EFFECT OF PHOSPHOROUS AND SULPHUR FERTILIZATION ON VEGETATIVE GROWTH AND SEED YIELD OF FENUGREEK (*Trigonella foenum-graecum* L.)

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CERTIFICATE

This is to certify that the thesis entitled ***'EFFECT OF PHOSPHOROUS AND SULPHUR FERTILIZATION ON VEGETATIVE GROWTH AND SEED YIELD OF FENUGREEK*** *(Trigonella foenum-graecum L.) submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGRICULTURAL BOTANY,*** *embodies the result of a piece of bona fide research work carried out by* ***S. M. MASUDUR RAHMAN MITOO****, Registration No.* ***10-03939*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated: 25 May, 2017
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ABSTRACT

An experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2016 to march 2017 to investigate the effect of four levels of phosphorous viz., 0, 20, 30, 40 kg P ha^{-1} and three levels of sulphur viz., 0, 10 and 20 kg S ha^{-1} on vegetative growth and seed yield of fenugreek (cv. BARI Methi-1). The highest plant height (26.73 cm) was found from the application of 40 kg P ha^{-1} and 10 kg S ha^{-1} at 30 days after sowing (DAS), whereas the maximum plant height (32.47 cm) was found with the dose of 40 kg P ha^{-1} and 20 kg S ha^{-1} at 60 DAS. The maximum number of primary branches $plant^{-1}$ (4.60 at 30 DAS and 5.73 at 60 DAS) was obtained from the application of 40 kg P ha^{-1} and 20 kg S ha^{-1}. Number of pods $plant^{-1}$ (23.08), weight of straw $plot^{-1}$ (172.59 g/3.6 m^2) and 1000-seed weight (9.98 g) were found maximum from the combined application of 40 kg P ha^{-1} and 20 kg S ha^{-1}, which was closely followed by the combination of 40 kg P ha^{-1} and 10 kg S ha^{-1}. The highest weight of single pod (4.40 g), weight of seeds pod^{-1} (15.07 mg), weight of seeds $plant^{-1}$ (4.12 g) and maximum number of seeds pod^{-1} (15.33) were recorded from 40 kg P ha^{-1} in combination with 10 kg S ha^{-1}. The combination of 40 kg P ha^{-1} and 10 kg S ha^{-1} produced the maximum seed yield (770.0 kg ha^{-1}) which was statistically similar with that of 30 kg P ha^{-1} and 10 kg S ha^{-1} (767.2 kg ha^{-1}) and 40 kg P ha^{-1} and 20 kg S ha^{-1} (765.3 kg ha^{-1}). Application of 40 kg P ha^{-1} in combination with 10 kg S ha^{-1} increased seed yield over the control (0.0 kg ha^{-1} P + 0.0 kg S ha^{-1}) by 50.69%, followed by 50.51% obtained from 30 kg P ha^{-1} with 20 kg S ha^{-1}. There was highly significant correlation between seed yield of fenugreek at different levels of phosphorus and sulphur. Therefore, application of P-S (40+10) kg ha^{-1} with a blanket dose of N-K (80+67) kg ha^{-1} + 5.0 tons cowdung might be considered as suitable fertilizer dose for production of fenugreek.

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ABBREVIATIONS AND ACRONYMS

ANOVA	=	Analysis of Variance
cm	=	Centimeter
CV	=	Coefficient of Variation
DAS	=	Days after sowing
et al.,	=	And others
g	=	gram
ha	=	Hectare
i.e.	=	That is
J.	=	Journal
kg	=	Kilograms
DMRT	=	Duncun's Multiple Range Test
Mg L^{-1}		Milligram per litre
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
Viz.	=	Namely
%	=	Percentage
(^{0})	=	Degree

CHAPTER I

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) locally known as 'methi' belonging to the family Leguminosae and sub family Papilionaceae is widely used as spice and condiment to add flavor in various foods. It was also named, *Trigonella*, from Latin language that means "little triangle" due to its yellowish-white triangular flowers (Flammang *et al*., 2004). It is named as *Methi* (Hindi, Urdu, Punjabi and Marathi), *Hulba* (Arabic), *Moshoseitaro* (Greek), *Uluva* (Malayalam), *Shoot* (Hebrew), *Dari* (Persian) and Heyseed in English. Fenugreek (*Trigonella foenum-graecum* L.) is one of the oldest medicinal plants originated in central Asia ~4000 BC (Altuntas *et al*., 2005). Its description and benefits had been reported in the *Ebers Papyrus* (one of the oldest maintained medicinal document) earlier in 1500 BC in Egypt (Betty, 2008). It is being commercially grown in India, Pakistan, Afghanistan, Iran, Nepal, Egypt, France, Spain, Turkey, Morocco, North Africa, Middle East and Argentina (Flammang *et al*., 2004; Altuntas *et al*., 2005).

