INFLUENCE OF SOME MACRONUTRIENTS AND SPACING ON THE GROWTH AND SEED YIELD OF FENUGREEK (*Trigonella foenum-graecum* L.)

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CERTIFICATE

This is to confirm that thesis titled, "**INFLUENCE OF SOME MACRONUTRIENTS AND SPACING ON THE GROWTH AND SEED YIELD OF FENUGREEK (*Trigonella foenum-graecum*)"** 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** in **SEED TECHNOLOGY,** represents the result of a piece of genuine research work carried out by **MD. ALI REZA**, **Reg. No. 14-06095** under my direction and guidance. No portion of the thesis has been submitted for any other degree or diploma in any organization.

I further declare that such help or source of information, as has been availed of during the course of this research has properly been approved.

Dated: June, 2021

Place: Dhaka, Bangladesh

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Dedicated

To

My Beloved Parents

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The Author

INFLUENCE OF SOME MACRONUTRIENTS AND SPACING ON THE GROWTH AND SEED YIELD OF FENUGREEK (*Trigonella foenum-graecum* L.)

ABSTRACT

An experiment was conducted at the Agronomy Farm Sher-e-Bangla Agricultural University, Dhaka, Bangladesh October, 2019 to March, 2020 to study the influence of some macronutrients combination (N, P & K) and spacing on the growth and yield of fenugreek seed (*Trigonella foenum-graecum* L.). Fenugreek variety BARI Methi-1 was used as planting material in this study. The experiment consisted of two factors: Factor-A: macro nutrient combinations (4 levels): T_0= $N_0P_0K_0$ kgha^{-1}(control), T_1= $N_{40}P_{30}K_{30}$ kg ha^{-1}, T_2= $N_{80}P_{60}K_{60}$ kgha^{-1}, T_3= $N_{120}P_{90}K_{90}$ kg ha^{-1}; Factor-B: plant spacing (3 levels): S_1= 30×10cm, S_2= 30×20cm and S_3= 30×30cm. The experiment was laid out in a randomized complete block design (factorial) with three (3) replications. Data on different growth, yield contributing and yield parameter of fenugreek were recorded and significant variation was observed from different treatments. In case of nutrient combinations, seed yield per plot (332.12g), seed yield (1142.8 kg ha^{-1}), stover yield (865.49 kg ha^{-1}), germination percentage (80.30 %) were observed from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment. In terms of plant spacing the maximum seed yield per plot (353.20g), seed yield (1251.9 kg ha^{-1}) and stover yield (1271.4 kg ha^{-1}) were observed from S_1 (30×10cm) treatment. The maximum primary branch plant^{-1} at 30DAS (3.4) was observed from S_2 (30×20cm) treatment. The highest BCR (3.39) was obtained from the T_3S_1 treatment combination whereas the lowest BCR (1.04) was from T_0S_3 treatment combination It can be concluded that, sowing of fenugreek providing 120 kg N, 90 kg P and 90 kg K nutrient combination with 30 × 10 cm plant spacing was recorded to be more suitable practice for getting higher yield (1.82 t/ha) and quality of seed yield of fenugreek.

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LIST OF ACRONYMS

AEZ	= Agro-Ecological Zone
viz.	= As follows
BARI	= Bangladesh Agricultural Research Institute
cv.	= Cultivar
DAS	= Days after sowing
et al.	=And others
g	= gram
ha^{-1}	= Per hectare
J.	= Journal
kg	= Kilogram
LSD	= Least Significant Difference
Max	= Maximum
m	= Meter
mg	= milligram
Min	= Minimum
N	= Nitrogen
No.	= Number
NPK	= Nitrogen, Phosphorus and Potassium
NS	= Not significant
P	= Phosphorus
SAU	= Sher-e-Bangla Agricultural University
SRDI	= Soil Resources and Development Institute
t ha^{-1}	= Ton per hector
TSP	= Triple Super Phosphate
i.e.	= That is
%	= Percentage
^0C	= Degree Celsius

CHAPTER I

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an annual plant of Fabaceae family. It is used as a spice and herb. Fenugreek seeds, also known as "methi" in India, are well renowned for their spicy aromatic qualities (Max, 1992). The word fenugreek comes from *foenum-graecum*, which meaning Greek hay, because the herb was often used to scent poor hay. The Latin dialect *Trigonella* means "little triangle" because of its yellowish-white triangular blossoms (Flammang *et al*., 2004). 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). Fenugreek is a medicinal plant native to Central Asia that has been used for thousands of years. 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)

Fenugreek is an annual herbaceous plant with seeds that contain a variety of vitamins and proteins, comprising for 25-36 percent of the plant's dry weight. (Mehrafarin *et al.*, 2011). Iron, calcium, phosphorus, potassium, and other mineral components are all present in various amounts in the seeds. (Abbas *et al*., 2012). Fenugreek is well-known for its hypoglycemic and cholesterol-lowering properties. Recent study has revealed fenugreek as a significant therapeutic plant with multipurpose potential, as well as a source for pharmaceutical industry raw materials, particularly steroidal hormones. According to studies, fenugreek reduces blood sugar levels, raises testosterone, and increases milk supply in nursing mothers. Although more research is needed in these areas, fenugreek may help with appetite control, cholesterol reduction, and inflammation reduction. Natural fibers in fenugreek seeds can enlarge and fill the stomach, suppressing hunger and aiding weight loss goals. Some of the skin advantages of fenugreek seeds include glowing, face toner, cleansing, exfoliating, moisturizing, reducing blemishes and dark circles, anti-aging characteristics, and cure acne. It reduces hair loss, fights dandruff, conditions and shines hair, promotes hair growth, and prevents premature greying. It helps with digestion, diabetes symptoms, menstrual cramps, arthritis pain, heart disease prevention, kidney function improvement, and cholesterol reduction. A big increase in quantity and quality yields could provide an immediate and significant contribution to agricultural and pharmaceutical sector income through efficient management of cultivation, breeding, and technological methods (Mehrafarin *et al*., 2011).

Fertilizer management is a critical component of each crop's production and yield. Increased yield due to adequate nutrient supply Because Bangladesh's land is limited, it's critical to boost per-hectare yields of any crop by all means necessary. Food in the form of N, P, K, and other nutrients was essential for plant growth and development. Plant nutrients come primarily from the soil. It provides crop plants with nearly all of the nutrients they require.

Nitrogen (N) is an essential component of plant development. It gives plants energy, allowing them to grow and produce fruit or vegetables. It's a component of the chlorophyll molecule, which gives plants their green color, and it also plays a role in photosynthesis, which provides sustenance to plants. A lack of nitrogen causes the plant to turn yellow (chlorosis). Older growth yellows more than fresh growth because nitrogen can move around in the plant. The living matter in cells is the translucent substance that makes up protoplasm. Floral distinction, quick shoot growth, flower bud health, and increased fruit set quality all require it. It is the most important element for optimal plant growth and development, as it boosts and improves yield and quality by playing a key role in biochemical and physiological processes (Leghari *et al.* 2016). Protein, which catalyzes chemical reactions and transports electrons, and chlorophyll, which allows photosynthesis, both require nitrogen. It gives plants a dark green hue that aids in the growth and development of their leaves, stems, and other vegetative components. Nitrogen deficiency causes stunted development, chlorosis (leaf color changes from green to yellow), and the emergence of red and purple patches on the leaves, all of which inhibit lateral bud extension. Symptoms of deficiency usually occur first on older leaves (Bianco, 2015). The excess nitrogen causes leaf senescence, but it also has a negative influence on plant development, resulting in darker green leaves, succulents developing throughout the growth, and a predilection for fewer but lower-quality fruits. Plants only absorb nitrogen in the form that is most beneficial to them; most plants absorb nitrogen in the nitrate structure, which is ineffective in some soils, such as submerged soils, but is the best option in others (King *et al*., 1992). To grow and develop properly, plants require the right amount of nitrogen.

Plant growth, root development, and enhanced stem strength all require phosphorus (P). It promotes the development of blooms and guarantees more constant seed production. It also improves seed quality and increases disease resistance in plants. When fenugreek was supplied 26 kg P (60 kg P_2O_5) ha^{-1} of phosphorus, plant growth and seed yield enhanced. (Bismillah Khan *et al.* (2005). Singh *et al.* (2019) produced maximum plant height, number of branches, number of pods per plant, number of seeds per pod, pod length, seed yield, straw yield and biological yield in 40 kg P/ha $^{-1}$. 80 kg P_2O_5 ha^{-1} and 75 kg P_2O_5 ha^{-1} were also found to boost fenugreek seed yield reported by Jat (2004) and Deepak *et al.* (2000) respectively.

Potassium (K) is one of the three basic elements in fertilizers applied to soils and is an important component in crop yield management. When potassium is added to the mix, the quantity of flowers, peduncle length, fruit set, and fruit number all increase. Potassium (K) has been found to assist boost agricultural productivity and quality, according to Tisdale *et al.* (1985). In plant tissue, potassium is linked to the flow of water, minerals, and carbohydrates. It influences protein, starch, and adenosine triphosphate (ATP) production by activating enzymes within the plant. Plant growth is stunted and yield is reduced when K is insufficient or not given in sufficient proportions. Potassium assists in photosynthesis and food production, improves drought resistance and root growth, preserves turgor, lowers water loss and wilting, and enhances drought resistance and root growth. It lowers respiration, which means less energy is lost. Sugar and starch translocation has improved. It provides starch-rich grain, boosts plant protein levels, promotes cellulose formation, minimizes lodging, and helps to avoid crop disease.

Plant density in a crop is influenced by plant spacing, and it's commonly known that achieving an adequate plant density per unit area is one of the most essential variables in increasing yield. Crop yield may be harmed by spacing that is too wide or too narrow. For each crop, there is an ideal plant density at which assimilates are mostly employed for vegetative growth and improved respiration rather than reproductive growth. Furthermore, single-plant production improved under conditions of similar plant density, but yield per square unit dropped. Kurubetta *et al.* (2018) reported that row spacing of 30 x 10 cm combined with fertilizer dosage N+ P_2O_5+ K_2O (50: 50: 0 kg/ha) resulted in a considerably increased seed yield of 15.5 q/ha. Kumar *et al.* (2018) discovered that a seed rate of 24 kg/ha and a row spacing of 40 cm was the most effective treatment. Several attempts to improve fenugreek cultivation production and quality have been made in the past, with optimal plant geometry and cultivars possibly playing a key role. In light of these observations, the current study was designed to look into the effects of macronutrients and spacing on the growth and seed yield of fenugreek.

- To find out the growth and seed yield of fenugreek under different nutrient levels.
- To determine the suitable spacing for higher seed yield of fenugreek
- To examine the suitable combination of plant nutrients and spacing on growth and seed yield of fenugreek.

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh, fenugreek research and development is poor. However, many studies have been carried out in India and other parts of the world in relation to agro-climatic conditions. The next paragraphs evaluate and discuss a few of the research that have been conducted so far.

Nandal *et al.* (2007) conducted a field experiment at Vegetable seed production and Research Farm, Krishi Vigyan Kendra, Sonipat of CCS Haryana Agricultural University, Hisar during the year 2005-06 to 2006-07, to study the effect of different levels of nitrogen and phosphorus on growth and seed yield of fenugreek. The experiment consisted of four levels of nitrogen (20, 40, 60 and 80 Kg N/ha) and three levels of phosphorus (35, 50 and 65 Kg P/ha) applied as basal dose and top dressing as per treatment. Application of 80 Kg N/ha and 65 Kg P/ha significantly increased the plant height and number of primary branches per plant. The treatment of 80 Kg N/ha with different levels of phosphorus delayed the maturity time as compared to other treatment combination. The results indicated that application of 60 Kg N+65 Kg P/ha produced highest test weight (10.4 g) as well as seed yield (20.4 q/ha) whereas minimum test weight (8.6 g) and seed yield (15.1 q/ha) was recorded under 20 Kg N/ha and 35 Kg P/ha.

Patel *et al.* (2014) conducted a field experiment during winter seasons of 2007–08 to 2010–11 (except 2008–09) at Sardarkrushinagar (Gujarat) on loamy sand soil to evaluate the effect of different organic manures and biofertilizers on yield, nutrient uptake and economics of fenugreek (*Trigonella foenum-graecum* L.) under organic farming. Results revealed that combined application of 50% RDN through castor cake along with *rhizobium*+PSB seed inoculation recorded significant improvement in yield attributes viz., number of pods/plant, seeds/pod and test weight as well as seed and stover yields of fenugreek in pooled results. It also proved its superiority with respect to N, P and K content (%) in seed as well as in straw and total N, P and K uptake. Conjuctive use of 50% RDN through castor cake+*rhizobium* and PSB seed inoculation, remarkably improved soil fertility viz., organic carbon, available N, P and K after harvest of fenugreek crop as compared to RDF through inorganic fertilizers and sole application of either organic manures or bio fertilizers. It recorded maximum net returns (Rs. 22,859) and benefit: cost ratio (1.65).

Singh *et al.* (2019) carried out a field experiment entitled “Effect of different levels of nitrogen and phosphorus on growth and yield of fenugreek (*Trigonella foenum-graecum* L.) in South West Punjab” during rabi season of 2017-18 at experimental field, Guru Kashi University, Talwandi Sabo, Punjab. The experiment was laid out in split plot design with two levels of nitrogen (15 and 30 kg N/ha) in main plots and five levels of phosphorus (0, 10, 20, 30 and 40 kg P_2O_5/ha) in sub plots, replicated thrice. The results indicated that highest plant height, number of branches, number of pods per plant, number of seeds per pod, pod length, seed yield, straw yield and biological yield were found in 30 kg N/ha and 40 kg P/ha. The application of 30 kg N/ha gave significantly higher (1441 kg/ha) seed yield as compare to 15 kg N/ha treatment. Increasing levels of phosphorus up to 40 kg/ha phosphorus (P_2O_5) significantly increased the seed yield of fenugreek over 0, 10, 20 and 30 kg P_2O_5/ha. There was 39.1, 21.2, 12.5 and 5.7% increase in seed yield due to application of 40 kg P_2O_5/ha over 0, 10, 20 and 30 kg P_2O_5/ha, respectively. Thus it can be concluded that nitrogen application at 30 kg/ha and phosphorus @ 40 kg/ha were found more effective than rest of the treatments.

Dahiya *et al.* (2009) carried out a field experiment at Vegetable Seed Production and Research Farm, Krishi Vigyan Kendra, Sonipat of CCSHAU, Hisar during 2005-06 and 2006-07 to work out the effect of nitrogen levels and leaf cuttings on seed yield of fenugreek. The results indicated that treatment consisting of 75 kg N/ha with no cutting produced highest seed yield (18.80 q/ha), whereas minimum seed yield was recorded under 25 kg N/ha with two cuttings. The maximum green leaves weight was obtained in treatment combination of 100 kg N with two cuttings and it was followed by 75 kg N/ha with two cuttings.

Ibrahim and Helaly (2017) conducted at a privet farm in Mansoura, Dakahlia Governorate, Egypt, during the two winter consecutive seasons of 2014/2015 and 2015/2016 with an objective to evaluate the optimum rates of nitrogen and potassium (N×K) and level of humic acid for obtaining maximum growth and productivity of fenugreek plants. Four different rates of N×K (0, 50, 75 and 100 % of recommended rate) and three levels of humic acid (0, 1 and 2 l/fed.) were applied, thereby making twelve treatment interactions. The recommended rate of NK was 200: 50 kg/faddan of ammonium sulfate (20.5% N) and potassium sulphate (48.5% K_2O), respectively. The statistical layout of this experiment was split-plot experiment included 12 treatments were arranged in a randomized complete block design with three replicates. The obtained results indicated that NK fertilization rates at 75 and 100 % of recommended rate (RR) significantly increased plant growth parameters (plant height, number of branches and leaves /plant and dry weight/plant), yield components (number of pods/plant and seed yield/plant and /feddan), fixed oil production (fixed oil percentage, fixed oil yield/plant and /feddan) and chemical constituents (total N, P, K and carbohydrates percentages, total chlorophyll content as SPAD unit and trigonilline content as mg/100g of dry weight) without significant differences between them, in most cases, compared to control. Moreover, the highest values of above mentioned characters were registered by foliar spray of humic acid at 2 l/feddan with significant differences between the other levels under study. Generally, the better growth parameters, higher yield components, fixed oil production, chemical constituents of seeds and as well as trigonilline content in seeds could be obtained by spraying humic acid at 2 l/feddan level on fertilized fenugreek plants with NK at 75% of recommended rate.

