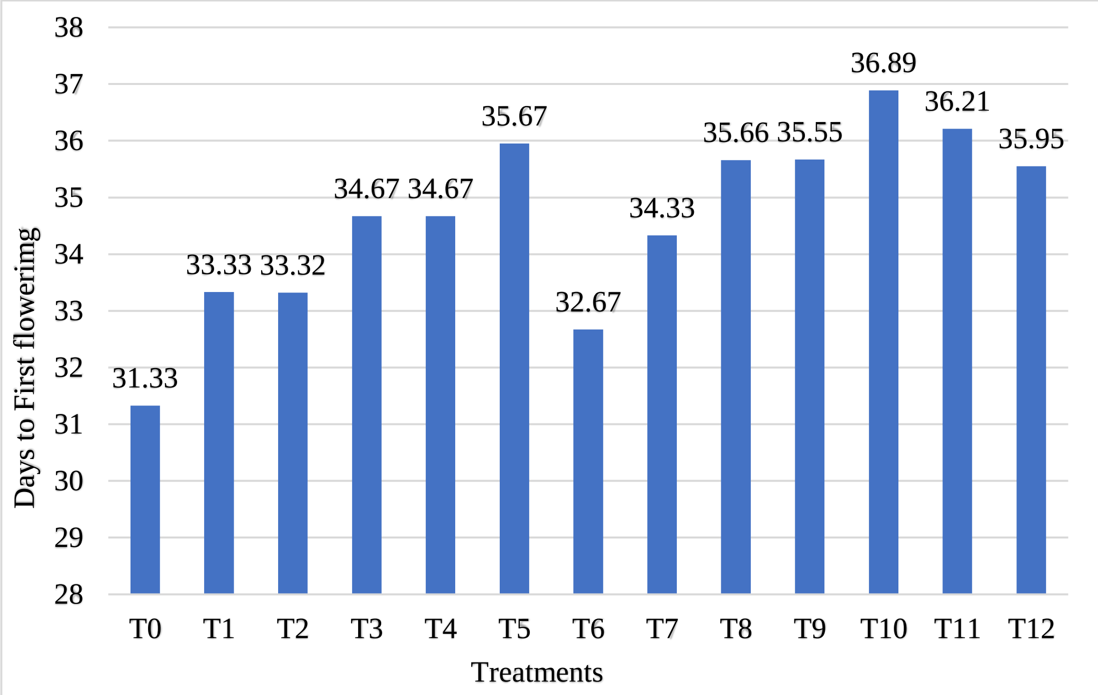


Figure 4.3: Effects of different levels of nutrient application on days required to first flowering of fenugreek at different data recording intervals. (LSD = 0.425).Note. T_0 = Biofertilizer 3 kg ha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1},T_3=Biofertilizer 3 kg + 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg + 75 kg N ha^{-1},T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg + 100 kg N+ 40 kg P+ 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg+ 75 kg N+ 30 kg P + 45 kg K ha^{-1}, T_{12} = Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.5 Days required for 50% flowering

There was marked variation was noticed on days to 50% flowerings of fenugreek due to different application of nutrients. It was revealed that the maximum days to 50% flowerings (57.02) were observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment which was statistically similar with T_{11} (57.04). On the other hands the minimum days to 50% flowerings (49.13 days) were observed from T_0 (control) treatment (Figure 4.4). The results of the experiment coincide with the findings of Meena *et al.* (2014). A similar result was observed by Jagdale and Dalve (2010), who reported that maturation parameters such as the number of days required to initiate the first flowering, the number of days required to flower 50%, first fruit formation, 50% fruit formation and seed maturity were found to be delayed with increased nitrogen and phosphorus levels.

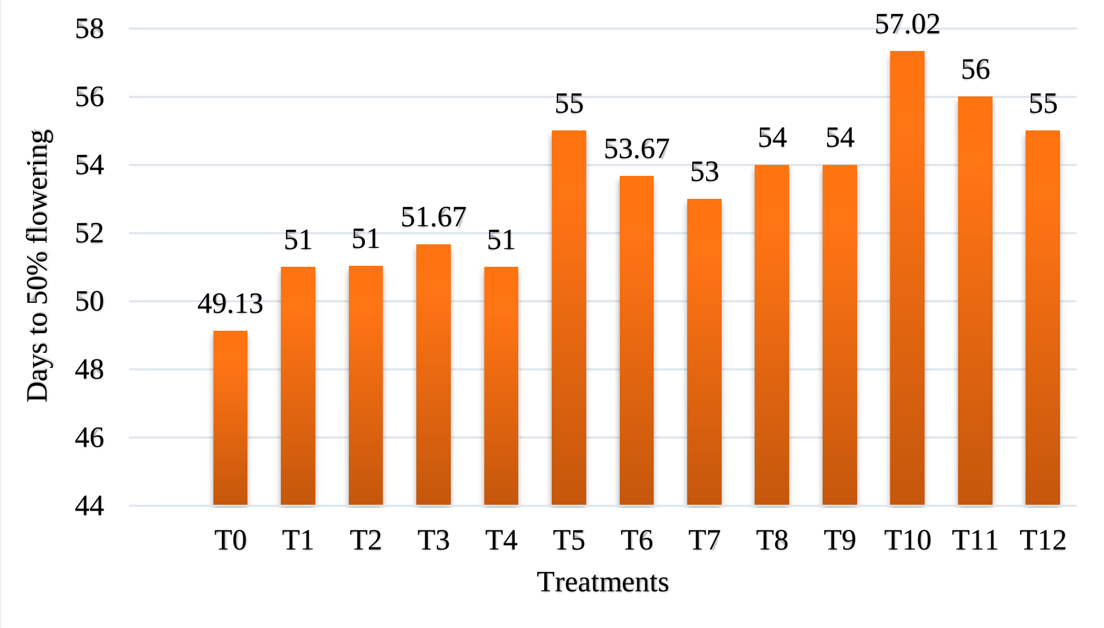


Figure 4.4: Effects of different levels of nutrient application on days required to 50% flowering of fenugreek at different data recording interval. (LSD = 0.879). Note.T_0 = Biofertilizer 3 kgha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg + 100 kg N + 40 kg P + 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg + 75 kg N + 30 kg P + 45 kg K ha^{-1}, T_{12} = Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.6 Pod length