Fenugreek (*Trigonella foenum - graecum* L.) is herbaceous annual whose seeds contain proteins (25-36% of the dry weight of the plant) and a range of vitamins (Mehrafarin *et al.*, 2011). Its seeds also contain different amounts of nutrients, most important like iron, calcium, phosphorus, potassium and other mineral elements (Ali *et al.*, 2012). The seeds contain a substantial amount of fiber, phospholipids, glycolipids, oleic acid, linolenic acid, linoleic acid, choline, vitamin A, B1, B2, C, nicotinic acid, niacin and many other functional elements.

The seeds of fenugreek contain 26% mucilage, 22% protein comprising of globulin, histidine, lecithin and albumin with a good amount of

phosphorus, sulphur. It also contains handsome amount of minerals and soluble/insoluble fiber for good health (Gopalan *et al*., 1989). The fenugreek seeds contain 7.1% oil by percentage with unacceptable and bitter taste. It mostly contains PUFA, as ω-3 and ω-6, fatty acids. There are various researchers who analyzed Egyptian origin fenugreek oil and reported as linoleic and linolenic acids, 33.7 and 13.8% respectively (Shahat, 1947). The presence of hexadecanoic acid was also reported by Badami and Daulatbad (1969) and Sauvaire *et al*. (1991). The effect of place and conditions of cultivation of plant on linoleic and linolenic acids is also an important factor and effects on composition. Despite its exceptional nutritional and medicinal values, only a few studies have been done for its genetic enhancements and development the production of fenugreek.

Fenugreek *(Trigonella foenum-graecum* L.*)* has a long history of medicinal uses in Ayurveda. It is well-known as traditional medicine for diabetes, indigestion, elevation of lipids and edema (fluid retention) of the legs. Fenugreek is also good source of dietary protein for human and animals. Its seeds have a strong aroma and somewhat bitter in taste. Seeds of fenugreek are used locally as yellow dye in cosmetics and medicinal purposes. Fenugreek is a good soil renovator and is widely used as a green manure (Abdelgani *et al*., 1999). It is used as a spice, vegetable and a medicinal plant. Since antioxidant properties have been linked to health benefits of natural products, such properties were studied in germinated fenugreek seeds which are considered to be more beneficial than dried seeds (Dixit *et al*., 2005).

These plants are used for blood lipids and sugar decreasing in diabetic and non-diabetic peoples and have antioxidant and antibacterial activity. This plant decreases body fats and is effective on obesity. This plant is

used in therapy atherosclerosis (Nandini *et al*., 2007), rheumatism (Vyas *et al*., 2010), sugar lowering (Gupta *et al*., 2001), blood lipids lowering (Xue *et al*., 2007), appetizer (Max, 1992) and contain antioxidant activity (Birjees *et al*., 2008).

Phosphorus is essential for the general health of the plant and root development and more stem strength. It improves flower formation and makes seed production more uniform. It also improves seed quality and resistant to plant disease. Plant growth and seed yield was increased in fenugreek when phosphorus was applied @ 26kgP (60 kg P_2O_5) ha^{-1} (Bhairagi, 2014; Purbey and Sen, 2005). Sharma et al. (2014) obtained maximum number of primary branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1}, seed yield from 17.6 kg P (40 kg P_2O_5) ha^{-1}. It is also reported that an increase in seed yield of fenugreek was obtained with phosphorous doses of 40 and 60 kg ha^{-1} (Khiriya *et al*., 2001; Khiriya *et al*., 2003 and sheoran *et al*., 1999).

Sulphur is one of the major plant nutrients for increasing yield of the crop. Sulphur plays a vital role in plant metabolism. It constitutes the main element of amino acids such as cysteine and methionine, which are of essential nutrients. Sulphur has positive effects on the root growth in plants (Kacar, 1984). Lal *et al.* (2015) reported that application 30 $kgSha^{-1}$ produced the highest number of primary branches $plant^{-1}$ and number of pods $plant^{-1}$ with maximum seed yield of fenugreek. Gordara *et al*. (2013) obtained the highest seed yield of fenugreek from the application of 45 $kgSha^{-1}$ which was statistically similar to 30$kgSha^{-1}$; whereas Nehara *et al.* (2006) got the highest seed yield from 25$kgSha^{-1}$. Therefore, it is clear that seed yield of fenugreek can be increased by judicious application of phosphorous and sulphur fertilization. But the information on fenugreek

research regarding phosphorous and sulphur fertilization is not available in Bangladesh.