Muhammed *et al.* (2018) conducted a field experiment at College of Agricultural Sciences-University of Sulaimani, during the winter season of 2014-2015, to study the response of two (Mithe and EP 101) fenugreek varieties (*Trigonella foenum-graecum* L.) to different level of nitrogen fertilizer (0, 40 and 80 kg N ha^{-1}) for yield and its component. The results of experiment showed the highest seed yield and all traits were obtained by Mithe variety and 40kg N ha^{-1} produce highest seed yield and yield component. The highest seed yield for most of traits were obtained by interaction between Mithe variety and 40kg N ha^{-1} in comparison with the interaction between EP 101 variety and 40kg N ha^{-1}.

Güzel and Özyazıcı (2021) conducted a study to determine fenugreek genotypes yield and quality characteristics under semiarid climatic conditions for two seasons from 2018 to 2020. Field trials were conducted with four replications according to the randomized complete block design. The results revealed that the time to emergence varied from 16.0 to 19.9 days, 50% flowering from 160.9 to 170.4 days, and the vegetation period from 202.0 to 209.3 days. According to the results of two years of research, plant height varied from 64.60 to 78.70 cm, first pod height from 25.26 to 41.76 cm, pod width from 2.91 to 3.29 mm, pod length from 10.07 to 12.60 cm, number of pods per plant from 12.00 to 18.73, number of seeds per pod from 12.55 to 15.55, biological yield from 5.12 to 7.62 t/$ha^{−1}$, seed yield from 0.91 to 1.38 t/$ha^{−1}$, harvest index from 17.91 to 24.35%, 1000 seed weight from 13.87 to 17.45 g, fatty oil content from 5.18 to 9.16%, fatty oil yield from 49.3 to 111.6 kg ha^{-1}, and the trigonelline ratio varied from 0.71 to 1.32%. Statistically significant differences ($p \leq 0.05$) were observed for the pod width, while highly significant differences ($p \leq 0.01$) were observed for all other parameters. According to the research results, Mardin, Kayseri, and Adana genotypes were statistically in the same group with Berkem cultivar in terms of seed yield.

Sahu *et al.* (2020) used Fenugreek cultivar AFG-3 was for the experiment. Twelve treatments consisting of integrated nutrient management with organic, inorganic and bio fertilizers along with control. The observations on different growth and yield parameters were recorded and the results obtained are summarized below. On the basis of one year research trial it could be concluded that the treatment (T11) i.e. 50% RDF + Neem cake @ 1 ton ha^{-1} + Rhizobium + PSB was best at all the stages of growth parameters like plant height 30, 60 and 90 das (cm), number of primary branches per plant at 30, 60 and 90 DAS, number of secondary branches per plant at 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 per plant, weight of pod, pod length at number of seeds per pod, weight of seeds per pod, seed yield per plant, seed yield (q ha^{-1}), harvest index and days taken to maturity showed better performance from other treatments of organic, inorganic and bio fertilizers applications.

Yousuf and Nayak (2018) conducted an experiment to determine studies on the influence of nitrogen levels and herb harvests on the growth and yield of fenugreek (*Trigonella foenum-graecum* L.) Cv. Ajmer Fenugreek-1 under Southern Telangana agro-climatic conditions in the Department of Plantation, spices, medicinal and aromatic crops, was conducted during kharif season (August 2017 to December 2017) at the Department of Plantation, Spices, Medicinal and Aromatic crops section, College of Horticulture, Hyderabad. The laboratory experiment was conducted in Factorial Randomized Block Design with three replications and Nitrogen was applied at three levels (30, 45 and 60 kg/ha). Application of nitrogen at different levels had a significant impact on growth and yield parameters of fenugreek recorded during the course of investigation different treatments. The result reveals that application of nitrogen at 60 kg per hectare improved and recorded maximum values for all the growth and yield parameters such as plant height, number of branches per plant, fresh and dry weight per plant, fresh and dry herb yield, number of pods per plant, pod length, number of seeds per pod, test weight of seeds, seed yield, biological yield, harvest index, NPK content and uptake. However, there was significant delay in flowering and maturity with 60 kg nitrogen per hectare. Among the harvesting practices (single, double and no herb harvest), the uncut plants showed maximum plant height, early flowering and maturity.

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" at the Main garden, University Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. 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 parameters 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).

Aher *et al.*(2010) showed that the character contributing for seed yield *viz.*, number of pods per plant, pod length, number of seeds per pod, seed yield per plot and seed yield per hectare were found to be increased with an increasing level of nitrogen. Maximum seed yield and yield contributing characters were obtained with an application of 90 kg nitrogen per hectare. All these characters were found superior in the variety Pusa Early Bunching.

Amirnia *et al.* (2018) conducted an experiment in the experimental field of Agronomy Department, Faculty of Agriculture, Urmia University in 2017. The purpose of this study was, 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) on yield and yield components of Fenugreek herb. Results showed that foliar application of macro nutrients was significant in plant height, number of pod, number of seeds per pod, pod length, 1000 grain weight, seed yield and biomass, seed nitrogen and protein percentage of Fenugreek. The highest grain yield (1029.2 kg/ha) and seed protein percentage (12.4%) were obtained in the nitrogen treatment. Also the lowest 1000-seed weight was achieved in control. The dosage of macro nutrients (excluding number of seeds per pod and seed yield) had a significant effect on the observed traits. The highest biomass yield (1574.17 kg/ha) was gained through 4g/1000, however the highest seed protein percentage (11.26%) was observed by 2g/1000. Therefore, foliar application method reduces utilization of chemical fertilizers, which can increase the efficiency of fertilizer application and decrease fertilizer nutrient losses.

Shivran *et al.*(2016) conducted a field experiment during the winter seasons of 2007–08 to 2009–10 at Jobner, India on loamy sand soil to evaluate the effect of integrated nutrient management on growth, productivity and economics of fenugreek *(Trigonella foenum-graecum).* The experiment consisted of fourteen combinations of integrated nutrient management practices for application of recommended dose of nitrogen (RDN) to fenugreek *i.e.*, 40 kg/ha, through different sources, *viz.*, control, inorganic or organic [farmyard manure (FYM), poultry manure (PM), vermicompost (VC) and neem cake (NC)] alone or in combinations was laid out in randomized block design with three replications. Based on three years of study the results revealed that application of all nutrient management treatments through organic and inorganic sources alone or in combination brought significant effect on growth, yield and economics of fenugreek. Further the results revealed that integration of 50% RDN through vermicompost (VC) + 50% RDN through inorganic source to fenugreek recorded higher plant height, branches/plant, pods/plant, seeds/pod, test weight, seed yield (1781 kg/ha), stover yield (3392 kg/ha), biological yield (5173 kg/ha) and net returns (Rs. 52151/ha). However, maximum benefit cost ratio was fetched with application of 100% RDN through inorganic source.

Jat (2004) conducted an experiment during two consecutive years (1997–98 and 1998–99). The soil of experimental field was sandy loam having low available nitrogen and phosphorus and well supplied with potassium and alkaline in reaction. Increased application of phosphorus increased the dry matter accumulation and plant height of fenugreek significantly. Application of 80 kg P_20_5 ha^{-1} increased the dry matter accumulation per 0.5 m row length at 30, 60, 90 DAS and at harvest by 22.38, 20.09, 27.74 and 2272 per cent and plant height at 60,90 DAS and at harvest by 9.06, 17.20 and 15.74 per cent over control respectively. Application of 100 kg sulphur per hectare significantly increased the mean dry matter accumulation of fenugreek at 30, 60, 90 DAS and at harvest by 6.87, 6.25, 8.45 and 5.10 per cent over control, respectively. Seed treatment with *Rhizobium* + PSB, PSB alone and *Rhizobium* alone increased the mean dry matter accumulation of fenugreek by 2.84, 1.63 and 1.03 per cent at 90 DAS over control, respectively. The maximum seed yield of fenugreek was recorded in the application of 80 kg P_2O_5 ha^{-1}, 100 kg S ha^{-1} and seed treatment with *Rhizobium* + PSB.

Deepak *et al.*(2000) reported that fenugreek cv. hisar sonal was treated with N at 20, 40 and 60 kg/ha, and P at 25, 50 and 75 kg/ha, and sown at rates of 15, 20, 25 and 30 kg seed/ha 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 + P at 75 kg/ha. Seed yield was highest (14.80 q/ha) at treatments with 20 kg N/ha + 75 kg P/ha + sowing rate of 25 kg seed/ha. The highest plant height was obtained in the treatment 40 kg N/ha + 75 kg P/ha + 20 kg seed/ha.

Singh *et al.* (2010) conducted a field study during winter seasons of 2003-04 and 2004-05 at Udaipur to assess the performance of two fenugreek (*Trigonella foenum-graecum*) cultivars (RMt-1 and RMt-303) at 3 fertilizer levels (control, 20 + 8.6 kg N + P/ha and 40 + 17.2 kgN+P/ha) and 4 bio fertilizer inoculations (uninoculated control, *Rhizobium* alone, PSB alone and *Rhizobium* + PSB). Application of 40 + 17.2 kg N + P/ha proved optimum for fenugreek as it significantly improved growth, yield attributes, yield (1.76 tons/ha), N, P uptake, net returns (Rs 25,640/ha) and B:C ratio (2:49) over 20 + 8.6 kg N + P/ha and control and also favours soil N and P status. With significant higher seed yield (1.56 tons/ha), net returns (Rs 22,680/ha) B:C ratio (2:31) and with higher N and P status of soil, the variety 'RMt-303' proved superior when compared with 'RMt-1'. Dual inoculation showed superiority by retaining higher available N and P in soil, higher yield, net returns and B:C ratio compared to Rhizobium, PSB alone and uninoculated control.

Nehra *et al.*(2002) conducted a field experiment during rabi season of 1998-99 on loamy sand soil of Jobner (Rajasthan) to study the response of fenugreek (*Trigonella foenum graecum* L.) to phosphorus and potassium. The experiment consisted of four levels of phosphorus (0, 20, 40 and 60 kg P/ha) and five levels of potassium (0, 15, 30, 45 and 60 kg K/ha). The results showed that increasing levels of P up to 40 kg P/ha and K up to 45 kg K/ha significantly increased all the growth characters (plant height, dry matter/metre row length, branches/plant and number and dry weight of root nodules), yield attributes (pods/plant, seeds/pod, length of pod and test weight), yield (seed, straw and biological yield), net retums and B : C ratio per hectare as compared to other phosphorus and potassium levels. Optimum doses of phosphorus and potassium as worked out through production function were 50.86 and 57.49 kg/ha, respectively.

Rana *et al.* (2015) conducted a field experiment at Indian Agricultural Research Institute Regional Station, Karnal, Haryana to evaluate the effect of spacing and frequencies of leaf cutting on seed yield in fenugreek (*Trigonella foenum- graecum* L.) cv. Pusa Early Bunching. The treatments comprised of three row spacing (30, 45 and 60 cm) in main plot and three leaf cuttings (none, one and two cuttings) in sub plots. Row spacing at 45 cm recorded significantly higher leaf yield ha^{-1} (89.05q) than 30 cm (70.53q) and 60 cm (75.95q) spacing, respectively. Spacing at 60 cm resulted in significantly higher test weight than the lower spacing. No leaf cutting treatment recorded higher test weight than one and two leaf cutting levels. The treatment comprising row spacing at 45 cm with one leaf cutting at 60 DAS resulted in a seed yield of 9.10 q ha^{-1} and leaf yield of 48.96 q ha^{-1}. This treatment also recorded highest net returns ha^{-1} (Rs. 34065/-) and B: C ratio (1.41).

Randhawa *et al.* (1997) reported that the agronomic technology of fenugreek (*Trigonella foenum graecum* L.) during the 1991-1992 and 1992-1993 growing seasons were studied at the Students Farm, Punjab Agricultural University, Ludhiana, India. Results indicated highest yields were obtained when fenugreek was sown during the last week of October to the first week of November in rows 22.5 cm apart using 30 kg seed per hectare. The plant has meager nitrogen requirements and does not respond to phosphorus application on soils rich in this element.

Kurubetta *et al.*(2018) studied that the three years (2011, 2012 and 2013) pooled results of the experiment conducted at Horticulture Research and Extension Station, Devihosur, Haveri, Karnataka revealed that sowing of fenugreek in a row spacing of 30 x 10 cm recorded significantly higher seed yield of 13.9 q/ha compared to other row spacing. Among the fertilizer doses the application of fertilizer F2 - 75: 50: 0 kg $NP_2O_5K_2O$/ha recorded significantly highest seed yield of 13.2 q/ha. However, it is found on par with the fertilizer dose F1 - 50: 50: 0 kg $NP_2O_5K_2O$/ha. The interaction of row spacing (S2) 30 x 10 cm with fertilizer dose F1 - 50: 50: 0 kg $NP_2O_5K_2O$/ha recorded significantly higher seed yield of 15.5 q/ha however, it was on par with the interaction of row spacing S2: 30 x 10 cm with fertilizer dose F2 - 75: 50: 0 kg $NP_2O_5K_2O$/ha.

Kumar *et al.* (2018) conducted a field experiment at Chaudhary Charan Singh Haryana Agricultural University, Hisar to evaluate the effect of seed rate and row spacing on growth and yield of fenugreek (*Trigonella foenum-graecum*) cv. Hisar Sonali. The treatment comprised of three rows spacing (20, 30 and 40 cm) in main plot and five seed rate (16, 18, 20, 22 and 24 kg/ha). Ten competitive plants are selected randomly from each plot to record data on various parameters. The maximum number of seeds per pod was observed with seed rate of 16 kg/ha and row spacing 40 cm. The treatment combination of seed rate 24kg/ha and row spacing 40cm was found to be best. The seed rate 20kg/ha and 40cm row spacing shows significantly higher yield than other.

Sharanya *et al.* (2018) carried out an experiment entitled effect of plant geometry on growth, yield and quality of different varieties of fenugreek during rabi season of 2016-17at College of Horticulture, Mandsaur (M.P.) with 12 treatment combinations, comprising three plant geometry 20 cm x 15cm, 30 cm x 10cm and 30 cm x 15 cm with four varieties of fenugreek i.e. AFg-1, AFg-2, AFg-3 and AFg-4. These treatments were replicated four times in split spot design and analyzed. Treatment with plant geometry 20 cm ×15 cm recorded significantly maximum plant height, seed yield, straw yield, biological yield, harvest index and chlorophyll content. While, 30 cm ×15 cm treatment recorded significantly maximum days for 50% flowering and for maturity, number of branches, fresh weight, dry weight, number of pods per plant, pod length, weight of pod, number of seeds per pod, weight of seeds per pod,1000-seed weight, germination percent, seedling vigour index, protein and galactomannon content. Between varieties studied, fenugreek variety AFg-2found to be significantly superior in respect of number of branches per plant, fresh and dry weight of plant at harvest, number of pods per plant, length of pod, weight of pod, number of seeds per pod, weight of seeds per pod, 1000-seed weight , seed yield, straw yield, biological yield, chlorophyll content in leaves at 75 DAS (SPAD), germination percentage of seeds, seedling vigor index, protein and galactomannon in comparison to other varieties tested.