The pod length differed significantly due to the application of different nutrient. The length of pods ranged from 9.21 cm to 12.16 cm. The highest pod length (12.16 cm) was recorded in T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K) treatment. The lowest pod length (9.21 cm) was found in T_0 (control) treatment (Table 4.2). Nitrogen application at this level may stimulating cell division, elongation and ultimately promoted the vegetative growth and pod formation. Phosphorus helped in developing flowers and fruits and K maintains balance between N and P. Higher and lower dose of phosphorus than 80 kg ha^{-1} did not favor to obtain the potential number of pods plant^{-1} which may be due to promotion in extensive root development and nodulation (Detroja *et al.*, 1996).

4.7 Pod breadth

Statistically non-significant variation on pod breadth of fenugreek plant was noticed due to different nutrient application during the present study. Pod breadth was increased significantly up to a certain level of N , P and K application individually , but in case of combine effect it didn't show any significant variation over the entire duration of experiment. It was observed that results were almost similar in some of the treatments of the experiment including the maximum pod breadth (0.47 cm) which was recorded from T_{10}, T_{11} and T_{12} treatment whereas the minimum breadth of single pod (0.36 cm) was revealed from T_0 (control) treatment.

Table 4.2. Effects of different nutrient on pod length (cm) and pod breadth (cm) of fenugreek at days after sowing (DAS)

Treatment	Pod length (cm)	Pod breadth (cm)
T_0	9.21 g	0.36
T_1	10.02 f	0.40
T_2	10.34 e	0.41
T_3	10.85 d	0.42
T_4	10.75 d	0.40
T_5	11.27 bc	0.43
T_6	10.03 f	0.43
T_7	10.23 ef	0.40
T_8	10.93 d	0.44
T_9	10.98 cd	0.40
T_{10}	12.16 a	0.47
T_{11}	11.37 b	0.47
T_{12}	11.32 b	0.47
Lsd (0.05)	0.1383	0.0891^{NS}
CV %	3.24	8.75

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Note. T_0 = Biofertilizer 3 kgha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}, T_{12}= Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.8 Seeds pod^{-1}

Number of seeds pod^{-1} of fenugreek showed significant influence due to different nutrient application. Increased seeds pod^{-1} was observed due to increased number of pods plant^{-1} was produced at higher level of nitrogen and moderate level of phosphorus and potassium application under this present field trial. The maximum number of seeds pod^{-1} (15.22) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg) treatment and followed by T_{11} (14.55) treatment. On the other hand, the minimum number of seeds pod^{-1} (10.48) was observed from T_0 (control) treatment (Table 4.3).

These results correspond with the finding of those of Godara *et al.* (2012). which might be due to the application of balanced nutrition through different organic sources as well as biofertilizer resulted in increased vegetative growth and synthesis of relatively more amount of food materials and photosynthates were translocated and accumulated in the reproductive parts, led to maximum number of seed pod^{-1}. Meena *et al.* (2014) stated that the maximum dry matter accumulation, number of pods plant^{-1}, number of seeds pod^{-1}, pod length, pod weight, and pod shelling percentage were noted from judicial application of NAA containing biofertilizer.

4.9 Seed weight pod^{-1}

Seed weight pod^{-1} showed significant variation due to different nutrient application. Maximum weight of seed pod^{-1} (147.11 mg) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment while the minimum seed weight pod^{-1} (92.63 mg) was shown in T_0 (control) treatment (Table 4.3). Similar result was observed by Singh *et al.* (1990) who reported that increased level of macronutrients (N, P and K) with suitable amount of biofertilizer application provided optimum condition for fenugreek and significantly improved plant growth, yield and yield attributes such as seed production and seed weight.

4.10 Seed weight plant^{-1}

Statistically significant influence was observed on weight of seeds plant^{-1} due to different levels of nutrient application during the experimentation. It was revealed that the maximum weight of seeds plant^{-1} (12.33 g) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment while the minimum weight of seeds plant^{-1} (6.08 g) was recorded from T0 (control) treatment (Table 4.3). Godara *et al.* (2012) observed the similar trends and revealed that yield parameters in respect to number of pods plant^{-1}, seeds pod^{-1}, seed yield plant^{-1}, seed yield plot^{-1}, seed yield ha^{-1} and test weight were observed significantly maximum during judicious application of nutrients on fenugreek plant.