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

i. To investigate the combined effect of phosphorous and sulphur on vegetative growth of fenugreek.
ii. To observe the influence of phosphorous and sulphur on seed yield attributes of fenugreek.
iii. To find out the suitable combination of phosphorous and sulphur for higher seed yield of fenugreek.

CHAPTER II

REVIEW OF LITERATURE

Improvement work on fenugreek is limited in Bangladesh. However, a good number of investigations were done under the agro-climatic situations of India and elsewhere in the world. Some the studies so far were reviewed and described under the following paragraphs.

Ahmad (2017) conducted a research where the values of moisture, oil and total phenolic contents were recorded higher in fenugreek as 5.47 ± 0.66, 7.04 ± 0.21 and 18.52 ± 1.80 respectively, whereas ash content was higher in Egyptian seed with sodium, iron and copper content. Calcium and magnesium were the most abundant mineral in all the samples followed by potassium and sodium. The polyunsaturated linoleic and linolenic fatty acid were the major fatty acids. The amino acid composition revealed the presence of most essential amino acids in Yeman seeds. These wide variations in compositions indicated the effects of environmental, cultivars regions and biotic factors.

Lal *et al.* (2017) investigated an experiment on the standardization of organic module for production of fenugreek (*Trigonella foenum-graecum* L.) was conducted during *rabi* season of 2009-10 to 2012-13 (four years). The experiment was laid out in Factorial Randomized Block Design (RBD) consisting of three organic modules (M_1, M_2 and M_3) and two fenugreek varieties (AFg-1 and RMt-305) with four replications. Findings of present study showed significant differences among the performance of different organic modules tested for two fenugreek varieties. Organic module-1 (M_1) comprising of soil application of vermin-compost @ 5 t/ha+ foliar spray of 5% garlic extract @ 2.0 kg/ha + 2% neem oil @ 5

litre/ha+ soil application of neem cake @ 150 kg/ha and *Trichoderma* @ 2.5 kg/ha, seed treatment with *Rhizobium* @ 100 ml/kg seed, PSB @ 100 ml/kg seed and *Trichoderma* @ 10 g/kg seed exhibited earliest seed germination and maximum plant height (5.78, 19.69, 43.39 and 50.97 cm) at 30, 60, 90 DAS and at harvest, respectively with maximum number of branches (6.76/ plant), number of pods (42/ plant), number of seeds (16.01/ pod), highest grain yield (1515.21 kg/ha), gross return and net returns in fenugreek crop. Similarly significant differences were recorded in the performance of fenugreek varieties under different organic modules and the highest plant height, maximum number of branches and pods per plant, highest number of seeds per pod with maximum grain yield (1568.36 kg/ha), gross returns, net returns with higher B:C ratio (2.22) were recorded in fenugreek variety AFg-1 than variety RMt-305. Cultivation of fenugreek variety AFg-1 with the application of Module-1 exhibited maximum values for all the growth parameters, yield attributing characters, maximum grain yield, net returns with improvement in soil organic carbon % (OC) and soil fertility (available N, P and K) after 4 crop cycles. Hence, variety AFg-1 is recommended to grow organically with the application of Module-1 (M_1) under semi-arid environmental conditions.

Ahmad *et al.* (2016) stated fenugreek is one of the oldest medicinal plants with exceptional medicinal and nutritional profile. Fenugreek seeds contain a substantial amount of fiber, phospholipids, glycolipids, oleic acid, linolenic acid, linoleic acid, choline, vitamins A, B1, B2, C, nicotinic acid, niacin, and many other functional elements. It may grow well under diverse and a wide range of conditions; it is moderately tolerant to drought and salinity, and can even be grown on marginal lands in profitable way. Owing to these characteristics and heavy metal

remediation potential, fenugreek may well fit several cropping systems. In addition to its medicinal uses, it may serve as an excellent off-season fodder and animal food supplement. However, efforts should be initiated to develop strategies for improving its biomass production; genetic diversity among different accessions may be mapped, breeding and crop improvement programs may be initiated to improve the biomass and nutritional and functional elements. This review highlights the morphology, adaptability, nutritional constituents and associated functionality and medicinal significance of fenugreek; its ethno-historical uses, pharmacological assumptions have also been discussed. Researchable areas are also indicated to improve its production and adaptability.