Sudeep *et al.* (2009) laid out an experiment was in split plot design with three varieties of fenugreek viz. HM-103, ML-150 and HM-57 in main plots and two row spacings of 22.5 cm and 30 cm in sub plots for two years. The results showed that variety HM-57 produced significantly higher seed yield over the varieties HM-103 and ML-150. This variety has also produced significantly higher numbers of pods per plants and number of seeds per pods during both years. The closer row spacing of 22.5 cm gave higher seed yield as compared to 30 cm. Significantly more number of pods per plant was recorded in closer row spacing, during both the years. So, for getting higher productivity in fenugreek, variety HM-57 may be sown at row spacing of 22.5 cm under semi-arid region of Punjab.

AL-Saidi (2017) conducted a study at the Field Crops Research Station at the college of Agriculture, University of Diyala and for the Agricultural Season 2016-2017 and The experiment included two factors, the first is the planting distances (15-20-30 cm) between the plants and the second spraying with the sea extract at a concentration of 2 and 4 ml /L , The experiment was designed to study the effect of the planting distances of agriculture and spraying with on marine extracts on the growth and yield characteristics of the fenugreek plant. The experiments was applied as a factorial experiment using the (Randomized Complete Block Design). The results showed that the agricultural distances had a significant effect on the studied parameters) between plants was significantly superior in several parameters such as: number of leaves per plant (24.78 leaves), plant fresh weight (28.33 g / plant), dry weight (9.044 g / plant), pods (10.78 pod plant), weight of 1000 seeds (11.32 g) and seed yield (2.974 g) while plant with (10 cm) between plant gave the highest plant height (63.44 cm) and seed yield (486.6 kg / h) while spraying with 4ml gave the highest plant height, number of branches (6.67 branches / plants), the number of leaves (27.00 leaves / plants), the fresh weight (31.88 g), the dry weight (9.166 g) and the number of corneas (13.56) Seed yield (3,433 g), number of seeds (14.12 seeds, pod) and seed yield (413.5 kg / h) and weight of 1000 seeds (13.99 g).

Singh *et al.* (2021) studied that fenugreek is an annual herb having light green leaves, 30-60cm tall and produces slender, beaked pods, 10-15 cm long and each pod contains 10-15 cm long and each pod contain 10-20 small hard yellowish brown seeds, which are smooth and oblong, about 3mm long, each grooved across one corner, giving them a hooked appearance. A field experiment was conducted and treatments imposed with two factors i.e., three cuttings level (C) (C_0: No cutting, C_1: One cutting and C_2: Two cuttings) and four intra row spacing level (S) (S_1:30 x 5.0cm, S_2: 30 x7.5cm, S_3:30 x 12.5 cm). Result revealed that closer spacing (30 x 5.0 cm) and two cuttings (60 & 90 DAS) better for leaf harvest. As far as seed production better at 30x 7.5 cm spacing followed by 30 x 10cm at one or no cutting condition. Economic point of view single cutting at 60 days after sowing and spacing at 30 x7.5 cm better in Uttar Pradesh condition.

Arslan (1994) carried out a work on fenugreek (*Trigonella foenum-graecum* L.) at inter-row spacing of 15, 30 or 45 cm and seeding rates of 20, 30 or 40 kg/ha. Highest seed yield was obtained from inter-row spacing of 15 cm and seeding rates of 20 or 30 kg/ha. Inter-row spacing of 45 cm produced the lowest seed yield. At all inter-row spacing applications, increases in sowing rate increased the height of fruit setting but reduced the number of branches and number of fruits per plant and seed yield. Average fruit (pod) lengths varied from 10.7 cm to 132 cm and 1000 seed weight ranged from 14.9 g to 16.8 g.

Bismillah Khan *et al.*(2005) reported that significant increased seed yield of fenugreek (1358.29 kg ha^{-1}) was obtained for the crop raised with 60 kg P_2O_5 ha^{-1} but was statistically at par with 45 kg P_2O_5 ha^{-1} (1326.47 kg ha^{-1}).

Mitoo *et al.* (2017) conducted an experiment at the Sher-e-Bangla Agricultural University's research field in Dhaka from November 2016 to March 2017 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.

Awasthi *et al.* (2020) found that the application of 30 kg K_2O recorded significantly maximum growth and yield attributes, seed yield, biological yield and harvest index.

Datta and Hore (2017) carried out an experiment at the Horticultural Research Station,Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, and West Bengal during the year 2013-14 and 2014-15. The variety ‘Hissar Sonali’ was taken under the study. 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. The experiment was laid out in factorial randomized block design with three replications. 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) per plant. The minimum days required for 50 per cent pod formation was noticed in $N_{40}P_{60}K_{40}$ (68.12 days). The yield attributing parameters like maximum number of pods $plant^{-1}$ (76.48) and seed yield plant^{-1} (14.36 g) were observed in $N_{60}P_{80}K_{40}$ combination. 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. In majority of parameters, the increasing trend was noticed with medium level of nitrogen (N_{60}) and phosphorus (P_{80}) but positive response was observed with higher level of potassium. From yield maximization point of view, the most effective treatment was NPK @ 60:80:40 kg ha^{-1} followed by NPK @ 40:80:40 kg ha^{-1} and NPK @ 60:100:40 kg ha^{-1} under alluvial plains of West Bengal.

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. Maximum net returns (Rs 78,705) was also recorded under the same treatment. 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.

Purbey and Sen (2005) reported that dual inoculation of seed with Rhizobium + phosphate solubilizing bacteria resulted in significantly higher number of pods/plant (31.46), pod length (13.13 cm), number of seeds/pod (16.58), shelling percentage (72.74), seed and straw yield of 1.70 and 4.60 tons/ha, respectively over single inoculation and uninoculated control. Significant enhancement in N, P and protein content of seed were also recorded under conjoint inoculation of Rhizobium and phosphate solubilizing bacteria. Under the foliar application of bio regulators 20 ppm NAA recorded significantly higher number of pods/plant (32.65), pod length (13.48 cm), number of seeds/pod (17.16), shelling percentage

(73.28), seed and straw yield (1.76 and 4.70 tons/ha) that was closely followed by 10 ppm NAA. Quality parameters like N, P protein and diosgenin content in seed were also significantly influenced by foliar application of bio regulators.

Thapa and Maity (2004) conducted An experiment at Horticultural Research Station, Mondouri, West Bengal during rabi season of 1997-98 and 1998-99 to study the effect of nitrogen (fiz. 30, 40 and 50 kg/ha) and phosphorus fertilization viz. 40, 60 kg/ha) with cutting treatments (0, 1 and 2 cuttings) on green and seed yield of fenugreek cv. Pusa Early Bunching. Green and seed yield and 1000 seed weight were significantly influenced by different levels of nitrogen phosphorus and number of cuttings. Green yield was maximum at 50 kg N/ha. The highest seed yield and 1000 seed weight were obtained with 50kg N/ha. The maximum green, seed yield and 1000 seed weight were obtained with 60 kg P/ha. Green yield was highest with two cuttings while seed yield and 1000 seed weight were maximum with no cutting.

Tiwari *et al*. (2016) was conducted a field experiment d on clay loam soil at MAPs Block, College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal (Uttarakhand) India during 2015 to evaluate the response of plant spacing on growth and yield of fenugreek. The experiment was conducted in the randomized block design with four replications. In the present investigation, the treatment comprised of the six treatments of plant spacing viz, 5 cm x 10 cm, 10 cm x 10 cm, 15 cm x 10 cm, 20 cm x 10 cm, 25 cm x 10 cm and 30 cm x 10 cm. The highest seed yield (494.45 kg /ha) was obtained with 20 cm x 10 cm plant spacing.

Saxena and Singh (2019) examined the efficiency of FYM and bio fertilizers on growth and yield attributes of fenugreek cv. Rajendra Kanti. For this, a field experiment was carried out in Randomized Block Design with three replications. The experiment was conducted at the Horticulture Research Block of Shri Guru Ram Rai School of Agricultural Sciences, during rabi season of 2017-18 on sandy loam soil at Dehradun. For the experiment, ten treatment combinations are taken viz. T_1-Control, T_2 – NPK@ 40-40-20 kg/ha, T_3 –FYM @5 t/ha, T_4 -FYM @5 t/ha + Rhizobium, T_5 -FYM @5 t/ha + PSB, T_6 –FYM@ 5 t/ha + KSB, T_7 -FYM @5 t/ha + Rhizobium + PSB, T_8 –FYM@ 5 t/ha + Rhizobium + KSB, T_9 -FYM @5 t/ha + PSB + KSB and T_{10} –FYM @5 t/ha + Rhizobium + PSB + KSB. The results revealed that significantly greater values of growth parameters viz., plant height, number of branches, number and dry weight of root nodules, dry matter production, crop growth rate as well as yield attributes viz., number of pods per plant, length of pods, number of seed per pod, seed yield and straw yield were recorded in the treatment T_{10} FYM @5 t/ha + Rhizobium + PSB + KSB) which is being at par with treatments T_2, T_7, T_8 and T_9.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2019 to March 2020 to study the influence of macronutrients (nitrogen, phosphorus & potassium) and spacing on the growth and seed yield of fenugreek. The details of the experimental materials and methods used in this experiment have been described below:

3.1. Site description

3.1.1. Geographical location

The experimental area was situated at 23°41′N and 90^0 22′E longitude at an elevation of 8.6 meter above the sea label.

3.1.2. Agro-Ecological Zone

The location of experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments repressed the dissected edges of the Modhupur tract leaving small hillocks of red soils as "islands" surrounded by floodplain. The location of experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3. Soil

The soil at the experimental site corresponds to the Shallow Red Brown Terrace soils of the Tejgaon series, which is a general soil type. Organic matter makes up 1.08 percent of soil, which has a pH range of 5.47 to 5.63. The experimental zone was flat and above flood level, with an accessible irrigation and drainage infrastructure. Experimental fields yielded soil samples ranging in depth from 0 to 15 cm. Soil Resource and Development Institute (SRDI, Dhaka) analyzed the collected soil sample. Appendix II contains the chemical parameters of the soil.

3.1.4. Climate

The experimental site is located in a subtropical environment with three distinct seasons: the winter season, which runs from November to February, the pre-monsoon period, or hot season, which runs from March to April, and the monsoon season, which runs from May to October. The Weather Station of Bangladesh, Sher-e-Bangla Nagar, provided detailed data on air temperature, relative humidity, rainfall, and sunshine hour during the experiment period, which is reported in Appendix III.

3.2. Test crop and its characteristics

The test crop used for the experiment was BARI Methi-1. After multilocation trials, Bangladesh Agricultural Research Institute (BARI) released this variety for general cultivation with a popular name BARI Methi-1 in the year 2000. The seed was collected from Regional Spices Research Centre, BARI, Joydebpur, Gazipur. The main characteristics are plant height 60-70 cm, number of leaf/primary branch 4-5 and number of pods/plant 40-50, pod length 7-9cm, number of seed/10-12, 1000 seed weight 12.25g, seed color yellowish brown, smooth and oblong. Very low disease and pest infestation. Immature stage green and mature stage brown in color fruit size 7-9cm. Harvesting time – March, yield- 1.2-1.5t/ha.

3.3. Experimental details

3.3.1. Treatments

Two factors were used in the experiment viz. four levels of nutrient combinations (T) and three levels of spacing (S).

Factor A: Four levels of macronutrients

i. $T_0 = N_0P_0K_0$ kg ha^{-1} (control)

ii. $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}

iii. $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}

iv. $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

Factor B: Spacing-3

i. S_1 = 30 ×10 cm

ii. S_2 = 30 × 20 cm

iii. S_3 = 30 × 30 cm

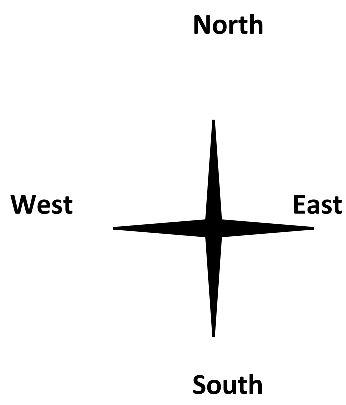
There were 12 (4 × 3) treatment combinations viz., T_0S_1, T_0S_2, T_0S_3, T_1S_1, T_1S_2, T_1S_3, T_2S_1, T_2S_2, T_2S_3, T_3S_1, T_3S_2 and T_3S_3.

3.3.2. Experimental design and layout

The experiment was set up in a three-replication randomized complete block design (RCBD). The experiment's arrangement was developed to distribute a combination of fertilizer doses and spacing, as indicated in Fig.1. The experiment's 12 treatment combinations were assigned to 36 plots. Each unit plot is 1.8 m x 1.5 m in size. Blocks and plots were separated by 1 m and 0.4 m, respectively.

$R_1T_1S_1$	$R_2T_0S_2$	$R_3T_2S_2$
$R_1T_2S_1$	$R_2T_1S_1$	$R_3T_1S_2$
$R_1T_2S_2$	$R_2T_3S_1$	$R_3T_1S_3$
$R_1T_1S_3$	$R_2T_2S_3$	$R_3T_0S_1$
$R_1T_0S_2$	$R_2T_1S_3$	$R_3T_2S_3$
$R_1T_3S_2$	$R_2T_2S_2$	$R_3T_0S_2$
$R_1T_0S_1$	$R_2T_3S_2$	$R_3T_3S_1$
$R_1T_0S_3$	$R_2T_0S_1$	$R_3T_3S_2$
$R_1T_1S_2$	$R_2T_2S_1$	$R_3T_0S_3$
$R_1T_2S_3$	$R_2T_0S_3$	$R_3T_3S_3$
$R_1T_3S_3$	$R_2T_1S_2$	$R_3T_1S_1$
$R_1T_3S_1$	$R_2T_3S_3$	$R_3T_2S_1$

Legend



Treatments

Factor A: Four levels of macronutrients

$T_0 = N_0P_0K_0$ kg ha^{-1} (control)

$T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}

$T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}

$T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

Factor B: Three levels of spacing

$S_1 = 30 \times 10$ cm

$S_2 = 30 \times 20$ cm

$S_3 = 30 \times 30$ cm

Figure 1. Layout of the experimental field

3.4. Growing of crops

3.4.1. Seed collection

The test crop (BARI Mathi-1) seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.4.2. Land preparation

The field was initially ploughed using a tractor-drawn disc plough, and then four times with a power tiller and ladder. Every nook and cranny of the ground had been plowed. After that, the plot was harrowed to improve the tilth of the soil. Using a ladder, the land was then completely leveled. The land was cleared of weeds and stubble. The plot's clods were all shattered into small pieces. Finally, before spreading seed, the unit plots were prepared with a spade.

3.4.3. Manure and fertilizer application

Cow dung was applied at a rate of 10t ha^{-1} during the initial ploughing. The experimental area was fertilized as follow

Fertilizers		**Doses/ha**	**Nutrients**	**Sources**
Cow dung		5t	-	Nature
Urea	T_1	87 kg	40 kg N	$CO(NH_2)_2$
	T_2	174 kg	80 kg N	
	T_3	261 kg	120 kg N	
TSP	T_1	62 kg	30 kg P	$Ca(H_2PO_4)_2$
	T_2	124 kg	60 kg P	
	T_3	186 kg	90 kg P	
MP	T_1	50 kg	30 kg K	KCl
	T_2	100 kg	60 kg K	
	T_3	150 kg	90 kg K	

The full amounts of triple super phosphate and muriate of potash and half of the urea were applied at final land preparation as a basal dose. Rest half of the Urea was applied in two equal splits at 25 and 50 days after seed sowing.