Table 4.3. Effects of different nutrient on seed pod^{-1}, seed weight pod^{-1}, seed weight plant^{-1} and 1000 seed weight of fenugreek at days after sowing (DAS)

Treatment	Seeds pod^{-1}	Seed weight pod^{-1} (g)	Seed weight plant^{-1} (g)	1000 seed weight (g)
T_0	10.48 h	92.63 i	6.08 h	11.03 h
T_1	11.45 g	110.48 e	6.59 g	11.33 g
T_2	13.44 d	103.38 fgh	7.77 e	11.87 e
T_3	11.45 g	108.50 ef	7.89 de	12.40 d
T_4	12.56 e	99.59 h	7.71 e	12.20 d
T_5	13.56 d	122.36 cd	8.55 c	12.33 d
T_6	13.45 d	107.93 efg	7.56 ef	11.87 e
T_7	12.24 f	107.75 efg	7.22 f	11.53 fg
T_8	13.55 d	118.86 d	8.33 c	12.33 d
T_9	12.24 f	102.21 gh	8.26 cd	11.56 f
T_{10}	15.22 a	147.11 a	12.33 a	13.58 a
T_{11}	14.55 b	130.82 b	10.17 b	13.33 b
T_{12}	13.93 c	125.32 bc	9.87 b	12.77 c
Lsd (0.05)	0.0809	6.2186	0.1950	0.2061
CV %	4.54	6.23	7.84	4.69

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.NoteT_0 = Biofertilizer 3 kgha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}, T_{12}= Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.11 Weight of 1000 seed

Significant influence was observed on weight of 1000-seed due to different levels of nutrient application during the experimentation. It was revealed that the maximum weight of 1000-seed (13.58 g) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment. The minimum weight of 1000-seed (11.03 g) was recorded from T_0 (control) treatment (Table 4.3). Similar result was observed by Ali *et al.* (2009) who revealed that macronutrient application improved the performance of fenugreek plants for number of seeds plant^{-1}, 1000 seed weight, biological yield, seed yield and harvest index of fenugreek. The outcomes of present study corroborate with the outcomes of Meena *et al.*, (2014) who reported that biofertilizers are also accomplished to secret some biologically active compounds such as auxin, gibberellins, vitamins etc. which are deliberated to be imperative for suitable growth and development of plants.

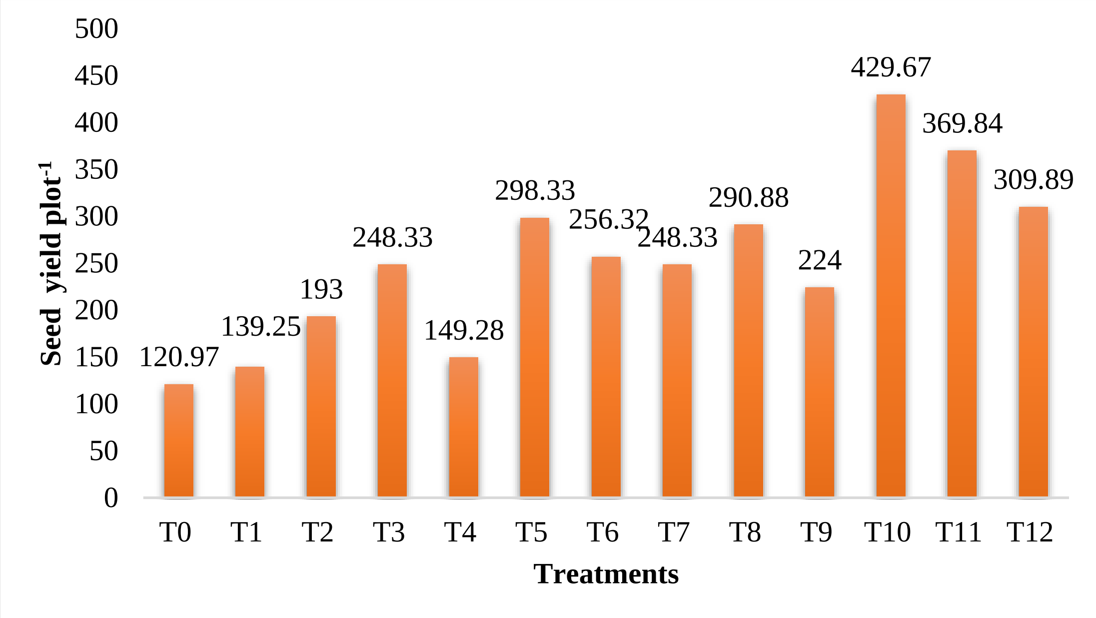


Figure 4.5: Effects of different levels of nutrient application on seed weight plot^{-1} of fenugreek at different data recording intervals. (LSD = 17.45). Note, T_0 = Biofertilizer 3 kgha^{-1}, T_1 = Biofertilizer 3 kg + 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg + 40 kg P ha^{-1},T_3 =Biofertilizer 3 kg + 60 kg K ha^{-1}, T_4 =Biofertilizer 3 kg + 75 kg N ha^{-1}, T_5= Biofertilizer 3 kg + 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg + 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg + 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg + 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg + 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg + 100 kg N + 40 kg P + 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg + 75 kg N + 30 kg P + 45 kg K ha^{-1}, T_{12}= Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.12 Seed yield plot^{-1}