Jasim *et al.* (2016) directed on the extension experiment farm in Babylon during the growing season 2013 - 2014 to study the effect of 5 soil fertilization treatments [control, 200 kg ha^{-1} of NPK (18-18-0) , 4 and 8 t ha^{-1} of compost of poultry], and its interaction with 4 treatments of foliar fertilizers [control, spray urea 1 g/liter, spraying humic acid 2 ml l^{-1} and spray polimet 2 ml l^{-1}] on growth and yield of fenugreek. Randomized complete block design (RCBD) with three replications was used. Seeds are sown on lines (30 cm apart) and the experimental unit contained 6 lines. After a week of germination the seedlings were thinned to 10 cm apart. Soil fertilizers were added as side dressing and the foliar fertilizers were added twice. The results showed that chemical fertilizer was superior significantly compared to other treatment in plant height, number of leaves, leaf area and wet and dry weight, while poultry (8 t ha^{-1}) was superior compared to control in branches number and wet weight. Urea spray was superior in plant height, leaves no. and soft weight. Polimet spray was superior compared to control in branches $plant^{-1}$. The interaction between the soil and spraying fertilizers had a significant

effect in increasing plant height, branches no., leaves no., leaf area and wet and dry weight.

Shrivastava (2015) stated fenugreek (*Trigonella foenum-graecum* L.) is an annual herb and because of its strong flavor and aroma and its leaves and seeds are used as spices and condiments. Fenugreek has also attracted attention as a component of traditional medicines. Reports regarding the chemical constituents and pharmacological properties are available in the literature. Many studies stated the influence of nitrogen and phosphorus applications on fenugreek, however, there are hardly any reports available on the effects of potassium treatments. The present study focuses on potassium induced alterations in fenugreek. Laboratory and pot experiments have been conducted on two cultivars of fenugreek viz., RMT-1 and PEB (procured from JNKVV, Jabalpur and Government Nursery, Dhar respectively) in School of Studies in Botany, Jiwaji University, Gwalior. Different potassium treatments were employed to evaluate the effects of potassium on growth and biochemical parameters. Nitrate reductase activity, total phenols, chlorophyll and carotenoid contents were estimated using standard methods. K^+ rate was calculated using flame photometer. Supplementation of potassium has resulted into enhanced nitrate reductase activity in leaf, stem and root which is also reflected in the fresh and dry weight of respective parts. Interestingly, applied potassium has also shown an impact on total phenols, total chlorophylls and carotenoids which may have a bearing on its pharmacological value in general and antioxidant potential in particular. Chlorophyll and carotenoid contents exhibited an increase as a result of potassium treatment more conspicuously in cultivar ‘PEB’ so also is true for nitrate reductase activity indicating cultivar difference. This communication presents and discusses these aspects of fenugreek as influenced by potassium treatments.

Ramkishor *et al.* (2015) evaluated the effect of clay mixing, irrigation and sulphur on growth and yield of fenugreek (*Trigonella foenum- graecum* L.) on loamy sand soil, was conducted at S.K.N. College of Agriculture, Jobner (Rajasthan) during *rabi* seasons 2006-07 and 2007-08. The experiment consisted of 36 treatment combinations of 3 levels of clay mixing (0, 1 and 2 %), 3 levels of irrigation [4 application of irrigation at lateral bud initiation (LBI) + flower initiation (FI)+ pod initiation (PI) + grain development (GD), 6 application of irrigation at LBI + PI and 8 irrigations applied at all the phenological stages of crop growth (LBI + branching + FI + full flowering + PI + pod enlargement and grain formation + GD + ripening] as main plot treatments and 4 levels of sulphur (0, 20, 40 and 60 kg S/ha through gypsum) as sub plot treatments was laid out in split plot design with three replications. The results indicated that application of clay @ 2 per cent gave significantly higher growth, yield attributes and yield and remained at par with application of clay @ 1 per cent in both the year as well pooled mean over control. The results further indicate that application of 8 irrigation resulted in significantly higher growth, yield attributes and yield and remained at par with the application of 6 irrigation in pods per plant and seeds per pods in both the years as well as pooled mean over the control. The application of sulphur @ 40 kg/ha gave significantly higher the growth, yield attributes and yield in pooled mean basis over rest of treatments.