3.4.4. Sowing of seeds

To improve germination, fenugreek seeds were immersed in water for 6 hours. Before sowing, seeds were additionally treated with Bavistin at a dose of 2 g per kilogram of seeds. On November 6th, 2019, Fenugreek seeds were planted in the research field. Hand ploughing was used to sow seeds in rows. The spacing between rows and seeds were calculated based on the treatment variables. Two mature seeds were planted in each spot at a depth of 2–3 cm below the soil surface.

3.4.5. Intercultural operations

3.4.5.1. Thinning

The thinning was done 15 days after sowing on 6^{th} November, 2019 maintaining plant to plant distance as per treatment variables.

3.4.5.2. Weed control

The crop was infested with some weeds during the early stage of crop establishment. Three hand weeding were done; 1^{st}, 2^{nd} and 3^{rd} weeding were done at 15DAS, 30DAS and 50DAS respectively.

3.4.5.3. Irrigation

For good germination water was given to the plots every two days by water can with fine mashed nozzle till germination. Then three irrigations were given at 30, 60 and 90 days after sowing.

3.4.5.4. Plant protection measures

The field was inspected from time to time to discover visual changes between the treatments as well as any weed, insect, or disease infestations, in order to reduce pest losses. With usual green hue flora, the field looked great. There was no evidence of insect assault, but some plots began to rot in the basal area of the plant, which is a symptom of fungal attack. Dithane M-45 was sprayed at 2 g L^{-1} water at 10-day intervals as a control.

3.4.6. Harvesting

Seeds were harvested on 6 March 2020 when pod colour changed into yellowish brown in colour. To avoid shattering of pods, 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.

3.5. Seed quality

The seeds collected in the field experiment were separated. In the laboratory, these seeds were utilized to conduct quality control tests.

3.6. Procedure of recording data

i. **Plant height (cm)**

The height of the 5 selected plants was measured from the ground level to the plant's tip and expressed in centimeter.

ii. **Number of primary branches per plant**

The number of branches on five randomly chosen plants from each plot were counted, and mean values were calculated and reported.

iii. **Days of 50% flowering**

Five plants were tagged in each plot. Five flowering dates were taken, added, and the added values were split by five when five plants flowered. This parameter was given a value of days to 50% flowering.

iv. **Pods plant^{-1}**

Plant^{-1} pods were counted from each of the five plant samples, and the average pod number was calculated.

v. **Pod length**

Ten pods of each of five randomly chosen plants were considered, the length of the pod was measured on a centimeter scale, and the average pod length was computed.

vi. **Seeds pod^{-1}**

Ten pods of each of five randomly chosen plants were considered, and seeds per pod were counted from all of the pods, with the average data used to calculate the number of seeds pod^{-1}.

vii. **1000 seed weight**

Thousand seeds were counted and an electric balance was used to measure weight of thousand seed from every treatment.

viii. **Yield of seed per plant**

Electric Balance was used to determine the seed weight plant^{-1} (g). Seeds from five randomly chosen plants from each unit plot were collected and divided by five to determine seed weight per plant.

ix. **Weight of seed per pod**

The seed weight pod^{-1} (mg) was determined in gram using an electric balance (mg). To calculate the weight of seeds per plant, seeds from five selected plants from each unit plot were gathered and divided by five.

x. **Weight of Single pod**

Pod weight was measured by Electric Precision Balance in gram (g). Five fruits from each treatment were randomly weighted and then divided by five to achieve a single pod weight.

xi. **Yield plot^{-1}**

All plants' seeds were removed and cleaned after they reached maturity, with the exception of 5 selected plants. The seed was then weighed using an electronic balance. Then, to obtain seed yield plot^{-1}, this weight was added to the seed weight of five selected plants.

xii. **Seed yield**

Seed yield plot^{-1} (g) was converted to per hectare yield (kg ha^{-1}).

xiii. **Stover yield**

Stover yield plot^{-1} was converted to per hectare yield.

xiv. **Biological yield**

Biological yield (kg ha^{-1}) was measured by adding seed yield and stover yield.

xv. **Harvest index (%)**

HI was calculated according to the following formula:

Harvest index (%) = seed yield / Biological yield × 100.

xvi. **Total germination (TG %)**

Total germination (TG) was calculated as the number of seeds which was germinated within 15 days as a proportion of number of seeds set for germination test in each treatment.

$$TG(\%) = \frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ seeds\ set\ for\ germination}$$

xvii. **Shoot length of seedling**

Randomly selected 5 seedlings from each treatment were collected and cotyledons were removed from them and shoot was measured with a ruler.

xviii. **Root length of seedling**

Randomly selected 5 seedlings from each treatment were collected and cotyledons were removed from them and root was measured with a ruler.

xix. **Seedling vigor index**

The seedling vigor index was calculated according to the following formula (Abdul-Baki & Anderson, 1973)

Seedling Vigor index (VI) = [(shoot length + root length) × germination percentage]

xx. **Moisture content**

The moisture content (MC) are calculated as percentage (%) by weight (up to one decimal place), using the following formula (Hasanuzzaman).

$$MC\% = \frac{M2-M3}{M2-M1} \times 100$$

Where,

M_1 = weight of the container with cover (g)

M_2 = weight of the container with its cover and seed materials before drying (g)

M_3 = weight of the container with its cover and seed materials after drying (g)

M_2–M_3 = Moisture loss

M_2–M_1= Fresh weight of sample

xxi. **Economic analysis**

The cost of production was analyzed in order to find out the most economic combination different macro nutrient and plant spacing. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interest were calculated @ 14% in simple rate. The wholesale market price of black cumin was considered for estimating the cost and return. The benefit cost ratio (BCR) was calculated as follows:

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

Net income = Gross income – Total cost of production

3.7 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatments by using the Statistix-10 computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Different Test (LSD) at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to evaluate how macronutrients and spacing affected fenugreek growth and seed yield. To determine the growth and seed yield of fenugreek under different nutrient levels and spacing, data on various morphological, yield contributing features, yield, and seed quality were recorded. This chapter summarizes and discusses the experiment's findings.

4.1. Effect on morphological characters

4.1.1 Plant height

The analysis of variance suggested that different levels of macronutrient combinations at different days after sowing (DAS) had a significant effect on plant height (Appendix IV). The height of the plants increased as the plants grew older. T_3 treatment resulted in a maximum plant height of 65.91 cm at 100 DAS. Control (T_0) treatment at 100 DAS, on the other hand, resulted in a minimum height of 56.90 cm. It was noticed that when the content of macro nutrients grew, plant height increased gradually. This could be attributed to increased macronutrient availability and uptake, which improved the plant's vegetative growth over time (Figure 2). According to Datta and Hore (2017), increasing the nitrogen level from N_{40} to N_{80} increased the plant height from 55.04 cm to 64.24 cm, increasing the phosphorus level from P_{60} to P_{100} increased the plant height from 55.98 cm to 63.11 cm, and increasing the potassium level from K_{20} to K_{40} increased the plant height from 56.90 cm to 63.95 cm.

Different plant spacing had a significant effect on fenugreek plant height at 30, 60, 80, and 100 DAS (Appendix IV). The tallest plants (24.14, 46.81, 54.63, and 63.71cm at 30, 60, 80, and 100 DAS, respectively) were discovered in the S_3 (30 x 30 cm) spacing, whereas the smallest plants (23.09, 45.54, 53.05, and 60.01cm at 30, 60, 80, and 100 DAS, respectively) were found in the S_1 (30 x 10 cm) spacing (Figure 3). The increased competition for nutrients, space, and light caused by the denser plant population have resulted in stunted development. Plants with a wider spacing (30 x 30 cm) received the most nutrients, space, and light, resulting in the highest plant height. Tiwari *et al*. (2016) found that as plant spacing increased, plant height rose. Plant spacing of 30 x 10 cm produced the highest plant height compared to all other spacing. With spacing of 5 x 40 cm, the lowest height was observed.

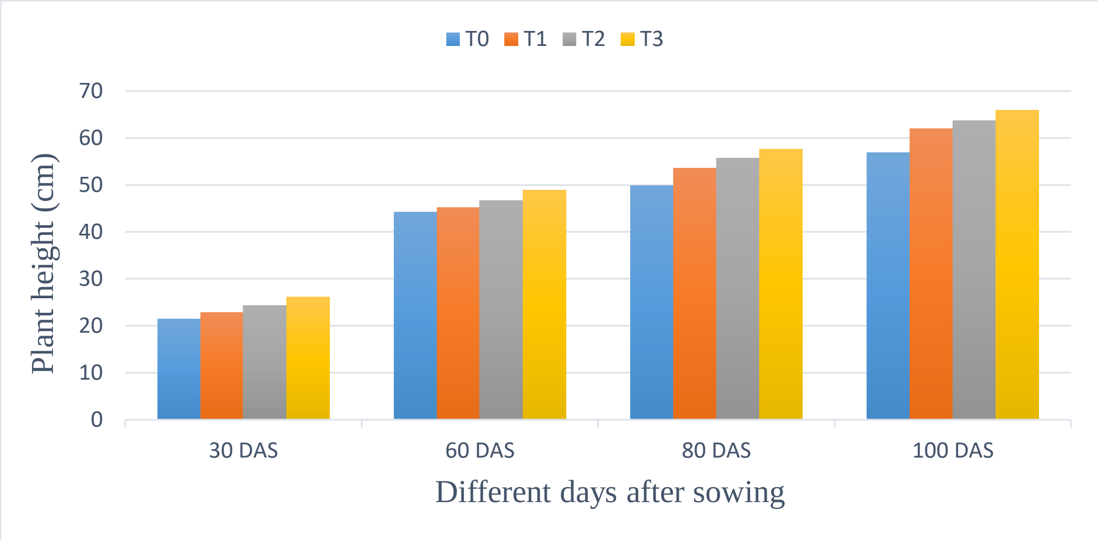


Figure 2. Effect of different nutrients on plant height of fenugreek.
(LSD value= 0.09, 0.08, 0.94 and 0.70 at 30, 60, 80 and 100 DAS respectively), Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

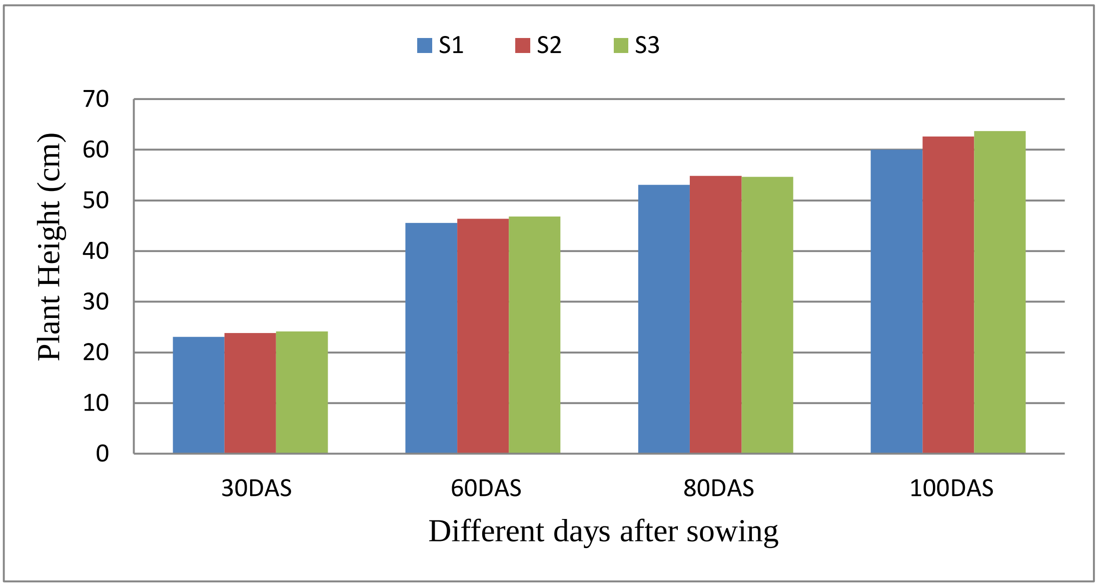


Figure 3: Effect of plant spacing on plant height of fenugreek.
(LSD value= 0.07, 0.07, 0.82 and 0.61 at 30, 60, 80 and 100 DAS respectively)
Note: S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.)

The combined effect of various macro nutrients and spacing demonstrated statistically significant variation in fenugreek plant height (Appendix IV). Plant height grew steadily as macronutrient levels and spacing increased. T_3S_1 treatment combination has a maximum height of 67.01 cm at 100 DAS, which is statistically identical (66.49 cm) to T_3S_2 treatment at 100 DAS (Table 1). T_0S_1 treatment combination at 100 DAS, on the other hand, yielded the shortest plant height (52.44 cm). The synergistic effects of both N and P improve nutrient levels and promote plant growth by promoting meristematic activity, which promotes plant development and ultimately boosts seed, straw, and biological yields. Similar results were reported by Nandal *et al.* (2007), Singh *et al.* (2019) and Deshmukh *et al.* (2020).

Table 1. Combined effect of macro nutrient levels and spacing on plant height at different growth stages of fenugreek.

Treatment	Plant height (cm)			
	30DAS	60DAS	80 DAS	100 DAS
T_0S_1	20.58 i	43.99 j	45.61 i	52.44 i
T_0S_2	21.34 h	44.29 i	50.78 h	57.77 h
T_0S_3	22.31 g	44.43 hi	53.14 g	60.47 g
T_1S_1	22.99 f	45.69 f	53.95 e-g	63.03 cd
T_1S_2	22.97 f	45.51 g	53.77 fg	61.77 ef
T_1S_3	22.44 g	44.47 h	53.03 g	60.95 fg
T_2S_1	24.79 d	46.86 d	55.41 c-e	64.33 b
T_2S_2	24.67 d	46.72 d	56.40 b-d	64.40 b
T_2S_3	23.57 e	46.47 e	55.33 d-f	62.41 de
T_3S_1	26.45 a	50.27 a	57.22 ab	67.01 a
T_3S_2	26.27 b	49.10 b	58.49 a	66.49 a
T_3S_3	25.75 c	47.21 c	57.01 a-c	64.22 bc
$LSD_{(0.05)}$	0.16	0.15	1.64	1.22
CV (%)	0.41	0.19	1.78	1.16

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: T_0 = $N_0P_0K_0$ kg ha^{-1} (control), T_1 = $N_{40}P_{30}K_{30}$ kg ha^{-1}, T_2 = $N_{80}P_{60}K_{60}$ kg ha^{-1}, T_3 = $N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.

4.1.2. Number of primary branches plant^{-1}

The application of different amounts of macronutrients combinations at 30 DAS changed the number of primary branches plant^{-1} of fenugreek significantly (Appendix V). The T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment produced the highest number of primary branches plant^{-1} (3.78). The T_0 (control) treatment, on the other hand, had the smallest number of branches plant^{-1} (2.84) (Table 2). According to Nandal *et al*. (2007), applying 80 kg N/ha and 65 kg P/ha enhanced the number of primary branches plant^{-1} considerably.

The number of primary branches at 30 DAS (days after sowing) was not significantly influenced by spacing (Appendix V).S_2 (30 × 20 cm) treatment yielded the highest number of primary branches (3.4), while S_1 (30 × 10 cm) treatment yielded the lowest number of primary branches (3.3). They are, nonetheless, statistically identical (Table 3). Sharanya *et al.* (2018) found that the 30 ×15 cm treatment resulted in the greatest number of branches.

Table 2: Effect of macronutrient levels on primary branches at 30 DAS (days after sowing) and days to 50% flowering.