Significant influence was observed on seed weight plot^{-1} due to different levels of nutrient application during the experimentation. It was revealed that the maximum seed yield plot^{-1} (429.67 g) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment and followed by T_{11} (369.84 g) while the minimum seed yield plot^{-1} (120.97 g) was recorded from T_0 (control) treatment (Figure 4.10). The result revealed that application of biofertilizer increased the seed yield than that of no biofertilizer application up to a certain level. The highest seed yield of was obtained due to the positive contribution of growth characters under the study. The application of combined doses of NPK levels especially at higher doses have increased the seedling fresh weight as compared to lower doses due to the fact that nutrients applied at optimum rate induced the formation of protein and enzymes as well in adequate quantity which might have acted on the metabolites in the seed and resulted in the better seed quality and hence more seedling fresh weight. Consequently, several yield attributes of crops resulted in significant improvement due to organic manures and fertilizer in the trend of increase in yield in this study is in close conformity with the findings of Munirathnam *et al.* (2004). Meena *et al.* (2014) found that seed yield plot^{-1}

were maximum with judicious nutrient application. Similar result was observed by Ali *et al.* (2009) who stated that an increase in macronutrient level significantly increased the yield-attributing characters; the seed, straw and biological yields; and the net returns of fenugreek. Detroja *et al.* (1996) have also shown that seed yield in fenugreek was positively correlated with the plant height, number of branches plant^{-1}, number pods plant^{-1}, number of seed pod^{-1} and test weight. These findings lead us to believe that fenugreek makes a moderate demand on nitrogen and phosphate application.

4.13 Seed yield

Significant influence was exerted on seed yield ha^{-1} due to different levels of nutrient application during the experimentation. It was revealed that the maximum seed yield ha^{-1} (1790.30 kg) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment while the minimum seed yield ha^{-1} (504.00) was recorded from T_0 (control) treatment (Figure 4.11). Increase in seed yield was due to increase in plant growth and seed components attribute especially significant increase in the number of branches and pods plants^{-1}.

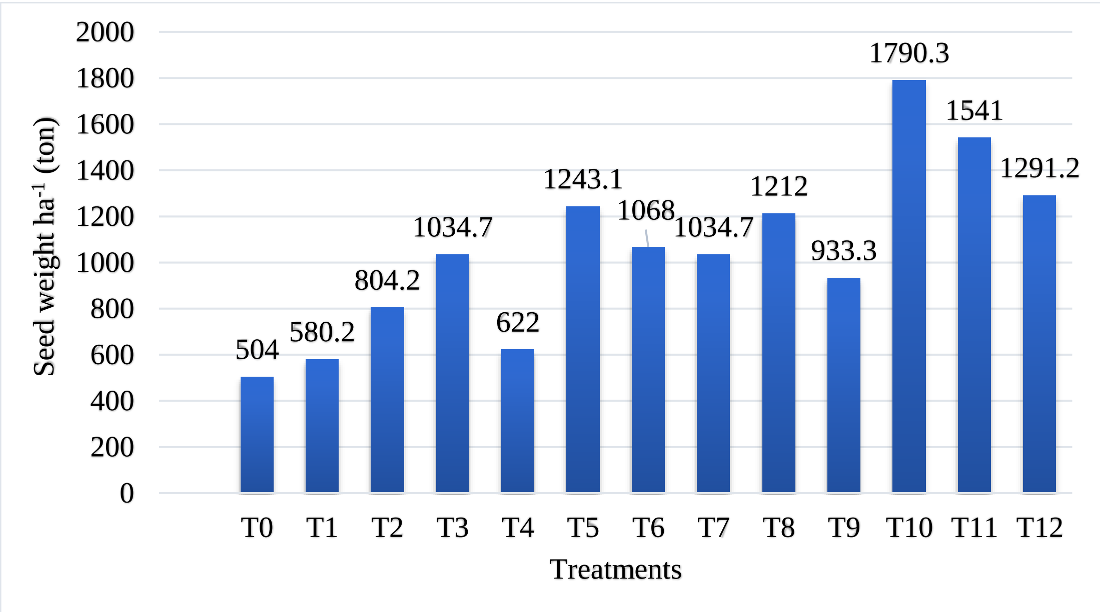


Figure 4.6: Effects of different levels of nutrient application on seed weight kg ha^{-1} of fenugreek at different data recording intervals. (LSD = 72.73).
Note. T_0 = Biofertilizer 3 kg ha^{-1}, T_1 =Biofertilizer 3 kg + 100 kg N ha^{-1}, T_2 =Biofertilizer 3 kg + 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg + 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg + 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg + 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg + 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg + 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg + 100 kg N + 40 kg P + 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg + 75 kg N + 30 kg P + 45 kg K ha^{-1}, T_{12} = Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.14 Harvest index

The harvest index was influenced significantly due to different levels of nutrient application during the experimentation. The highest harvest index (41.68) was found in BARI methi-1 from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment while the lowest (21.54) in T_0 (control) treatment (Figure 4.4). It seems that integrated bio-fertilizers help better sink source relations in to allocate more nutrients to seed and increase the harvest index in fenugreek plants.

4.15 Germination (%)

Non-significant influence was exerted on germination percentage due to different levels of nutrient application during the experimentation. It was revealed that the maximum germination percentage (94.67) of fenugreek seed was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment (Table 4.4). On the other hand, the minimum germination percentage (86.67) of fenugreek seed was recorded from T_0 (control) treatment.