Lal *et al.* (2015) carried out an experiment during the rabi season of 2011-12 and 2012-13 at NRCSS, Ajmer, Rajasthan, to study growth and yield of fenugreek as influenced by different levels of sulphur and zinc nutrients. Treatments comprising of three sulphur levels (soil application of 20, 30 and 40 kg sulphur ha^{-1}) and three zinc levels (foliar application of 0.4, 0.5 and 0.6 % zinc) were studied in factorial randomized block

design with three replications. Non-significant influence with respect to reduction in days to seed germination and days of flowering were observed due to higher dose of sulphur. Similarly plant height at different growth stages after sowing was not significantly influenced with varying levels of sulphur. Number of primary and secondary branches, number of pods and seed yield was affected significantly with different levels of sulphur. The highest number of primary branching plant (6.87) and number of pods plant (50.72) with maximum seed yield (1571.53 kg ha^{-1}) was obtained with soil application of 30 kg -1 ha sulphur. Different levels of zinc as foliar application did not influence significantly the seed germination, plant height at different growth stages and number of primary and secondary branches. However, it influenced significantly the number of pods and seed yield of fenugreek. The highest number of primary branches plant (6.57), number of pods plant (51.80) and maximum seed yield (1544.43 kg ha) were obtained with foliar application of 0.5% zinc. Application of sulphur in the soil as basal dose @ 30 kg ha along with 0.5 percent zinc as foliar spray is better for realizing better plant growth, flowering, nodulation and maximum seed yield of fenugreek.

Sharma *et al.* (2014) conducted an experiment at Agronomy farm, College of Agriculture, Bikaner during *rabi* season, 2010-11 on loamy sand soil to investigate the effect of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}), molybdenum (0.0, 0.5 and 1.0 kg Mo ha^{-1}) and PSB (without inoculation and with inoculation) on yield attributes, yield and seed quality of fenugreek (*Trigonella foenum-graecum* L.). The application of phosphorus up to 40 kg P_2O_5 ha^{-1} resulted in significantly higher number of branches per plant, chlorophyll content at flowering stage, nodules per plant, pods per plant, seeds per pod, seed and straw yield over their

respective preceding levels (0 and 20 P_2O_5 ha^{-1}) but it was found at par with 60 kg P_2O_5 ha^{-1}in respect to branches per plant, chlorophyll content at flowering stage, nodules per plant, pods per plant, seeds per pod, seed and straw yield of fenugreek. Among different levels of molybdenum, 0.5kg Mo ha^{-1} gave significantly higher branches per plant, chlorophyll content at flowering stage, nodules per plant, pods per plant, seeds per pod, seed and straw yield over respective lower level. PSB inoculation significantly enhanced the branches per plant, chlorophyll content at flowering stage, nodules per plant, pods per plant, seeds per pod, seed and straw yield of fenugreek. The test weight increased with the successive levels of applied phosphorus, molybdenum and PSB inoculation but difference could not reach the level of significance. The interaction effect of phosphorus × PSB was found significantly higher branches per plant, pod per plant and seed yield (1568 kg ha-1) recorded with treatment combination 40 kg P_2O_5 ha^{-1} + with inoculation of PSB which was at par with other treatment combination 60 kg P_2O_5 ha^{-1} + with inoculation of PSB.

Bairagi (2014) obtained that the optimum dose of phosphorus and ideal row spacing for obtaining maximum yield of good quality seed of fenugreek. Four different phosphorus (as single super phosphate) doses (P_0 = 0, P_3 = 30, P_6 = 60 and P_9 = 90 kg P_2O_5 ha^{-1}) and three different row spacing (S_2 = 20, S_3 = 30 and S_4 = 40 cm) were applied, thereby making 12 treatment combinations. The results obtained from the experiment tallest plants (49.8 cm), highest number of branches per plant (6.7) and number of pods per plant (50.5), maximum thousand seed weight (18 g) and seed yield (1575 kg ha^{-1}) were observed with the application of 60 kgP_2O_5 ha^{-1}. Application of 60 kg$P_2O_5$$ha^{-1}$ coupled with a row spacing of 30 cm was found to be most suitable for obtaining highest yield of good quality fenugreek seed in North Indian conditions.

Gaddamwar and Rajput (2013) collected water, soil samples and analyzed for the better planning of cultivation and also analyzed the Tender, Mature coconut water which contains a remarkable quantity of micronutrients as well as vitamins and proteins which is required to the Fenugreek crop. Author sprayed the coconut liquid on the Fenugreek crops at regular interval of 15 days and compared it with the unsprayed Fenugreek crops and studied a number of leaves, pods, branches and shoot height of the plant. The natural micronutrients which are present in the coconut liquid enhance the growth of plant and root. Fenugreek leaves and seeds have been used extensively for medicinal purposes. The fenugreek plant which is under treatment of Mature, Tender coconut liquid having 27, 24 pods & 145, 137 number of leaves and 9, 7 number of branches, 55, 51 centimeter shoot height were as untreated having 12 pods, 78 numbers of leaves, 2 number of branches, 31 centimeter shoot height respectively.