Treatment	Primary branches at 30 DAS	Days to 50% flowering
T_0	2.84 d	50.20 d
T_1	3.27 c	54.62 c
T_2	3.53 b	56.42 b
T_3	3.78 a	56.87 a
$LSD_{(0.05)}$	0.18	0.16
CV (%)	5.36	0.30

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

Table 3: Effect of plant spacing on primary branches and days to 50% flowering

Spacing	No. of primary branches	Days to 50% flowering
S_1	3.3	53.98 b
S_2	3.37	54.77 a
S_3	3.4	54.83 a
$LSD_{(0.05)}$	0.15^{NS}	0.14
CV (%)	5.36	0.30

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.)

The combined influence of macronutrient levels and plant spacing produced a significantly different result in terms of the number of primary branches at 30 DAS (Appendix V). T_3S_2 treatment combination had the most primary branches (3.87), which is statistically similar to T_3S_3 (3.80), T_3S_1 (3.67), and T_2S_2 treatments (3.60) combination. T_0S_2 treatment combination, on the other hand, had the lowest branches (2.60), which is statistically similar (2.73) to T_0S_1 treatment (2.73) (Table 4). Mitoo *et al.* (2017) have observed similar findings. They discovered that the application of fertilizer with a dose of 40 kg P ha^{-1} and 20 kg S ha^{-1} at 30 days after sowing (DAS) resulted in the highest number of primary branches $plant^{-1}$

(4.60), while the application of 0.0 kg P ha^{-1} and 0.0 kg S ha^{-1} at 30 DAS resulted in the lowest number of primary branches $plant^{-1}$ (2.80).

Table 4. Combined effect of macronutrient levels and spacing on number of primary branches at 30DAS and days of 50% flowering of fenugreek.

Treatment	No. of primary branches at 30 DAS	Days of 50% flowering
T_0S_1	2.73 gh	49.07 i
T_0S_2	2.60 h	50.40 h
T_0S_3	3.20 ef	51.13 g
T_1S_1	3.33 de	54.13 f
T_1S_2	3.53 b-d	55.13 d
T_1S_3	2.93 fg	54.60 e
T_2S_1	3.47 c-e	56.13 c
T_2S_2	3.60 a-d	56.87 b
T_2S_3	3.53 b-d	56.27 c
T_3S_1	3.67 a-c	56.60 b
T_3S_2	3.87 a	56.67 b
T_3S_3	3.80 ab	57.33 a
$LSD_{(0.05)}$	0.30	0.28
CV (%)	5.36	0.30

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.

4.1.3. Days of 50% flowering

On days of 50% flowering, significant variance was seen due to the treatment of different dosages of macro nutrients (Appendix V). In the T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment, maximum days (56.87 days) were required to reach 50% flowering, whereas minimum days (50.20 days) were required in the T_0 (control) treatment (Table 2).

There was significant difference on days of 50% flowering of fenugreek (Appendix V). S_3 (wider spacing) treatment requires the most days (54.83 days) to reach 50% flowering, which is statistically similar to S_2 (30 × 20 cm) and the least (53.98 days) in the control treatment (Table 3). According to Sharanya *et al*. (2018), the 30 × 15 cm treatment resulted in significantly more days for 50 percent flowering.

On days of 50% flowering, the combined effect of macronutrients and spacing was shown to be significant (Appendix V). T_3S_3 treatment combination required the most days (57.33 days) to reach 50% flowering, while T_0S_1 treatment combination required the least days (49.07 days) to reach 50% flowering (Table 4).

4.2. Yield contributing characters

4.2.1. Pods plant^{-1}

In fenugreek, one of the most important yield contributing features is the number of pods per plant. On the basis of the number of pods plant^{-1}, the macronutrient levels varied significantly (Appendix VI). T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment had the highest number of pods plant^{-1} (49.96), followed by T_2 (49.09) and T_1 (45) treatments. T_0 treatment yielded the smallest number of pods plant^{-1} (30.27) (Table 5). These findings showed that different levels of macro nutrients provided plant nutrients and improved growing circumstances, resulting in appropriate vegetative growth and a maximum number of pods per plant.

Because of the variance in spacing, the number of pods plant^{-1} changed greatly, and as the spacing rose, the number of pods plant^{-1} increased significantly (Appendix VI). The S_3 (30 × 30 cm) treatment yielded the highest number of pods plant^{-1} (46.18), whereas the S_1 (30 x 10 cm) treatment yielded the lowest number (41.00) (Table 6). Wider spacing produced more pods plant^{-1} than closer spacing, owing to the fact that wider spacing allowed for the most efficient use of solar energy and other natural resources, resulting in more dry matter plant^{-1}.

The combined influence of macronutrients and spacing resulted in a considerable difference in the number of pods per plant^{-1}. (Appendix VI). With the addition of fertilizer and space, the number of pod plant^{-1} rose progressively. The T_3S_3 treatment combination produced the highest number of pod plant^{-1} (50.80), which was statistically similar to the T_3S_2 (50.13) treatment combination. The T_0S_1 treatment combination, on the other hand, produced the smallest number of pod plant^{-1} (25.13) (Table 7).. Datta and Hore (2017) discovered that the $N_{60}P_{80}K_{40}$ combination produced the most pods plant^{-1}.

Table 5: Effect of macronutrient levels on pod per plant, pod length, seed per pod & 1000 seed weight

Treatment	Pod per plant	Pod length (cm)	Seed per pod	1000 seed weight (g)
T_0	30.27 d	9.48 d	10.16 d	11.91 d
T_1	45.00 c	10.21 c	11.11 c	11.97 c
T_2	49.09 b	10.41 b	12.58 b	12.10 b
T_3	49.96 a	11.71 a	13.87 a	12.30 a
$LSD_{(0.05)}$	0.41	0.05	0.15	0.01
CV (%)	0.96	0.49	1.27	0.11

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

Table 6: Effect of plant spacing on pod per plant, pod length, seed per pod & 1000 seed weight

Treatment	Pod per plant	Pod length (cm)	Seed per pod	1000 seed weight (g)
S_1	41.00 c	10.11 c	11.67 c	12.03 c
S_2	43.55 b	10.54 b	11.95 b	12.07 b
S_3	46.18 a	11.69 a	12.17 a	12.10 a
$LSD_{(0.05)}$	0.35	0.04	0.13	0.01
CV (%)	0.96	0.49	1.27	0.11

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.)

4.2.2. Pod length

The application of different levels of macro nutrients led to significant differences in pod length (Appendix VI). T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment had the longest pod length (11.70cm), followed by T_2 (10.41cm) and T_1 (10.21cm) treatments. T_0 (9.48cm) treatment yielded the shortest pod length. It's possible that optimal plant nutrition levels have a greater effect in vegetative growth and increasing pod length (Table 5). Purbey and Sen (2005) discovered that when Rhizobium and phosphate solubilizing bacteria were inoculated together, the largest average pod length (13.13 cm) was achieved. Sharanya *et al.* (2018), Singh *et al.* (2019), and Yousuf and Nayak (2018) all reported that nutrients enhanced pod length.

Table 7. Combined effect of macronutrient levels and spacing on pods per plant, pod length, seeds per pod and 1000 seed weight of fenugreek.

Treatment	Pod per plant	Pod length (cm)	Seed per pod	1000 seed weight (g)
T_0S_1	25.13 i	8.88 j	10.00 i	11.89 j
T_0S_2	30.27 h	9.59 i	10.07 i	11.92 i
T_0S_3	35.40 g	9.97 h	10.40 h	11.91 i
T_1S_1	42.47 f	10.14 g	10.93 g	11.95 h
T_1S_2	44.07 e	10.23 f	11.13 fg	11.96 h
T_1S_3	48.47 c	10.27 ef	11.27 f	11.99 g
T_2S_1	47.47 d	10.35 de	12.13 e	12.03 f
T_2S_2	49.73 b	10.39 d	12.67 d	12.13 e
T_2S_3	50.07 b	10.47 c	12.93 c	12.16 d
T_3S_1	48.93 c	11.09 b	13.60 b	12.25 c
T_3S_2	50.13 ab	11.97 a	13.93 a	12.30 b
T_3S_3	50.80 a	12.05 a	14.07 a	12.33 a
$LSD_{(0.05)}$	0.71	0.09	0.26	0.02
CV (%)	0.96	0.49	1.27	0.11

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.

Pod length of fenugreek differed significantly due to plant spacing (Appendix VI). Pod length increased steadily with increases of spacing. This might be due to lower plant density that progressively enhanced the reproductive growth of the plant. However, the maximum pod length (10.69cm) was recorded from S_3 (30 × 30 cm) treatment while the minimum (10.11cm) was recorded from S_1 (30 × 10 cm) treatment (Table 6).

The combination of macronutrient levels and spacing had a significant influence on pod length (Appendix VI). The maximum pod length (12.05 cm) was recorded in T_3S_3 treatment combination which is statistically identical (11.97 cm) to T_3S_2 treatment combination. On the other hand, the minimum pod length (8.88) was observed in T_0S_1 treatment combination (Table 7). Güzel *et al.* (2021) found pod length of fenugreek from 10.07 to 12.60 cm in the semiarid climate of Turkey.

4.2.3. Seeds pod^{-1}

The application of varying levels of macronutrient had a significant impact on the number of seeds pod^{-1}(Appendix VI). The maximum number of seeds pod^{-1} (13.87) was obtained from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment closely followed by T_2 and T_1 treatments respectively. The minimum number of seeds pod^{-1} (10.16) was produced by T_0 treatment (Table 5). This results revealed that number of seeds per pod increased with increasing levels of NPK application.. By increasing essential elements, no. of seeds per pod will increase. Similarly reported by Singh *et al.* (2019), Güzel *et al.* (2021) and Yousuf and Nayak (2018).

Number of seeds pod^{-1} differed significantly due to variation of plant spacing and as the spacing increased, the weight of seeds plant^{-1} increased significantly (Appendix VI). The maximum seeds pod^{-1} (12.17) was found from the wider spacing of S_3 (30 cm x 30 cm) treatment closely followed by S_2 (11.95) treatment and the minimum (11.67) was found from the closer spacing of S_1 (30 cm x 10 cm) treatment (Table 6). Kumar *et al.* (2018) reported maximum seeds per pod at 40 cm row spacing, while Sharanya *et al.* (2018) reported that a 30 cm ×15 cm treatment recorded a significantly higher number of seeds per pod.

The combined management of macronutrients and plant spacing had signicant effect on the number of seeds per pod (Appendix VI). The maximum number of pods per plant (14.07) was recorded from T_3S_3 treatment combination which is statistically similar (13.93) to T_3S_2 treatment combination. The minimum number of pods per plant (10.00) was recorded from T_0S_1 treatment combination which is statistically similar (10.07) to T_0S_2 treatment combination (Table 7). Verma *et al.* (1995) reported that Rhizobium inoculation and application of FYM and chemical fertilizers had significantly increased number of seeds per pod.

4.2.4. 1000 seed weight

Due to macronutrient levels, statistically significant changes in thousand seed weight of fenugreek were observed (Appendix VI). The table indicates that seed weight increased with the increase of macronutrient levels. The maximum weight of thousand seeds (12.30 g) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment and followed by T_2 (12.10 g) and T_1 (11.97 g) treatments respectively. The minimum weight of thousand seed (11.91 g) was recorded from T_0 (control) treatment (Table 5). Similar result was found by Thapa and Maity (2004).They obtained that thousand-seed weight (14.4 g) was obtained from increasing nitrogen levels up to 50 kg N ha^{-1}.

Due to spacing, a statistically significant difference in fenugreek thousand seed weight was detected (Appendix VI). The maximum weight of thousand seeds (12.10 g) was recorded from S_3 (30 × 30 cm) treatment. The minimum weight of thousand seeds (12.03 g) was recorded from S_1 (30 × 10 cm) treatment. Here, they were almost same but statistically different (Table 6).

The combined effect of macronutrient levels and plant spacing resulted in a significant difference in fenugreek thousand seed weight (Appendix VI). The maximum weight of thousand seeds (12.33 g) was recorded from the combination of T_3S_3 treatment which was statistically different to T_3S_2 (12.30 g), T_3S_1 (12.25 g) treatment combination. The minimum weight of thousand seeds (11.89 g) was recorded from the T_0S_1 treatment combination (Table 7). different nutrient levels have different effects on 1000 seed weight .1000 seed weight were observed differently such as 13.87 to 17.45 g, 11.32 g to 11.99 g and 14.9 g to 16.8 g by Güzel *et al.* (2021), AL-Saidi (2017) and Arslan (1994) respectively.

4.2.5. Single pod weight

The impact of macronutrient levels on the weight of a single fenugreek pod was similarly substantial (appendix VII). It was observed from the table that single pod weight (g) increased gradually with the increase of fertilizer doses. The maximum single pod weight (5.63g) was produced from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment. On the other hand, the minimum (3.25g) was observed in T_0 (control) treatment (Table 8).

Because of the plant spacing, there was a significant fluctuation in single pod weight (Appendix VII). It was observed from the figure that single pod weight increased gradually with the increasing plant spacing due to lower number of plant. Among the different spacing, S_3 (30 × 30 cm) treatment showed the maximum weight (4.45g). On the other hand, the minimum weight (3.90g) was observed in the S_1 (30 × 10 cm) treatment (Table 9).

The weight of a single pod was significantly affected by the combination of different macronutrient amounts and spacing (Appendix VII). The maximum single pod weight (6.19g) was observed in T_3S_3 treatment combination and followed by T_3S_2 (5.56g) and T_3S_1 (5.15g) treatment combinations respectively. On the other hand, the minimum single pod weight (3.09g) was recorded with T_0S_1 treatment (Table 10).

Table 8: Effect of macronutrient levels on single pod weight, weight of seed per pod & seed yield per plant

Treatment	Single pod weight (g)	Weight of seed per pod (mg)	Seed yield per plant (g)
T_0	3.25 d	68.41 d	2.08 d
T_1	3.53 c	97.36 c	4.01 c
T_2	4.30 b	109.63 b	4.97 b
T_3	5.63 a	121.01 a	5.70 a
$LSD_{(0.05)}$	0.07	0.50	0.02
CV (%)	1.70	0.52	0.51

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

Table 9: Effect of plant spacing on single pod weight, weight of seed per pod & seed yield per plant

Treatment	Single pod weight (g)	Weight of seed per pod (mg)	Seed yield per plant (g)
S_1	3.90 c	95.33 c	3.76 c
S_2	4.19 b	98.68 b	4.23 b
S_3	4.45 a	103.29 a	4.57 a
$LSD_{(0.05)}$	0.06	0.43	0.02
CV (%)	1.70	0.52	0.51

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.)

4.2.6. Weight of seed per pod

Fertilizers have a significant impact on the weight of seed per pod of fenugreek (Appendix VII). The maximum seed weight per pod (121.01mg) was recorded from the T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment while the minimum (68.41mg) was found in the T_0 (control) treatment. It was observed that seed per pod increased gradually with the increase of fertilizer doses (Table 8).

Plant spacing caused a statistically significant variation in the weight of seed per pod of fenugreek (Appendix VII). The maximum weight of seed per pod (103.29mg) was recorded from S_3 (30 × 30 cm) treatment. The minimum weight of seed per pod (95.33mg) was recorded from S_1 (30 × 10 cm) treatment (Table 9). seed per pod increased gradually with the increase of macronutrient levels and spacing. This might be due to higher availability of fertilizer and their uptake with the combination of lower plant density that progressively enhanced the reproductive growth of the plant The maximum weight of seed per pod (123.96mg) was recorded from the combination of T_3S_3 treatment followed by T_3S_2 (121.88mg) and T_3S_1 (117.19mg) treatment combination respectively. The minimum weight of seed per pod (65.12mg) was found T_0S_1 treatment combination (Table 10).