Table 4.4. Effects of different levels of nutrient application on harvest index (%), germination (%), vigor index of fenugreek at different data recording intervals

Treatment	Harvest index (%)	Germination (%)	Vigor index
T_0	21.54 g	86.67	413.33 i
T_1	23.36 fg	88.00	424.83 i
T_2	28.76 e	89.33	453.93 h
T_3	33.437 cd	89.33	496.67 fg
T_4	24.913 f	90.37	515.58 def
T_5	35.04 bc	90.67	537.87 cd
T_6	32.23 cd	89.33	476.33 gh
T_7	31.32 de	92.00	469.33 h
T_8	34.73 bc	89.33	532.47 cde
T_9	28.87 e	89.33	512.67 ef
T_{10}	41.68 a	94.67	590.33 a
T_{11}	37.87 b	93.33	566.27 ab
T_{12}	35.29 bc	92.00	543.73 bc
Lsd (0.05)	3.1778	8.186^{NS}	24.188
CV %	7.25	5.25	4.24

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability**.**Note,T_0 = Biofertilizer 3 kgha^{-1}, T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}, T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}, T_{12}= Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}

4.16 Vigor index

Significant influence was marked on vigor index due to different levels of nutrient application during the experimentation (Appendix VIII). It was revealed that the maximum vigor index (590.33) was observed from the treatment T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) while the minimum vigor index (413.33) was recorded from T_0 (control) treatment. (Table 4.4). NPK and their combined applications at higher doses have increased the seed vigor index significantly as compared to lower doses due to the fact that nutrients applied at higher rate might have induced the formation of proteins and enzymes in adequate quantity which would have acted on the metabolites in the seeds and resulted in the better seed development and quality and hence more seed vigor index. The result of this experiment is closely coincided with the finding of previous report of Geetha *et al.* (2022) who revealed that proper application of different biofertilizer in with suitable number of macronutrients (NPK) has ensured the improvement of various factor including soil fertility, nutrients, microbial biomass which resulted in better plant growth, germination and seed vigor in Fenugreek seeds. Hosein *et al.* (2014) reported in one of his finding that 50% chemical fertilizer combining with biofertilizer lead to higher yielding, biological yield and harvest index around 26% more comparing to other treatment.

4.17 Economic analysis

Land preparation, fertilizer, irrigation and human costa for all fenugreek treatments, from seeding to harvesting, were recorded per experimental plot and converted to cost ha^{-1} (Table 4.5). The cost of fenugreek was calculated using market rates. The following economic study is offered under the heading:

4.17.1 Gross return

In the application of different levels of nutrients maximum gross return (Tk. 3,40,157) was obtained from the T_{10}(Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment and the second highest gross return (Tk. 2,92,790) was obtained in T_{11}(Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}) treatment. The lowest gross return (Tk. 95,760) was obtained in the application of T_0 (control) treatment which was nearly to T_1(Biofertilizer 3 kg+ 100 kg N ha^{-1}) treatment (Tk. 110,238).

4.17.2 Net return

Different treatment application gave different types of net return. In application of nutrients highest net return (Tk 2,43,326) was obtained from the T_{10}(Biofertilizer 3 kg + 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment and second highest net return (Tk. 1,97,097) was obtained in T_{11}(Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}). The lowest net return (Tk. 3483) was obtained from the treatment of T_0 closely associated with T_1 (Biofertilizer 3 kg+ 100 kg N ha^{-1}) treatment (Tk. 15,661).

4.17.3 Benefit cost ratio

In different levels of nutrient application, the highest benefit cost ratio (3.51) was attained from the T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment and the lowest benefit cost ratio (1.04) was obtained from of T_0 closely associated to (1.17) from T_1(Biofertilizer 3 kg+ 100 kg N ha^{-1}) treatment.

Table 4.5. Cost and return analysis of fenugreek considering different levels of biofertilizer and macronutrients application

Treatment	Cost of production (Tk)	Seed yield per ha (kg)	Net Income (Tk)	Gross Income (Tk)	BCR
T_0	92278	504.00	3483	95760	1.04
T_1	94578	580.20	15661	110238	1.17
T_2	93290	804.20	59509	152798	1.64
T_3	93520	1034.70	103074	196593	2.10
T_4	94003	622.00	24178	118180	1.26
T_5	93037	1243.10	143153	236189	2.54
T_6	93209	1068.00	109711	202920	2.18
T_7	93428	1034.70	103166	196593	2.10
T_8	92784	1212.00	137497	230280	2.48
T_9	92899	933.30	84429	177327	1.91
T_{10}	96832	1790.30	243326	340157	3.51
T_{11}	95693	1541.00	197097	292790	3.06
T_{12}	94555	1291.20	150774	245328	2.59

Total cost of production was done in details according to the following procedure,

Where, Sale of marketable yield at 190 Tk/kg.

Gross income = Marketable yield × Tk/kg

Net income = Gross income – Total cost of production

Benefit Cost Ratio (BCR) = Gross return ÷ Cost of production

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The present research work was conducted at the Central Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during November 2021 to April 2022 to study the effect of different levels of biofertilizer and macronutrients on the yield and yield components of fenugreek seed. ‘BARI Methi 1’was used as planting material in this study. The experiment consists of single factor. Thirteen treatment were tested in this experiment: T_0=Biofertilizer 3 kg ha^{-1}**,** T_1 = Biofertilizer 3 kg+ 100 kg N ha^{-1}, T_2 = Biofertilizer 3 kg+ 40 kg P ha^{-1}, T_3 =Biofertilizer 3 kg+ 60 kg K ha^{-1}, T_4 = Biofertilizer 3 kg+ 75 kg N ha^{-1}, T_5 = Biofertilizer 3 kg+ 30 kg P ha^{-1}, T_6 = Biofertilizer 3 kg+ 45 kg K ha^{-1}, T_7 = Biofertilizer 3 kg+ 50 kg N ha^{-1}**,** T_8 = Biofertilizer 3 kg+ 20 kg P ha^{-1}, T_9 = Biofertilizer 3 kg+ 30 kg K ha^{-1}, T_{10} = Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}, T_{11} = Biofertilizer 3 kg+ 75 kg N+ 30 kg P+ 45 kg K ha^{-1}, T_{12}= Biofertilizer 3 kg+ 50 kg N+ 20 kg P+ 30 kg K ha^{-1}. The experiment was laid out in Randomized Complete Block Design (RCBD) with 13 treatment s having three replications. Total 39 units plots were made for the experiment with 13 treatments. Each plot was of required size. Data on different yield parameter of fenugreek were recorded and significant variation was recorded for different treatments.