Godara *et al.* (2013) studied during *rabi* 2005-06 at research farm of Adaptive Trial Centre, Ajmer to study the response of *Nagauri Methi* i.e. also called *Kasuri Methi* (*Trigonella corniculata* L.) to phosphorus and sulphur. In this study three levels of phosphorus (0, 40 and 60 kg ha^{-1}) and three levels of sulphur (0, 30 and 45 kg ha^{-1}) consisted of nine treatments were taken under factorial RBD with three replications. Growth parameters and yield of dried leaves of the crop increased almost linearly with increasing levels of phosphorus, however influence of sulphur was marginal on both growth as well as marketable yield. Maximum plant height (11.8 cm), numbers of trifoliate leaves (7.7) and dried leaves yield (21.56 q ha^{-1}) was obtained with 60 kgP_2O_5 + 45 kgSha^{-1} which was at par with 60 kgP_2O_5 + 30 kgSha^{-1}.

Maximum gross returns (Rs.140140 ha^{-1}), net return (Rs.105522 ha^{-1}) and returns due to treatment (Rs.62595 ha^{-1}) were recorded in 60 kg P_2O_5 + 45 kg S. However, highest benefit: cost ratio (4.06) was recorded from the application of 60 kgP_2O_5 + 30 kgSha^{-1}, which exhibited gross returns (Rs.139490 ha^{-1}), net returns (Rs.105172 ha^{-1}) and returns due to treatment (Rs.61945 ha^{-1}).

Verma *et al.* (2013) conducted an experiment during *rabi* season of 2011-2012 at Jobner (Rajasthan) to study the effect of vermicompost and sulphur on growth, yield and nutrient uptake of fenugreek. The experiment consisting of sixteen treatment combinations with four levels of vermicompost (0, 2, 4, and 6 t ha^{-1}) and four levels of sulphur (0, 20, 40, and 60 kg ha^{-1}) was laid in randomized block design with three replications. Application of vermicompost up to 4 t ha^{-1} significantly increased plant height (34.05, 50.2 and 58.9 cm), branches $plant^{-1}$ (3.69, 5.73 and 8.06) at 60, 90 DAS and at harvest, total (26.22) and effective root nodules (14.95), leg haemoglobin content in root nodules (1.94 mg g^{-1}), seed (15.26 q ha^{-1}) and straw yields (39.02 q ha^{-1}), net returns (34235 Rs ha^{-1}) total uptake of N (4.49 kg ha^{-1}), P (0.699 $kgha^{-1}$), K (3.29 $kgha^{-1}$) and S (0.494 $kgha^{-1}$) over lower levels. However, available nitrogen (140.71 kg ha^{-1}) status of soil after crop harvest was significantly increased with vermicompost up to 6 t ha^{-1} vermicompost 4 t ha^{-1} increased seed yield by 25.00 and 9.45 percent and net returns by 12.60 and 3.95 percent over control and 2 t ha^{-1} vermicompost, respectively. Results further indicated that application of sulphur up to 40 kg ha^{-1} resulted in significantly higher plant height (34.06, 50.2 and 59.0 cm) and branches/plant (3.53, 5.67 and 8.00) at 60, 90 DAS and at harvest, total (27.06) and effective root nodules (15.00), leghaemoglobin content in root nodules (1.91 mg g^{-1}), seed (15.05 q ha^{-1}) and straw yields (38.80 q ha^{-1}), net returns (35311 Rs ha^{-1}), total uptake of N (4.48 $kgha^{-1}$), P (0.683

kg ha^{-1}), K (3.29 kg ha^{-1}) and S (0.497 Kg ha^{-1}) and available Nitrogen (140.97 kg ha^{-1}) content in soil after crop harvest over lover levels of sulphur application. The application of 40 kg ha^{-1} sulphur increased seed yield by 29.10 and 11.55 percent and net returns by 36.55 and 12.40 percent, respectively, over control and 60 kg S ha^{-1}.

Metha *et al.* (2012) conducted an experiment at Sardarkrushinagar (Gujarat) during 2006–07 and 2007–08 to study response of nitrogen, phosphorus and bio-fertilizers on fenugreek with 16 treatment combinations in factorial RBD with three replications. The soil of the experimental field was low in organic carbon, available nitrogen, medium in phosphorus and good in respect to available potassium. Application of 20 kg N and 40 kgP_2O_5 ha^{-1} gave significantly higher plant height at all the growth stages, and seed, straw and biological yields as well as protein content in seed and straw over 10 kg N and 20 kgP_2O_5 ha^{-1}, respectively. Combined inoculation of seed with *Rhizobium* and PSB and their sole application significantly gave higher plant height over control at all the growth stages but significantly the highest seed, straw and biological yield as well as protein content in seed and straw was recorded with combined inoculation of seed with *Rhizobium* and PSB, which was higher over their individual application and control. Sole application of both *Rhizobium* and PSB was found at par in respect to seed, straw and biological yield. Harvest index was not significantly influenced with N, P and bio-fertilizer levels.