Table 10. Combined effect of macronutrient levels and plant spacing on single pod weight, weight of seed per pod and seed yield per plant of fenugreek.

Treatment	Single pod weight (g)	Weight of seed per pod (mg)	Seed yield per plant (g)
T_0S_1	3.09 j	65.12 l	1.63 l
T_0S_2	3.31 i	67.25 k	2.04 k
T_0S_3	3.35 i	72.86 j	2.57 j
T_1S_1	3.43 hi	93.16 i	3.20 i
T_1S_2	3.54 gh	95.30 h	4.20 h
T_1S_3	3.63 g	103.61 g	4.62 g
T_2S_1	3.92 f	105.87 f	4.75 f
T_2S_2	4.35 e	110.29 e	4.98 e
T_2S_3	4.62 d	112.72 d	5.19 d
T_3S_1	5.15 c	117.19 c	5.45 c
T_3S_2	5.56 b	121.88 b	5.72 b
T_3S_3	6.19 a	123.96 a	5.91 a
$LSD_{(0.05)}$	0.12	0.87	0.04
CV (%)	1.70	0.52	0.51

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.

4.2.7. Seed yield per plant

Because of the effect of macronutrient levels on seed yield per plant of fenugreek, a statistically significant difference was observed (Appendix VII and Table 8).The table indicates the higher of macronutrient levels gave the maximum and yield per plant. The maximum seed yield per plant (5.70g) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment followed by T_2 (4.97g) and T_1 (4.01g) treatment. The minimum amount (2.08 g) was recorded from T_0 (control) treatment. This might be due to optimum N, P and K levels increase of photosynthesis rate and translocation of food to seed.

Plant spacing caused a significant difference in fenugreek seed yield per plant (Appendix VII). It was observed from the figure that weight of seed per plant increased steadily with increases of spacing. This might be due to lower plant density that progressively enhanced the reproductive growth of the plant. However, the highest seed yield per plant (4.57g) was recorded from S_3 (30 × 30 cm) treatment, which was statistically different (4.23g) to S_2 (30 × 20 cm) treatment. The lowest amount (3.76g) was found S_1 (30 × 10 cm) treatment (Table 9). The fenugreek plants enjoyed more space, light and nutrient and other environmental factors that resulted higher weight of seeds plant for wider spacing compared to closer spacing. This implies that an intra- row spacing of 30 cm x 10 cm was best for a seed crop of fenugreek and beyond that was ineffective and not beneficial. Similar kinds of result have also been reported by Tuncturk (2011), Sahu *et al.* (2020.

The combined application of macronutrient levels and plant spacing greatly influenced seed production per plant of fenugreek (Appendix VII and Table 10). The result indicated that seed yield per plant increased gradually with the increase of macronutrient levels and spacing. This might be due to higher availability of fertilizer and their uptake with the combination of lower plant density that progressively enhanced the reproductive growth of the plant. The maximum seed yield per plant (5.91g) was recorded from the combination of T_3S_3 treatment followed by T_3S_2 and T_3S_1 treatment combination respectively. The minimum seed yield per plant (1.63g) was found T_0S_1 treatment.. Nitrogen levels might be attributed to the increased photosynthetic activities, translocation and accumulation of photo-syntheses from source to the developing seeds (sinks) resulting into higher seed yield of bolder and heavier seeds.

4.3. Yield parameter

4.3.1. Seed yield per plot

Due to the treatment of different macro nutrients levels, a statistically significant difference in seed yield per plot of fenugreek was identified (Appendix VIII). It was observed that seed yield per plot increased gradually with the increase of macro nutrients level. This might be due to higher availability of N, P_2O_5 & K_2O and their uptake that progressively enhanced the reproductive growth of the plant. The maximum seed yield (332.12 g) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment and the minimum seed yield (107.96 g) was observed from T_0 (control) treatment (Table 11). Similarly seed yield per plot found to be increased with an increasing level of nitrogen were reported by Aher *et al.* (2010).

Plant spacing caused a statistically significant variation in seed production per plot (Appendix VIII). The result indicated that seed yield reduced steadily with the increase of plant spacing. The maximum seed yield per plot (353.20g) was recorded from S_1 (30 × 10 cm) treatment. The minimum seed yield per plot (158.28g) was recorded from S_3 (30 × 30 cm) treatment (Table 12). The increase in grain yield at higher plant densities was mainly due to the increased number of plants per unit area, which ultimately helped to produce higher yield.

Combined application of macronutrients level and plant spacing revealed significant variation in seed yield per plot of fenugreek (Appendix VIII). It can be inferred from the table that seed yield increased gradually with the increase of fertilizer doses and higher plant density. This might be due to higher availability of fertilizer and their uptake with the combination of higher plant density that progressively enhanced the fenugreek seed yield. The maximum seed yield per plot (495.39 g) was recorded from the combination of T_3S_1 treatment and followed by T_2S_1 (434.19 g) and T_1S_1 (341.83 g) treatment combination respectively. The minimum seed yield per plot (112.10 g) was recorded from the combination of T_0S_3 treatment (Table 13). The seed yield per plot found to be increased by increasing essential macro nutrients were similarly reported by Nandal *et al.* (2007), Singh *et al.* (2019) and Muhammed *et al.* (2018).

4.3.2. Seed yield

Due to the application of different macronutrient levels, a statistically significant difference in seed production of fenugreek was reported (Appendix VIII). It was observed that seed yield increased gradually with the increase of macro nutrients level. This might be due to higher availability of N, P_2O_5 & K_2O and their uptake that progressively enhanced the reproductive growth of the plant. The maximum seed yield (1142.8 kg/ha) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment and the minimum seed yield (389.0 kg/ha) was observed from T_0 (control) treatment (Table 11). Result similarly found by Sudeep *et al.* (2009).

Because of plant spacing, there was a statistically significant variation in fenugreek seed production (Appendix VIII). The result indicated that seed yield reduced steadily with the increase of spacing. The maximum seed yield (1251.9 kg/ha) was recorded from S_1 (30 × 10 cm) treatment. The minimum seed yield (508.0 kg/ha) was recorded from S_3 (30 × 30 cm) treatment. The increase in grain yield at higher plant densities was mainly due to the increased number of plants per unit area, which ultimately helped to produce higher yield (Table 12).. similarly Rana *et al.* (2015) reported lower spacing for higher seed yield.

Table 11: Effect of macronutrient levels on seed yield per plot, seed yield, stover yield, biological yield & harvest index

Treatment	Seed yield per plot (g)	Seed yield (kg/ha)	Stover yield (kg/ha)
T_0	107.96 d	389.0 d	684.01 d
T_1	236.21 c	759.6 c	800.37 c
T_2	294.53 b	996.0 b	842.22 b
T_3	332.12 a	1142.8 a	865.49 a
$LSD_{(0.05)}$	1.94	5.45	2.95
CV (%)	0.82	0.68	0.38

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

Table 12: Effect of plant spacing on seed yield per plot, seed yield, stover yield, biological yield & harvest index

Treatment	Seed yield per plot (g)	Seed yield (kg/ha)	Stover yield (kg/ha)
S_1	353.20 a	1251.9 a	1271.4 a
S_2	216.63 b	705.6 b	669.7 b
S_3	158.28 c	508 c	453 c
$LSD_{(0.05)}$	1.68	4.72	2.55
CV (%)	0.82	0.68	0.38

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.)

Seed yield of fenugreek varied significantly as a result of the combined influence of differing quantities of macro nutrients and plant spacing (Appendix VIII). It can be inferred from the table that seed yield increased gradually with the increase of fertilizer doses and higher plant density. This might be due to higher availability of fertilizer and their uptake

Table 13. Combined effect of macronutrient levels and spacing on seed yield per plot, seed yield, stover yield of fenugreek.

Treatment	Seed yield per plot (g)	Seed yield(kg/ha)	Stover yield(kg/ha)
T_0S_1	141.41 i	542.2 i	1006.7 d
T_0S_2	118.64 j	439.4 k	619.4 h
T_0S_3	112.10 k	415.2 l	425.9 l
T_1S_1	341.83 c	1065.6 c	1301.1 c
T_1S_2	204.08 f	699.4 f	656.7 g
T_1S_3	162.70 h	513.7 j	443.3 k
T_2S_1	434.19 b	1582.2 b	1367.8 b
T_2S_2	266.57 e	829.4 e	693.3 f
T_2S_3	182.84 g	576.3 h	465.6 j
T_3S_1	495.39 a	1817.8 a	1410.0 a
T_3S_2	296.95 d	953.9 d	709.4 e
T_3S_3	204.01 f	656.7 g	477.0 i
$LSD_{(0.05)}$	3.37	9.44	5.11
CV (%)	0.82	0.68	0.38

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: T_0 = $N_0P_0K_0$ kg ha^{-1} (control), T_1 = $N_{40}P_{30}K_{30}$ kg ha^{-1}, T_2 = $N_{80}P_{60}K_{60}$ kg ha^{-1}, T_3 = $N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.

with the combination of higher plant density that progressively enhanced the fenugreek seed yield. The maximum seed yield (1817.8 kg/ha) was recorded from the combination of T_3S_1 treatment and followed by T_2S_1 (1582.2 kg/ha) and T_1S_1 (1065.6 kg/ha) treatment combination respectively. The minimum seed yield (415.2 kg/ha) was recorded from the combination of T_0S_3 treatment (Table 13). The seed yield (kg/ha) found to be increased by increasing essential macro nutrients and spacing were similarly reported by Deepak *et al.*(2000), Deshmukh *et al.* (2020) and Singh *et al.* (2010).

4.3.3. Stover yield

The influence of different quantities of macro nutrients on fenugreek stover yield was similarly significant (appendix VIII). It was observed that stover yield increased gradually with the increase of fertilizer doses. The maximum yield of stover (865.49 kg/ha) was produced from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment. On the other hand, the minimum yield of stover (684.01 kg/ha) was observed in T_0 (control) treatment (Table 11). Mitoo *et al.* (2017) found the highest weight of straw plot^{-1} (172.59g) from the application of fertilizer with the dose of 40kg P ha^{-1} and 20kgS ha^{-1}. Singh *et al.* (2019) found straw yield in 30 kg N/ha and 40 kg P/ha.

Plant spacing has a substantial impact on the stover yield of fenugreek (Appendix VIII). It was observed that stover yield increased gradually with the decreased spacing due to higher number of plant. The increase in stover yield at higher plant densities was mainly due to the increased number of plants per unit area, which ultimately helped to produce higher yield. The maximum stover yield (1271.4 kg/ha) was recorded from the S_1 (30 × 10 cm) treatment while, the minimum stover yield (453 kg/ha) was found in the S_3 (30 × 10 cm) treatment (Table 12).

On fenugreek stover yield, the combined effect of different levels of macro nutrients and plant spacing was significant (Appendix VIII). It can be inferred that stover yield increased gradually with the increase of fertilizer doses and higher plant density. This might be due to higher availability of fertilizer and their uptake with the combination of higher plant density that progressively enhanced the stover yield of the plant. The maximum stover yield (1410 kg/ha) was recorded from the combination of T_3S_1 treatment. The minimum stover yield (425.9 kg/ha) was found in the combination of T_0S_3 treatment (Table 13). Patel *et al.* (2014) reported that combined application of 50% RDN through castor cake along with *rhizobium*+PSB seed inoculation recorded significant improvement in stover yields of fenugreek

4.3.4. Biological yield

Because of the different levels of macronutrients, a statistically significant variation in biological yield of fenugreek was discovered (Appendix VIII). It was observed that biological yield increased gradually with the increase of fertilizer doses. This might be due to higher availability of N, P_2O_5 & K_2O and their uptake that progressively enhanced the reproductive growth of the plant. The maximum biological yield (2008.3 kg/ha) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment and the minimum biological yield (1073 kg/ha) was observed from T_0 (control) treatment (Table 14). Awasthi *et al*. (2020) found that the application of 30 kg K_2O recorded significantly maximum biological yield.

The plant spacing has a significant impact on the biological yield of fenugreek (Appendix VIII). It was observed that biological yield decreased gradually with the increase of plant spacing due to lower number of plant per unit area. Among the different spacing, S_1 (30 × 10 cm) treatment showed the maximum yield (2523.3 kg/ha). On the other hand, the minimum biological yield (960.9kg/ha) was observed in the S_3 (30 × 30 cm) treatment (Table 15).

Table 14: Effect of macronutrient levels on biological yield and harvest index (%)

Treatment	Biological yield (kg/ha)	Harvest index (%)
T_0	1073.0 d	36.83 d
T_1	1559.9 c	50.09 c
T_2	1838.2 b	54.48 b
T_3	2008.3 a	57.20 a
$LSD_{(0.05)}$	4.8622	0.18
CV (%)	0.31	0.36

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

On the biological yield of fenugreek, the combined influence of different quantities of macro nutrients and plant spacing was significant (Appendix VIII).It can be inferred from the table that biological yield increased gradually with the increase of fertilizer doses and higher plant density. This might be due to higher availability of fertilizer and their uptake with the combination of higher plant density that progressively increase the biological yield of the plant. The maximum biological yield (3227.8 kg/ha) was observed in T_3S_1 treatment combination. On the other hand, the minimum biological yield (711.1 kg/ha) was recorded with T_0S_3 treatment combination (Table 16). Saxena *et al*. (2019) reported that the seed yield, stover yield and biological yield were also recorded significantly higher in treatment T_{10} (FYM @5 t/ha + Rhizobium + PSB + KSB), T_2 N-P_2O_5-K_2O @40-40-20 kg/ha). These observations might be attributed due to application of FYM which helps to increase the photosynthetic activity in fenugreek and the translocation of photosynthesis in plant. Improvement of all the yield parameters might be due to the better availability of nutrients and their translocation resulted in significantly higher seed and stover yield in fenugreek. Singh *et al.* (2019) indicated highest biological yield found in 30 kg N/ha and 40 kg P/ha.

Table 15: Effect of plant spacing on biological yield & harvest index (%)

Treatment	Biological yield (kg/ha)	Harvest index (%)
S_1	2523.3 a	47.50 c
S_2	1375.3 b	49.70 b
S_3	960.9 c	51.75 a
$LSD_{(0.05)}$	4.21	0.15
CV (%)	0.31	0.36

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.)

4.3.5. Harvest index (%)

The application of different levels of macronutrients resulted in a significant change in harvest index (%) (Appendix IX). It was observed that harvest index (%) increased gradually with increasing fertilizer doses. This might be due to higher availability of fertilizer that progressively increase the harvest index of the plant .The maximum harvest index (57.20 %) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment while, the minimum harvest index (36.83%) was found in T_0 (control) treatment (Table 14).

A significant difference was found in harvest index due to plant spacing (Appendix IX). It was observed that harvest index increased gradually with increasing plant spacing. This might be due to lower plant density that progressively increases the harvest index of the plant. The maximum harvest index (51.75 %) was recorded from S_3 (30 × 30 cm) treatment while, the minimum harvest index (47.50 %) was found from S_1 (30 × 10 cm) treatment (Table 15).gradually with the increase of fertilizer doses and lower plant density. This might be due to higher availability of fertilizer and their uptake with the combination of lower plant density that progressively increase the harvest index of the plant. Each combination was different one another in harvest index. The minimum harvest index was (35.01%) produced from T_0S_1 treatment combination (Table 16). Sahu *et al*. (2020) found maximum harvest index (40.59%) from the treatment of 50% RDF + Neem cake @ 1 ton ha^{-1} + Rhizobium + PSB.

4.4. Seed quality parameter

4.4.1. Total germination (%)

Because different levels of macronutrients were used, there was a significant difference in fenugreek germination percentage (Appendix IX). The maximum germination percentage (80.30 %) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment and followed by T_2

(76.77%).The minimum germination percentage (68.69%) was taken from T_0 (control) treatment, which was statistically similar to (70.20%) T_1 treatment (Table 17).