Plant height was significantly influenced by different nutrients application at different days after sowing (DAS) of methi. At 30, 45, 60 and 75 DAS, the longest plant (15.84 cm, 22.59 cm, 36.48 cm and 54.24 cm) was achieved from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment respectively, whereas the shortest plant (11.55 cm, 15.65 cm, 26.57 cm and 37.23 cm) was observed from T_0 (control) treatment.

Application of different nutrients had significant effect on the number of primary branches of fenugreek at different days after sowing (DAS). At 30 DAS, the maximum number of primary branches (2.73) was observed from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment and the minimum (0.80) was observed from T_0 (control) treatment. At 45, 60 and 75 DAS, maximum no. of primary branches plant^{-1} (6.48, 7.43 and 7.68) was also recorded from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg

P+ 60 kg K ha^{-1}) treatment. At 45, 60 and 75 DAS, the minimum no. of primary branches plant^{-1} (3.21, 3.47, 4.13) was recorded from T_0 (Control) treatment.

There was significant difference in the number of secondary branches of fenugreek. Maximum no. of secondary branches (4.20 and 5.21) was observed at 60 and 75 days after sowing (DAS) from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment, whereas, the minimum number of secondary branches at 60 and 90 days after sowing (DAS) were (0.53 and 1.13) respectively observed in case of T_0 (control) treatment.

Maximum days required for first flowering (36.89 days), maximum days to 50% flowerings (57.02), the highest pod length (12.16 cm), number of seeds pod^{-1} (15.22), maximum weight of seeds pod^{-1} (147.11 mg), maximum seed weight plant^{-1} (12.33 g), maximum weight of 1000-seed (13.58 g), maximum seed yield plot^{-1} (429.67 g), maximum seed yield ha^{-1} (1.79 t), higher harvest index (41.68), maximum vigor index (590.33), highest benefit cost ratio (3.51) were recorded from T_{10} (Biofertilizer 3 kg+ 100 kg N+ 40 kg P+ 60 kg K ha^{-1}) treatment.

On the other hand, minimum number of days required for first flowering (31.33 days), minimum days to 50% flowerings (49.13 days), lowest pod length (9.21 cm), minimum breadth of single pod (0.36 cm), minimum number of seeds pod^{-1} (10.48), minimum weight of seeds pod^{-1} (92.63 mg), minimum weight of seeds plant^{-1} (6.08 g), minimum weight of 1000-seed (11.03 g), minimum seed yield plot^{-1} (120.97 g), minimum seed yield ha^{-1} (0.504 t), the lowest harvest index (21.54), minimum vigor index (413.33) were obtained from T_0 (control) treatment. In case of BCR (benefit cost ratio), the highest BCR (3.51) was attained from the T_{10} treatment while the lowest BCR was (1.04) from the T_0 treatment.

Conclusion:

- Effects of biofertilizer and macronutrients was found to be significant on yield and yield contributing parameters of fenugreek seed.
- Application of 3 kg of biofertilizer with 100 kg N, 40 kg P and 60 kg K ha^{-1} found to be most suitable for getting higher fenugreek seed yield.

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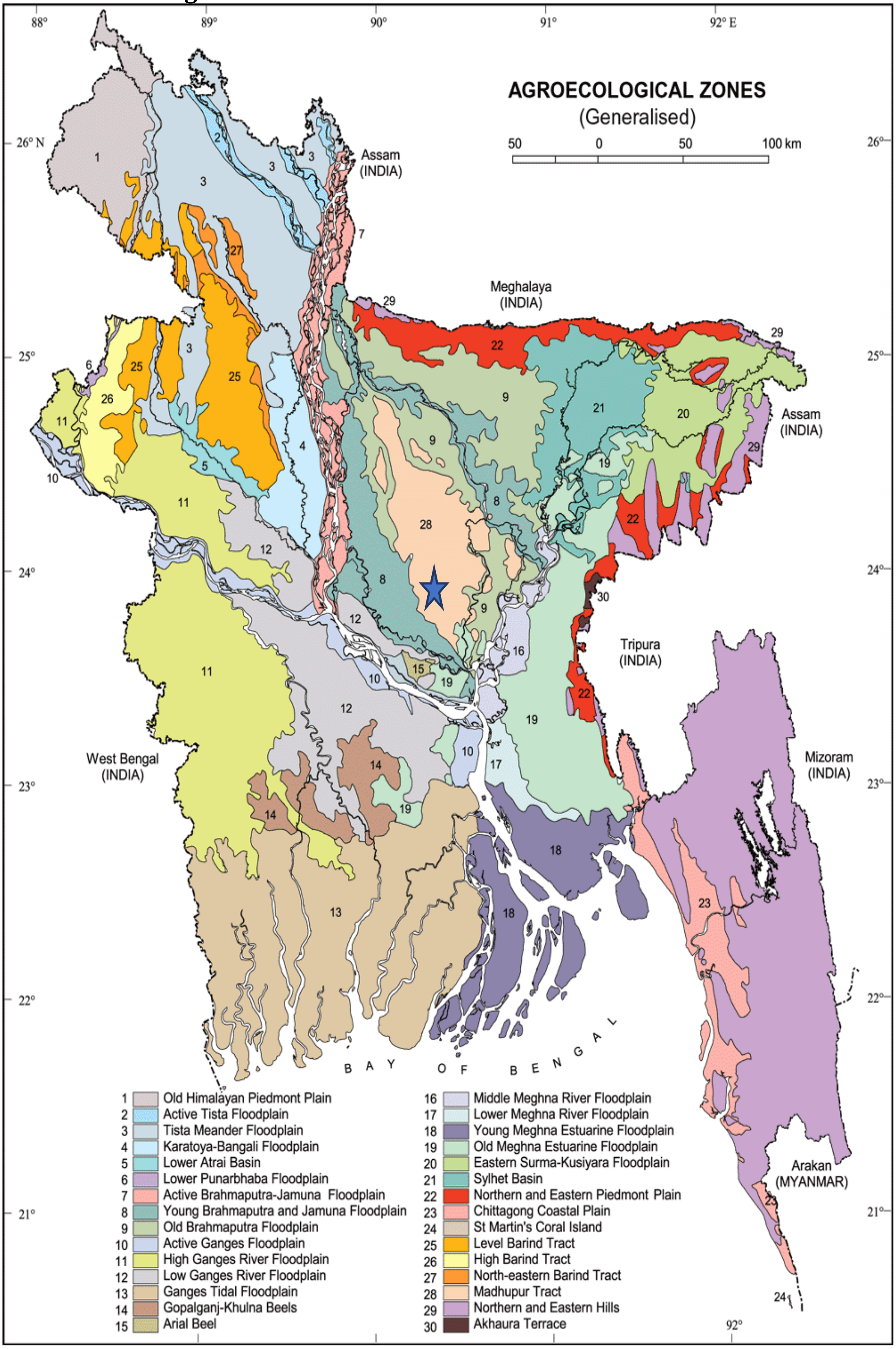
APPENDICES