Tuncturk (2011) accomplished a study to determine the effects of nitrogen and sulphur applications on the yield and quality of fenugreek in Van, Turkey in 2006 and 2007 growing seasons. Field trials were designed in Completely Randomized Block Design with three

replications at the experimental fields of Agricultural Faculty of Yüzüncü Yıl University. In the study, plant height (cm), the number of branches (branches plant^{-1}), first pod height (cm), the number of pods (pod plant^{-1}), the number of seeds in the pod (seed pod^{-1}), pod length (cm), thousand-seed weight (g), seed yield (kg ha^{-1}), protein content (%) and protein yield (kg ha^{-1}) were determined. The all growth and yield parameters except for thousand seed weight were significantly affected by nitrogen fertilization. All the parameters except for the number of branches, pod length and thousand seed weight were affected by sulphur fertilization. The highest seed yields (853.0 and 815 kg ha^{-1}) were obtained from 90 kg N ha^{-1} and 20 kg S ha^{-1} applications in 2006 and 2007, respectively.

Zandi *et al.* (2011**)** conducted a study on agronomic and morphological traits in fenugreek (*Trigonella foenum-graecum* L.) under nitrogen fertilizer and plant density, Four levels of nitrogen (0, 25, 50 and 75 kg ha^{-1}) as the main factor and four levels of plant density (60, 80, 100 and 120 plants m^{-2}) as sub-plots were investigated. The maximum number of pods plant^{-1} and seed yield (1468 kg ha^{-1}) produced by using 75 kg N ha^{-1}.

Jagdale and Dalve (2010) lead an experiment on fenugreek with five levels of nitrogen *i.e.* 0, 30, 60, 90 and 120 kg ha^{-1} and five levels of phosphorus *i.e.* 0, 15, 30, 45 and 60 kg ha^{-1}. The result of present investigation indicated that the vegetative growth in terms of plant height, number of leaves and number of branches was increased due to an application of 120 kg nitrogen and 60 kg phosphorus per ha. The maturity parameters like number of days required for first flower initiation, days required for 50% flowering, first pod formation, 50% pod formation and maturity of seed crop were found to be delayed with an increased level of 120 kg nitrogen and 60 kg phosphorus per ha.

Nehara *et al.* (2006) conducted an experiment during winter seasons (rabi) of 2001–02 and 2002–03 on a loamy sand soil of Jobner in Rajasthan, to study the response of fenugreek (*Trigonella foenum-graecum* L.) under different levels of phosphours (0, 25 and 50 kg P_2O_5 ha^{-1}), sulphur (0, 25 and 50 kg S ha^{-1}) and plant-growth regulators (control, Tricontanol 2 ppm, naphthaline acetic acid 20 ppm and etheophon 100 ppm). An increase in P level up to 50 kg P_2O_5 ha^{-1} and sulphur up to 50 kg S ha^{-1} significantly increased the yield-attributing characters; the seed, straw and biological yields; and the net returns of fenugreek. The N, P and S contents of fenugreek in seed and straw and their total uptake increased significantly with increase in the level of applied phosphorus and sulphur up to 50 kg ha^{-1}, except the P and S content in seed and straw, where significant increase was recorded only up to 25 kg P_2O_5 ha^{-1} and 25 kg S ha^{-1}. Among different growth-regulators, the application of NAA @ 20 ppm proved significantly better than the control, tricontanol and etheophon.

Abdin *et al.* (2003) accomplished a research work in Rajasthan, Haryana and Uttar Pradesh, India to study the effects of S and N on the yield and quality of Indian rapeseed cv. Pusa Jai Kisan (V_1) and rape cv. Pusa Gold (V_2). The treatments comprised: T_1 (SO: N 50 + 50); T_2 (S40:N50 + 50 for V_1 and S40:N50+25 + 25 for V_2); and T_3 (820 + 20:N50 + 50 for V_I and S20 + 10 + 10:N50 + 25 + 25 for V_2). Split application of S and N (T_3) resulted in a significant increase the seed and oil yield of both crops. The average seed yield obtained from the different experimental sites in the three states was 3.89 t ha^{-1} for V_1 and 3.06 t ha^{-1} for V_2 under T_3. The average oil yield under T_3 was 1.71 t ha^{-1} for V_I and 1.42 t ha^{-1} in V_2. The oil and protein contents in the seeds of V_1 and V_2 also increased with the

split application of S and N. It may be concluded from these results that the yield and quality of rapeseed. Rapeseed can be optimized with the split application of 40 kg S ha^{-1} and 100 kg N ha^{-1} during the appropriate phenological stages of crop growth and development