Table 16. Combined effect of macronutrient levels and spacing on biological yield and harvest index (%) of fenugreek.

Treatment	Biological yield(kg/ha)	Harvest index (%)
T_0S_1	1548.9 e	35.01 k
T_0S_2	958.9 j	35.40 j
T_0S_3	711.1 k	40.10 i
T_1S_1	2366.7 c	45.02 h
T_1S_2	1356.1 g	51.58 g
T_1S_3	957.0 j	53.68 f
T_2S_1	2950.0 b	53.64 f
T_2S_2	1522.8 f	54.47 e
T_2S_3	1041.8 i	55.32 d
T_3S_1	3227.8 a	56.32 c
T_3S_2	1663.3 d	57.35 b
T_3S_3	1133.7 h	57.92 a
$LSD_{(0.05)}$	8.42	0.31
CV (%)	0.31	0.36

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.

No significant variation was found on germination percentage of fenugreek due to plant spacing (Appendix IX). The highest germination percentage (75.00%) was recorded from S_3 (30 × 30 cm) treatment which was statistically identical to S_1 (73.86%) and S_2 (73.11%) treatment (Table 18). Sharanya *et al.*(2018) recorded 30×15 cm treatment significantly maximum germination percentage of fenugreek.

The combined effect of macro nutrients and plant spacing on germination percentage of fenugreek was significantly different (Appendix IX). It showed that the maximum germination percentage (81.82%) in T_3S_3 treatment combination was statistically similar to T_3S_2 (80.30%), T_3S_1 (78.78%) and T_2S_1 (78.79%) treatment combination (Table 19).

4.4.2. Shoot length

There was significant variation on shoot length of fenugreek due to application of different macronutrient levels (Appendix IX).The highest shoot length (10.65 cm) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment and followed by T_2 (9.59 cm) and T_1 (9.02 cm) treatment respectively. On the other hand, the lowest shoot length (7.22 cm) was taken from T_0 (control) treatment (Table 17).

Significant variation was found on shoot length of fenugreek due to plant spacing (Appendix IX).The highest shoot length (9.43cm) was recorded from S_3 (30 × 30 cm) treatment and followed by S_2 (9.31cm) treatment .The lowest shoot length (8.62 cm) was taken from S_1 (30 × 10 cm) treatment (Table 18).

Table 17: Effect of macronutrient levels on total germination %, shoot length and root length.

Treatment	Total germination (%)	Shoot length (cm)	Root length (cm)
T_0	68.69 c	7.22 d	4.62 d
T_1	70.20 c	9.02 c	5.18 c
T_2	76.77 b	9.59 b	5.92 b
T_3	80.30 a	10.65 a	6.88 a
LSD	3.28	0.05	0.03
CV (%)	4.53	0.51	0.53

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

Table 18: Effect of plant spacing on total germination %, shoot length and root length.

Treatment	Total germination (%)	Shoot length (cm)	Root length (cm)
S_1	73.86	8.62 c	5.39 c
S_2	73.11	9.31 b	5.68 b
S_3	75.00	9.43 a	5.88 a
LSD	2.84^{NS}	0.04	0.03
CV (%)	4.53	0.51	0.53

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.)

The combined effect of macronutrient levels and plant spacing on shoot length of fenugreek was significant (Appendix IX).Maximum shoot length (10.92 cm) was found in T_3S_3 treatment combination and closely followed by T_3S_2 (10.63 cm) and T_3S_1 (10.40 cm) treatment combination. In contrast, minimum shoot length (6.51 cm) in T_0S_1 treatment combination was very close to T_0S_2 (7.42 cm), T_0S_3 (7.73 cm) and T_1S_1 (8.21 cm) treatment combination respectively (Table 19).

Table 19. Combined effect of macronutrient levels and spacing on total germination (%), shoot length and root length

Treatment	Total germination (%)	Shoot length (cm)	Root length (cm)
T_0S_1	68.18 d	6.51 l	4.47 l
T_0S_2	66.67 d	7.42 k	4.63 k
T_0S_3	71.21 cd	7.73 j	4.77 j
T_1S_1	69.70 d	8.21 i	4.97 i
T_1S_2	69.70 d	9.55 f	5.23 h
T_1S_3	71.21 cd	9.29 h	5.33 g
T_2S_1	78.79 ab	9.37 g	5.57 f
T_2S_2	75.76 bc	9.65 e	5.93 e
T_2S_3	75.76 bc	9.76 d	6.27 d
T_3S_1	78.78 ab	10.40 c	6.57 c
T_3S_2	80.30 ab	10.63 b	6.93 b
T_3S_3	81.82 a	10.92 a	7.13 a
$LSD_{(0.05)}$	5.67	0.08	0.05
CV (%)	4.53	0.51	0.53

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.

4.4.3. Root length

There was significant variation on root length of fenugreek due to application of different macronutrient levels (Appendix IX).The highest root length (6.88 cm) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment and followed by T_2 (5.92 cm) and T_1 (5.18 cm) treatment respectively. On the other hand, the lowest root length (4.62 cm) was taken from T_0 (control) treatment (Table 17).

Significant variation was found on root length of fenugreek due to plant spacing (Appendix IX).The highest root length (5.88 cm) was recorded from S_3 (30 × 30 cm) treatment and followed by S_2 (5.68 cm) treatment .The lowest root length (5.39 cm) was taken from S_1 (30 × 10 cm) treatment (Table 18).

The combined effect of macronutrient levels and plant spacing on root length of fenugreek was significant (Appendix IX).Maximum root length (7.13 cm) was found in T_3S_3 treatment combination and closely followed by T_3S_2 (6.93 cm), T_3S_1 (6.57 cm) and T_2S_3 (6.27 cm) treatment combination. In contrast, minimum root length (4.47 cm) in T_0S_1 treatment combination was very close to T_0S_2 (4.63 cm), T_0S_3 (4.77 cm) and T_1S_1 (4.96 cm) treatment combination (Table 19).

4.4.4. Seedling vigor index

There was significant variation on seedling vigor index of fenugreek due to application of different macronutrient levels (Appendix X).The highest seedling vigor index (14.08) was recorded from T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) treatment and followed by T_2 (11.90) and T_1 (9.97).On the other hand, the lowest seedling vigor index (8.14) was taken from T_0 (control) treatment (Table 20).

Table 20: Effect of macronutrient levels on seedling vigor index & dry matter content

Treatment	Seedling vigor Index	Dry matter content (%)
T_0	8.14 d	91.04
T_1	9.97 c	90.88
T_2	11.90 b	90.96
T_3	14.08 a	90.54
LSD	0.50	0.60^{NS}
CV (%)	4.64	0.68

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

Significant variation was found on seedling vigor index of fenugreek due to spacing (Appendix X).From the figure, the highest seedling vigor index (11.56) was recorded from S_3 (30 × 30 cm) treatment followed by S_2 (11.06) .The lowest seedling vigor index (10.45) was taken from S_1 (30 × 10 cm) treatment (Table 21).

The combined effect of macronutrient levels and spacing on seedling vigor Index of (14.77) in T_3S_3 treatment combination was statistically similar to T_3S_2 (14.11) treatment combination which is similar with T_3S_1 (13.37) and again T_2S_3 (12.14) treatment combination was statistically identical to T_2S_2 (11.80) and T_2S_1 (11.77) treatment combination (Table 22). There are 6 groups in which the means are not significantly different from one another.

Table 21: Effect of plant spacing on seedling vigor index & dry matter content

Treatment	Seedling vigor Index	Dry matter content (%)
S_1	10.45 c	90.93
S_2	11.06 b	90.79
S_3	11.56 a	90.84
LSD	0.43	0.52^{NS}
CV (%)	4.64	0.68

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.)

4.4.5. Dry matter content %

There was no significant variation on dry matter content of fenugreek due to application of different macronutrient levels (Appendix X).The highest dry matter content (91.04 %) was obtained from T_0 (control) treatment which was statistically identical to T_2(90.96%), T_1(90.88 %) and T_3(90.54%) treatment (Table 20).

No significant variation was found on dry matter content of fenugreek due to plant spacing (Appendix X). The highest dry matter content (90.93%) was recorded from S_1 (30 × 10 cm) treatment which was statistically identical to S_2 (90.79%) and S_3 (90.84%) treatment (Table 21).

There are no significant differences among the combination of macronutrient levels and spacing (Appendix X). Maximum dry matter content (91.50 %) of T_1S_3 treatment combination was statistically identical toT_3S_3 , T_3S_2 , T_3S_1 , T_2S_3 ,T_2S_2 ,T_2S_1 ,T_1S_2 , T_1S_1 , T_0S_3 ,T_0S_2, and T_0S_1 treatment combination (Table 22).

Table 22. Combined effect of macronutrient levels and spacing on seedling vigor index and dry matter content

Treatment	Seedling vigor Index	Dry matter content %
T_0S_1	7.48 f	91.47
T_0S_2	8.03 f	91.17
T_0S_3	8.90 e	90.48
T_1S_1	9.18 e	90.55
T_1S_2	10.30 d	90.58
T_1S_3	10.41 d	91.50
T_2S_1	11.77 c	91.27
T_2S_2	11.80 c	90.96
T_2S_3	12.14 c	90.66
T_3S_1	13.37 b	90.45
T_3S_2	14.11 ab	90.45
T_3S_3	14.77 a	90.71
$LSD_{(0.05)}$	0.87	1.04^{NS}
CV (%)	4.64	0.68

Means in a column followed by the same letter(s) are not significantly different at 5% level, Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.

4.5. Economic analysis

Land preparation, fertilizer, irrigation, and human costs for all fenugreek treatments, from seeding to harvesting, were recorded per experimental plot and converted to cost per hectare. The cost of fenugreek was calculated using market rates. The following economic study is offered under the heading:

4.5.1. Gross return

In the combination of nutrients and plant spacing maximum gross return (Tk. 200200) was obtained from the T_3S_1 ($N_{120}P_{90}K_{90}$ kg ha^{-1} and 30 × 10 cm) treatment combination and the second highest gross return (Tk. 173800) was obtained in T_2S_1 ($N_{80}P_{60}K_{60}$ kg ha^{-1} and 30 × 20 cm). The lowest gross return (Tk. 46200) was obtained in the combination of T_0S_3 (control and 30 × 30 cm) treatment. (Table 23)

4.5.2 Net return

Different treatment combinations gave different types of net return. In combination of nutrients and plant spacing highest net return (Tk. 141,130) was obtained from the T_3S_1 ($N_{120}P_{90}K_{90}$ kg ha^{-1} and 30 × 10 cm) treatment combination and second highest net return (Tk. 118,665) was obtained in T_2S_1 ($N_{80}P_{60}K_{60}$ kg ha^{-1} and 30 × 10 cm). The lowest net return (Tk. 1,650) was obtained in the combination of T_0S_3 (control and 30 × 30 cm). (Table 23)

Table 23. Cost and return analysis of fenugreek considering macro nutrients combination and plant spacing

Treatments	Cost of production (Tk)	Yield (t ha^{-1})	Gross income (Tk)	Net income (Tk)	BCR
T_0S_1	47,163	0.54	59400	12,237	1.26
T_0S_2	45,862	0.44	48400	2,538	1.06
T_0S_3	44,550	0.42	46200	1,650	1.04
T_1S_1	51,149	1.07	117700	66,551	2.30
T_1S_2	49,847	0.7	77000	27,153	1.54
T_1S_3	48,536	0.51	56100	7,564	1.16
T_2S_1	55,135	1.58	173800	118,665	3.15
T_2S_2	53,833	0.83	91300	37,467	1.70
T_2S_3	52,521	0.58	63800	11,279	1.21
T_3S_1	59,070	1.82	200200	141,130	3.39
T_3S_2	57,767	0.95	104500	46,733	1.81
T_3S_3	56,455	0.66	72600	16,145	1.29

Note: $T_0 = N_0P_0K_0$ kg ha^{-1} (control), $T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}, $T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}, $T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1} and S_1 = 30 × 10 cm, S_2 = 30 × 20 cm and S_3 = 30 × 30 cm.
Sale price: 1,10,000 Tk/ton

4.5.3 Benefit cost ratio

In combination of nutrients and plant spacing the highest benefit cost ratio (3.39) was attained from the T_3S_1 ($N_{120}P_{90}K_{90}$ kg ha^{-1} and 30 × 10 cm) treatment combination and the closest benefit cost ratio (3.15) was acquired T_2S_1 ($N_{80}P_{60}K_{60}$ kg ha^{-1} and 30 × 10 cm). The lowest benefit cost ratio (1.04) was obtained from combination of T_0S_3 (control and 30 × 30 cm) (Table 23).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2019 to March 2020 to study the influence of some macronutrients (nitrogen, phosphorus & potassium) and spacing on the growth and yield of fenugreek seed. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment comprised of four levels of macro nutrient viz. $N_0P_0K_0$ kg ha^{-1} (control), $N_{40}P_{30}K_{30}$ kg ha^{-1}, $N_{80}P_{60}K_{60}$ kg ha^{-1}, $N_{120}P_{90}K_{90}$ kg ha^{-1} and three level of spacing viz. 30 × 10 cm, 30 × 20 cm and 30 × 30 cm. As the test crop, the variety BARI Methi-1 was used in this experiment. The two-factor experiment was carried out in Randomized Complete Block Design (RCBD) with three replications. There were 12 treatment combinations. The total numbers of unit plots were 36. The size of unit plot was 2.7 m^2 (1.8 m × 1.5 m). Nitrogen, phosphorus and potassium were applied as per treatment variables. Data on growth and yield parameters were recorded and analyzed statistically. The differences were evaluated by Duncan's Multiple Range Test (DMRT).

Fertilizers had significant effects on the growth and seed yield contributing characters of fenugreek. The maximum plant height recorded from T_3 treatment was 26.16 cm, 48.86 cm, 57.57 cm and 65.91 cm at 30, 60, 80 and 100 DAS respectively, while the minimum plant height recorded from T_0 treatment was 21.41 cm, 44.24 cm, 49.84 cm and 56.90 cm at 30, 60, 80 and 100 DAS respectively. The maximum and minimum number of primary branches plant^{-1} (3.78 and 2.84), days of 50% flowering (56.87 days and 50.20 days), pods plant^{-1} (49.96 and 30.27), pod length (11.70cm and 9.48cm), seeds pod^{-1} (13.87 and 10.16), 1000 seed weight (12.30 g and 11.91 g), seed yield per plant (5.70 g and 2.08 g), seed weight per pod (121.01mg and 68.41mg), single pod weight (5.63g and 3.25g), seed yield per plot (332.12 g and 107.96) ,seed yield (1142.8 kg/ha and 389 kg/ha), stover yield (865.49 kg/ha and 684.01 kg/ha), biological yield (2008.3 kg/ha and 1073 kg/ha), harvest index(57.20 % and 36.83 %) , germination percentage (80.30 % and 68.69 %), shoot length (10.65 cm and 7.22 cm), root length (6.88 cm and 4.62 cm) and seedling vigor index (14.08 and 8.14) were recorded in T_3 and T_0 treatment, respectively.