Appendix I. Experiment was conducted in Sher-e-Bangla Agricultural University, Dhaka (AEZ-28) on the map of Agro-ecological Zones of Bangladesh



Appendix II. **Monthly records of air temperature, relative humidity and rainfall during the period from November 2021 to April 2022**

Year	Month	Air temperature (°C)			Relative Humidity (%)	Rainfall(mm)
		Max	Min	Mean		
2021	November	29.6	19.8	24.7	53	00
	December	28.8	19.1	23.9	47	00
2022	January	25.5	13.1	19.3	41	00
	February	25.9	14	19.9	34	7.7
	March	31.9	20.1	26	38	71
	April	34.7	23.6	29.1	44	82

Source: Bangladesh Meteorological Department, Agargaon, Dhaka-1207

Appendix III. Plant height of BARI Methi-1 at 30, 45, 60 and 75 DAS as influenced by combined effects of bio fertilizer and macronutrients

Source of variation	Degree of freedom	Mean square value			
		Plant height			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.0269	0.0175	0.0785	0.5019
Nutrients	12	5.060**	13.932**	28.334**	84.061**
Error	24	0.12655	0.051	0.003	0.2412

** Significant at 1% level

Appendix IV. Primary branches of BARI Methi-1 at 30, 45, 60 and 75 DAS as influenced by combined application of biofertilizer and macronutrients

Source of Variation	Degrees of freedom	Mean square value			
		Primary branch			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.1825	0.0987	0.153	0.259
Nutrients	12	1.141**	2.951**	3.441**	2.521**
Error	24	0.00214	0.00335	0.02255	0.08109

** Significant at 1% level

Appendix V. Number of secondary branches at 60 DAS and 75 DAS influenced by combined effects of biofertilizer and macronutrients

Source of variation	Degree of freedom	Mean square value	
		60 DAS	75 DAS
Replication	2	0.12604	0.18133
Nutrients	12	3.80969**	3.76841**
Error	24	0.00319	0.00138

** Significant at 1% level

Appendix VI. First flowering, 50% flowering days, pod length(cm), pod breadth (cm) as influenced by combined application of biofertilizer and macronutrients

Source of variation	Degrees of freedom	Mean square value			
		First flowering	50% flowering	Pod length (cm)	Pod breadth (cm)
Replication	2	0.449	7.008	0.198	0.109
Nutrients	12	7.656**	15.978**	1.730**	0.003^{NS}
Error	24	0.257	0.672	0.014	0.003

** Significant at 1% level NS = Not significant

Appendix VII. Seeds pod^{-1}, seed weight pod^{-1}, seed weight plant^{-1} and 1000 seed weight of BARI Methi-1 as influenced by combined effects of biofertilizer and macronutrients

Source of variation	Degrees of freedom	Mean square value			
		Seeds pod^{-1}	Seed weight pod^{-1} (mg)	Seed weight plant^{-1}	1000 seed weight
Replication	2	0.09578	23.99	0.0285	0.19219
Nutrients	12	5.415**	580.53**	8.15055**	1.6936**
Error	24	0.00265	12.698	0.05943	0.00031

** Significant at 1% level

Appendix VIII. Seed yield plot^{-1}, seed yield ha^{-1} of BARI Methi-1 as influenced by combined effects of biofertilizer and macronutrients

Source of variation	Degree of freedom	Mean square value	
		Seed yield plot^{-1}	Seed yield ha^{-1}
Replication	2	351.2	6097
Nutrients	12	24301.4**	42189**
Error	24	87.9	1526

** Significant at 1% level

Appendix IX. **Harvest index, germination and vigor index of BARI Methi-1 as influenced by combined effects of biofertilizer and macronutrients**

Sources of variation	Degrees of freedom	Mean square value		
		Harvest index	Germination	Vigor index
Replication	2	0.10124	0.5679	0.095
Nutrients	12	21.681**	36.316 ^{NS}	5.415**
Error	24	0.465	0.063	0.002

** Significant at 1% level NS = Not significant

Appendix X. Cost of production of fenugreek ha^{-1}

i. Input cost (A)

Treatments	Labor	Ploughing	Seed	Irrigation	Pesti -cide	Fertilizer					Subtotal A
						Vermicompost	Urea	MoP	TSP	Biofertilizer	
T_0	4000	3000	2700	2000	1000	50000	0	0	0	150	62850
T_1	4000	3000	2700	2000	1000	50000	2000	0	0	150	64850
T_2	4000	3000	2700	2000	1000	50000	0	880	0	150	63730
T_3	4000	3000	2700	2000	1000	50000	0	0	1080	150	63930
T_4	4000	3000	2700	2000	1000	50000	1500	0	0	150	64350
T_5	4000	3000	2700	2000	1000	50000	0	660	0	150	63510
T_6	4000	3000	2700	2000	1000	50000	0	0	810	150	63660
T_7	4000	3000	2700	2000	1000	50000	1000	0	0	150	63850
T_8	4000	3000	2700	2000	1000	50000	0	440	0	150	63290
T_9	4000	3000	2700	2000	1000	50000	0	0	540	150	63390
T_{10}	4000	3000	2700	2000	1000	50000	2000	880	1080	150	66810
T_{11}	4000	3000	2700	2000	1000	50000	1500	660	810	150	65820
T_{12}	4000	3000	2700	2000	1000	50000	1000	440	540	150	64830

Urea = 20 tk/kg
TSP = 22 tk/kg
MoP = 18 tk/kg
Biofertilizer = 50 tk/kg
Vermicompost = 12000 tk/ton

ii. Overhead cost (B)

Treatment	Cost of lease of land (TK 14% of value of land cost/6 month)	Miscellaneous cost (TK. 5% of the input cost)	Interest on running capital for 6 moths (Tk. 10% of cost/year)	Sub-total (Tk.) (B)	Total cost production (tk./ha)[input cost(A) + overhead cost (B)]
T_0	20000	3143	6285	29428	92278
T_1	20000	3243	6485	29728	94578
T_2	20000	3187	6373	29560	93290
T_3	20000	3197	6393	29590	93520
T_4	20000	3218	6435	29653	94003
T_5	20000	3176	6351	29527	93037
T_6	20000	3183	6366	29549	93209
T_7	20000	3193	6385	29578	93428
T_8	20000	3165	6329	29494	92784
T_9	20000	3170	6339	29509	92899
T_{10}	20000	3341	6681	30022	96832
T_{11}	20000	3291	6582	29873	95693
T_{12}	20000	3242	6483	29725	94555

LIST OF PLATES

Plate 1: Preparation of land

Plate 2: Emerging seedling of Fenugreek

Plate 3: Experimental field with fenugreek plant

Plate 4: Flower emergence of fenugreek

Plate 5: Grown pod of fenugreek

Plate 6: Harvesting of fenugreek plant

Plate 7: Harvested seed of fenugreek

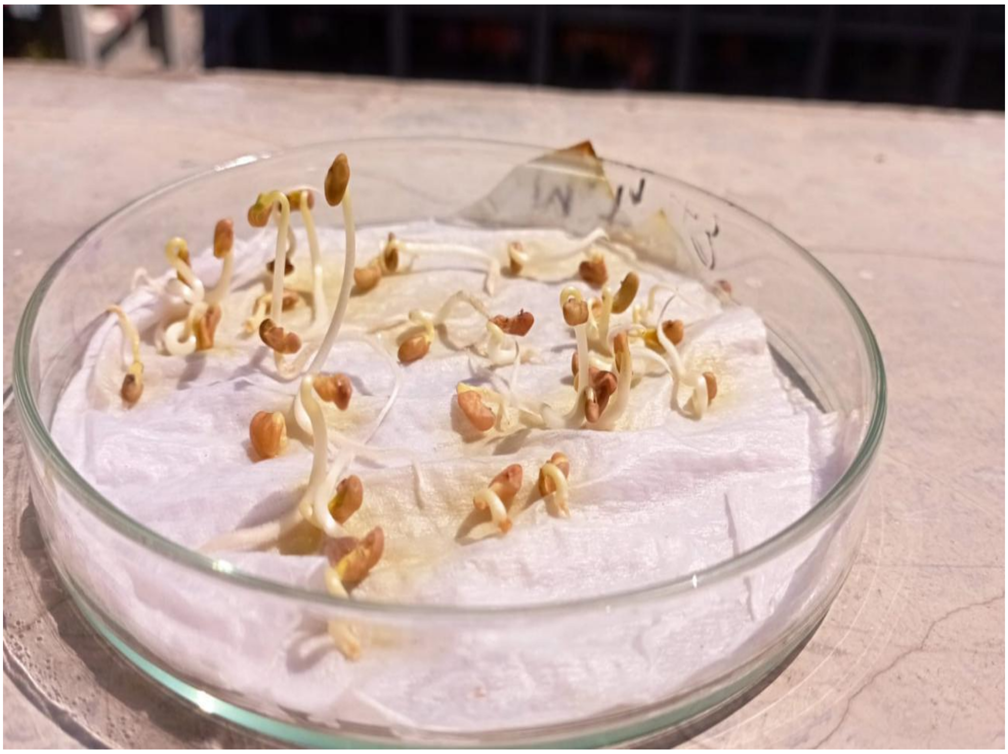


Plate 8: Germination of seedling with root and shoot system