Spacing had significant effects on the growth and seed yield contributing characters of fenugreek. The maximum plant height recorded from S_3 (30 x 30 cm) treatment was 24.14cm, 46.81cm, 54.63cm and 63.71cm at 30, 60, 80 and 100 DAS , respectively and the minimum plant height recorded from S_1 (30 x 10 cm) was 23.09cm, 45.54cm, 53.05cm and 60.01cm at 30, 60, 80 and 100 DAS, respectively. The maximum and minimum number of primary branches recorded from S_3 and S_1 treatment were 3.4 and 3.3, respectively but they were statistically identical. The maximum and minimum days of 50% flowering (54.83 days and 53.98 days), number of pods plant $^{-1}$ **(**46.18 and 41**),** pod length (10.69cm and 10.11cm), seeds pod^{-1} (12.17 and 11.67), 1000 seed weight (12.10g and 12.03g),seed yield per plant (4.57g and 3.76g), weight of seed per pod (103.29mg and 95.33mg), single pod weight (4.45g and 3.90g), shoot length **(**9.43 cm and 8.62 cm**),** root length (5.88 cm and 5.39 cm), seedling vigor index (11.56 and 10.45) and harvest index (51.75% and 47.49%) were recorded in S_3 and S_1 treatment, respectively. Again, the maximum and minimum seed yield per plot (353.20g and 158.28g), seed yield (1251.9 kg/ha and 508 kg/ha), stover yield (1271.4 kg/ha and 453 kg/ha) and biological yield (2523.3 kg/ha and 960.9 kg/ha) were recorded in S_1 and S_3 treatment, respectively. In case of germination percentages, S_3 treatment provides 75.00% and S_2 treatment provides 73.11%. The maximum dry matter content % recorded from S_1 (90.93%) treatment which was statistically identical to S_2 (90.79%) and S_3 (90.84%) treatment respectively.

Combined effects of spacing and fertilizer levels produced significant variation in respect of yield and seed yield contributing characters. The maximum plant height (26.45cm, 50.27cm and 67.01cm at 30, 60, 100 DAS, respectively) in T_3S_3 treatment combination and the minimum plant height (20.58cm, 43.99cm, 45.61cm and 52.44 cm at 30, 60, 80 and 100 DAS, respectively) in T_0S_1 treatment combination were recorded. The maximum and minimum number of primary branches were 3.87 and 2.60 in T_3S_2 and T_0S_2 treatment combination, respectively. The maximum and minimum number of days of 50% flowering (57.33 days and 49.07days), pods plant^{-1} (50.80 and 25.13), pod length (12.05cm and 8.88cm), seeds per pod (14.07 and 10.00), 1000 seed weight (12.33g and 11.89g), seed yield per plant (5.91g and 1.63g), weight of seed per pod (123.96mg and 65.12mg), single pod weight (6.19g and 3.09g), harvest index (57.92% and 35.01%), total germination (81.82% and 68.18%), shoot length (10.92 cm and 6.51 cm), root length (7.13 cm and 4.47 cm),seedling vigor index (14.77 and 7.48) were found in T_3S_3 and T_0S_1 treatment combination, respectively. In case of seed yield, stover yield and biological yield, the maximum and minimum seed yield per plot (495.39 g and 112.10 g), seed yield (1817.8 kg/ha and 415.2 kg/ha), stover yield (1410 kg/ha and 1006.7 kg/ha) and biological yield (3227.8 kg/ha and 711.1 kg/ha) were found in T_3S_1 and T_0S_3 treatment combination, respectively due to higher plantation per unit area. In case of BCR (benefit cost ratio), the highest BCR (3.39) was attained from the T_3S_1 ($N_{120}P_{90}K_{90}$ kg ha^{-1} and 30 × 10 cm) treatment combination. The lowest BCR (1.04) was obtained from combination of T_0S_3 (control and 30 × 30 cm).

Conclusion

Considering the above result of this experiment, the following conclusion and recommendation can be drawn.

i. Macronutrients combination of T_3 ($N_{120}P_{90}K_{90}$ kg ha^{-1}) was more effective than other treatments.
ii. Plant spacing S_3 (30 x 30cm) treatment gave maximum seed yield per plant but S_1 (30 x 10cm) treatment gave maximum seed yield per hectare.
iii. A combination of $N_{120}P_{90}K_{90}$ kg ha^{-1} with plant spacing 30 x 10cm was the most suitable combination in respect of the highest BCR (3.39) and seed yield of fenugreek.

Based on the findings of the study, trial may be given in different agro-ecological zones of Bangladesh for exploitation of other performances.

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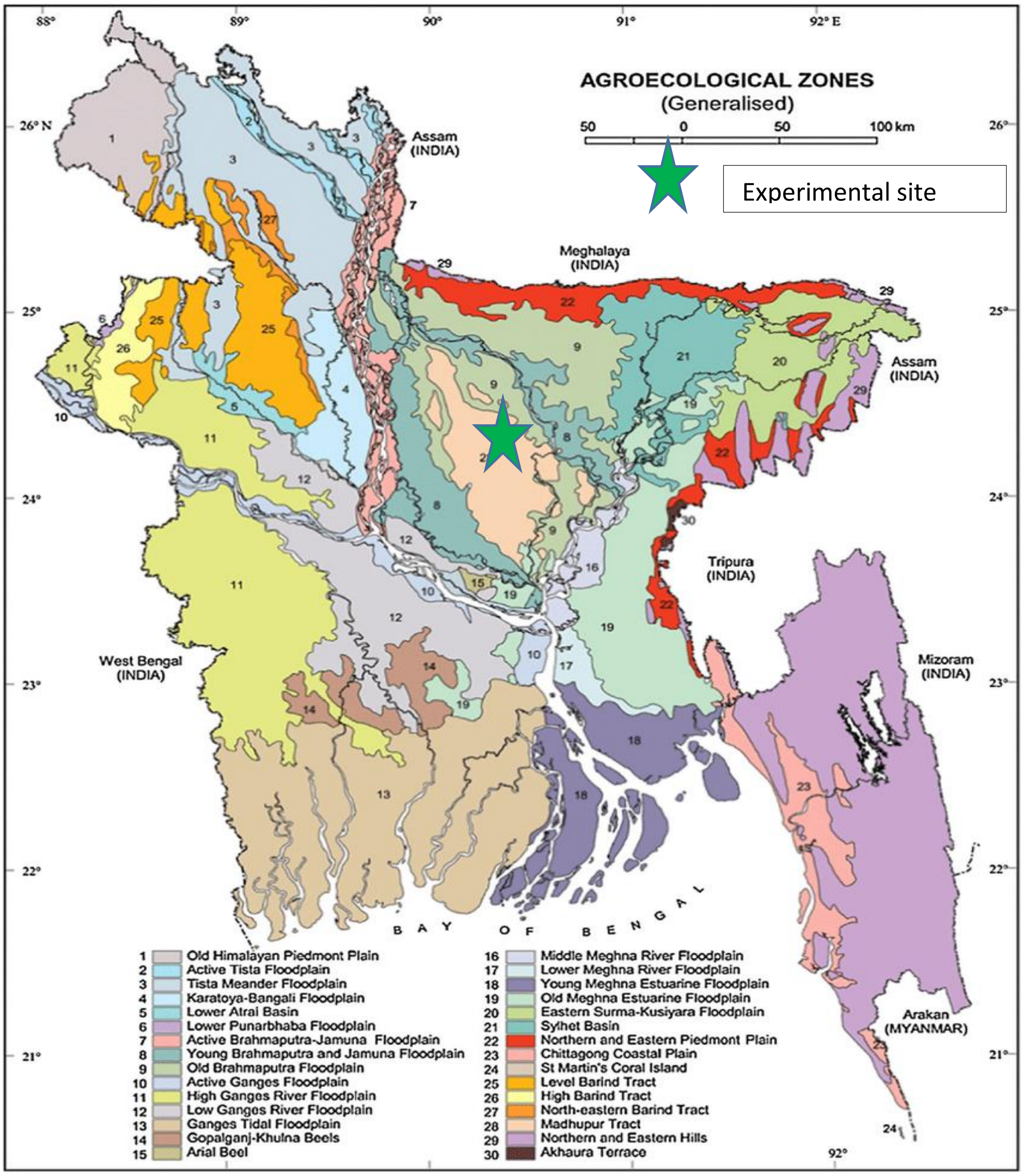
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Equally leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silt clay
Chemical characteristics	
Soil characters	**Value**
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly meteorological information during the period from November, 2019 to March, 2020

Year	Month	Air temperature (°C)		Relative humidity (%)	Total Rainfall (mm)
		Max	Min		
2019	November	29.2°C	20.5°C	67%	9
2019	December	26.4°C	17°C	60%	9
2020	January	26°C	15.3°C	53%	2
2020	February	29.8°C	17.4°C	45%	10
2020	March	34°C	21.3°C	48%	25

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix IV. Analysis of variance of the data on plant height at different DAS of Fenugreek.

	Mean Square for plant height				
Source of variation	**Degree of freedom (df)**	**30DAS**	**60DAS**	**90DAS**	**120DAS**
Replication	2	0.1427	0.0315	0.7474	0.910
Macronutrients	3	37.5844*	36.3608*	99.1983*	132.663*
Spacing	2	3.4583*	5.0982*	11.6670*	43.484*
Macronutrients* Spacing	6	0.2743*	1.2044*	12.1762*	6.796*
Error	22	0.0092	0.0075	0.9330	0.515

*Significant at 5% level of significance
^{NS} Non significant

Appendix V. Analysis of variance of the data on no. of primary branches at 30DAS and days of 50% flowering of fenugreek.			
	Mean Square		
Source of variation	**Degree of freedom (df)**	**No. of primary branches at 30 DAS**	**Days of 50% flowering**
Replication	2	0.23111	0.1378
Macronutrients	3	1.43704*	83.3937*
Spacing	2	0.03111[NS]	2.6811*
Macronutrients* Spacing	6	0.19704*	0.7715*
Error	22	0.03232	0.0275

*Significant at 5% level of significance

[NS] Non significant

Appendix VI. Analysis of variance of the data on pods per plant, pod length, seeds per pod and 1000 seed weight of fenugreek.					
	Mean Square				
Source of variation	**Degree of freedom (df)**	**Pods per plant**	**Pod length**	**Seeds per pod**	**1000 seed weight**
Replication	2	0.058	0.00608	0.1878	0.00066
Macronutrients	3	750.770*	7.73458*	23.9685*	0.26882*
Spacing	2	80.608*	1.07791*	0.7544*	0.01398*
Macronutrients* Spacing	6	12.031*	0.24102*	0.0463*	0.00193*
Error	22	0.174	0.00259	0.0229	0.00017

*Significant at 5% level of significance

[NS] Non significant

Appendix VII. Analysis of variance of the data on single pod weight, seed yield per plant and weight of seed per pod of fenugreek.

	Mean Square			
Source of variation	**Degree of freedom (df)**	**Single pod weight**	**Seed yield per plant**	**Weight of seed per pod**
Replication	2	0.0142	0.0158	3.14
Macronutrients	3	10.2142*	22.1258*	4607.44*
Spacing	2	0.9145*	2.0161*	191.37*
Macronutrients* Spacing	6	0.1268*	0.1874*	6.79*
Error	22	0.0050	0.0005	0.26

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on seed yield per plot, seed yield, stover yield, biological yield of fenugreek.

Mean Square					
Source of variation	**Degree of freedom (df)**	**Seed yield per plot (g)**	**Seed yield (kg/ha)**	**Stover yield (kg/ha)**	**Biological yield (kg/ha)**
Replication	2	23	611	0.16180	627
Macronutrients	3	86641*	973798*	58528.3*	1503677*
Spacing	2	120107*	1782184*	2157609*	7861676*
Macronutrients* Spacing	6	8190*	140718*	23665.9*	262996*
Error	22	4	31	9.09437	25

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Analysis of variance of the data on harvest index (%), total germination, shoot length and root length of fenugreek.

		Mean Square			
Source of variation	**Degree of freedom (df)**	**Harvest index (%)**	**Total germination (%)**	**Shoot length (cm)**	**Root length (cm)**
Replication	2	0.602	7.452	0.0157	0.03000
Macronutrients	3	733.963*	270.063*	18.5678*	8.58259*
Spacing	2	54.443*	10.917^{NS}	2.2747*	0.71083*
Macronutrients* Spacing	6	11.646*	7.839*	0.2621*	0.02676*
Error	22	0.033	11.223	0.0022	0.00091

*Significant at 5% level of significance

^{NS} Non significant

Appendix X. Analysis of variance of the data on seedling vigor index and dry matter content of fenugreek.

	Mean Square		
Source of variation	**Degree of freedom (df)**	**Seedling vigor Index**	**Dry matter content**
Replication	2	0.0408	1.12551
Macronutrients	3	58.7162*	0.44689^{NS}
Spacing	2	3.6877*	0.06288^{NS}
Macronutrients* Spacing	6	0.2861*	0.64606^{NS}
Error	22	0.2621	0.37957

*Significant at 5% level of significance

^{NS} Non significant

Appendix XI. Production cost of fenugreek per hectare

A. Input cost (Tk/ha)

Treatment combination	Labor cost	Ploughing cost	Cost of seed	Cost of irrigation	Cost of manure and fertilizers				Insecticide	Sub-total (A)
					Cow dung	Urea	TSP	MoP		
T_0S_1	6000	3000	1260	2000	10000	0	0	0	1000	23260
T_0S_2	5000	3000	1080	2000	10000	0	0	0	1000	22080
T_0S_3	4000	3000	900	2000	10000	0	0	0	1000	20900
T_1S_1	6000	3000	1260	2000	10000	1392	1488	800	1000	26940
T_1S_2	5000	3000	1080	2000	10000	1392	1488	800	1000	25760
T_1S_3	4000	3000	900	2000	10000	1392	1488	800	1000	24580
T_2S_1	6000	3000	1260	2000	10000	2784	2976	1600	1000	30620
T_2S_2	5000	3000	1080	2000	10000	2784	2976	1600	1000	29440
T_2S_3	4000	3000	900	2000	10000	2784	2976	1600	1000	28260
T_3S_1	6000	3000	1260	2000	10000	4176	4416	2400	1000	34252
T_3S_2	5000	3000	1080	2000	10000	4176	4416	2400	1000	33072
T_3S_3	4000	3000	900	2000	10000	4176	4416	2400	1000	31892

Net income = Gross income – Total cost of production

$T_0 = N_0P_0K_0$ kg ha^{-1} (control)
$T_1 = N_{40}P_{30}K_{30}$ kg ha^{-1}
$T_2 = N_{80}P_{60}K_{60}$ kg ha^{-1}
$T_3 = N_{120}P_{90}K_{90}$ kg ha^{-1}

S_1 = 30 × 10 cm
S_2 = 30 × 20 cm
S_3 = 30 × 30 cm

Ploughing time (2 times) = 1500 TK/cultivation
Seed rate = 7 kg/ha (S_1 = 30 ×10 cm)
6 kg/ha (S_1 = 30 ×20 cm)
5 kg/ha (S_1 = 30 ×30 cm)
(for the expt. about 180tk/kg)

Urea = 16 tk/kg
TSP=24 tk/kg
MoP = 16 tk/kg

B. Overhead cost (Tk/ha)

Treatment combination	Cost of lease of land (Tk 8% of value of land cost/6 months)	Miscellaneous cost (Tk. 7% of the input cost)	Interest on running capital for 6 months (Tk. 14% of cost/year)	Sub-total (Tk.) (B)	Total cost of production (tk./ha)[input cost (A) + overhead cost (B)]
T_0S_1	20000	1628	2275	23903	47163
T_0S_2	20000	1546	2236	23782	45862
T_0S_3	20000	1463	2187	23650	44550
T_1S_1	20000	1886	2323	24209	51149
T_1S_2	20000	1803	2284	24087	49847
T_1S_3	20000	1721	2235	23956	48536
T_2S_1	20000	2143	2372	24515	55135
T_2S_2	20000	2061	2332	24393	53833
T_2S_3	20000	1978	2283	24261	52521
T_3S_1	20000	2398	2420	24818	59070
T_3S_2	20000	2315	2380	24695	57767
T_3S_3	20000	2232	2331	24563	56455

Appendix XII. Experimental activities and photographs