McCormick *et al.* (2001) compared growth, yield and nitrogen (N) inputs of fenugreek with field pea, faba bean, lentil, vetch and medic. Four fenugreek accessions flowered at a similar time to faba bean, but earlier than other species. Faba bean produced the highest grain yield. Fenugreek yields ranged from 1.4 to 1.7 t ha^{-1}. The relative N fixation efficiency was highest for faba bean, field pea and vetch (21-23 kg N/t). Fenugreek accession 150265 had the highest RNFE for fenugreek (19.4 kg N/t). Medic and fenugreek accessions 150000 and 150292 had significantly lower RNFE values (<15 kg N/t). There were no significant differences in pre-sowing soil nitrate and water content, grain yield, grain size or grain protein for wheat sown on the sites in the following year. Thus, fenugreek performed similarly to other legumes grown in Wimmera farming systems. Differences among fenugreek accessions suggest that significant improvements in agronomic performance of fenugreek can be made by selection within current germplasm.

Jat and Shakwat (2001) conducted a research at Agricultural Research Station, Fatehpur-Shekhawati (Sikar), Rajasthan, during 1997–98 and 1998–99. Branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1} and test weight of fenugreek (*Trigonella foenum-graecum* L.) significantly increased with increasing dose of P up to 80 kg P_2O_5 ha^{-1}. These characters were marginally influenced by S application. Bio-fertilizers inoculation significantly increased branches $plant^{-1}$ during 1998–99 and seeds pod^{-1} during both the years. Seed, straw and biological yields of fenugreek also

increased significantly with phosphorus applied up to 80 kg P_2O_5 ha^{-1}. Yield estimates of fenugreek also responded significantly to S application up to 100 kg ha^{-1}. Dual inoculation with *Rhizobium* + PSB significantly increased the seed and biological yields during both the years and straw yield during the first year. Phosphorus and sulphur applied to fenugreek significantly increased the grain, stover and biological yields of succeeding pearl millet *[Pennisetum glaucum* (L.) R. Br. emend. Stuntz]. Seed treatment of fenugreek with bio-fertilizer did not influence the grain, straw and biological yields of succeeding pearl millet crop.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh during the period from November 2016 to March 2017 to find out the optimum Phosphorous and Sulphur fertilization rate on yield attributes and yield of fenugreek. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout of the experimental design, intercultural operations, data recording and their analyses under the following headings and sub-headings.

3.1 Experimental site and soil

The experimental field is located at 23^{o}41' N latitude and 90^{o} 22' E longitude at height of 8.6m above the mean sea level. It belongs to the AEZ 28, Modhupur Tract (FAO, 1998).

3.2 Climate

The experimental field was situated under Sub-tropical climate; usually the rainfall is heavy during *kharif* season, (April to September) and short duration in *rabi* season (October to March). In *rabi* season temperature is generally low and there is plenty of sunshine. The temperature tends to increase from February as the season proceeds towards *kharif*. The site where the experiment was conducted had subtropical climate and the *rabi* season extended from October to early March.

3.3 Seed

High yielding variety of fenugreek (cv. BARI Methi-1) developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur

was used as experimental material. The seed was collected from Regional Spices Research Centre, BARI, Joydebpur, Gazipur.

3.4 Treatments

Four levels of phosphorous and three levels of sulphur and their combinations were used in the experiment.

These were:

Factor A: Four phosphorous levels

i) 0 kg ha^{-1} (P_0)

ii) 20 kg ha^{-1} (P_1)

iii) 30 kg ha^{-1} (P_2)

iv) 40 kg ha^{-1} (P_3)

Factor B: Three levels of sulfur

i) 0 kg ha^{-1} (S_0)

ii) 10 kg ha^{-1} (S_1)

iii) 20 kg ha^{-1} (S_2)

A total of 12 treatment combinations:

P_0S_0	P_1S_0	P_2S_0	P_3S_0
P_0S_1	P_1S_1	P_2S_1	P_3S_1
P_0S_2	P_1S_2	P_2S_2	P_3S_2

3.5 Design and layout of the experiment

The experiment was laid out in randomized complete block design (RCBD) with 3 replications. The size of unit plot was 3 m x 1.2 m. The total number of treatments was 12 (4 levels of Phosphorous × 3 levels of Sulfur) and the number of plots were 36.

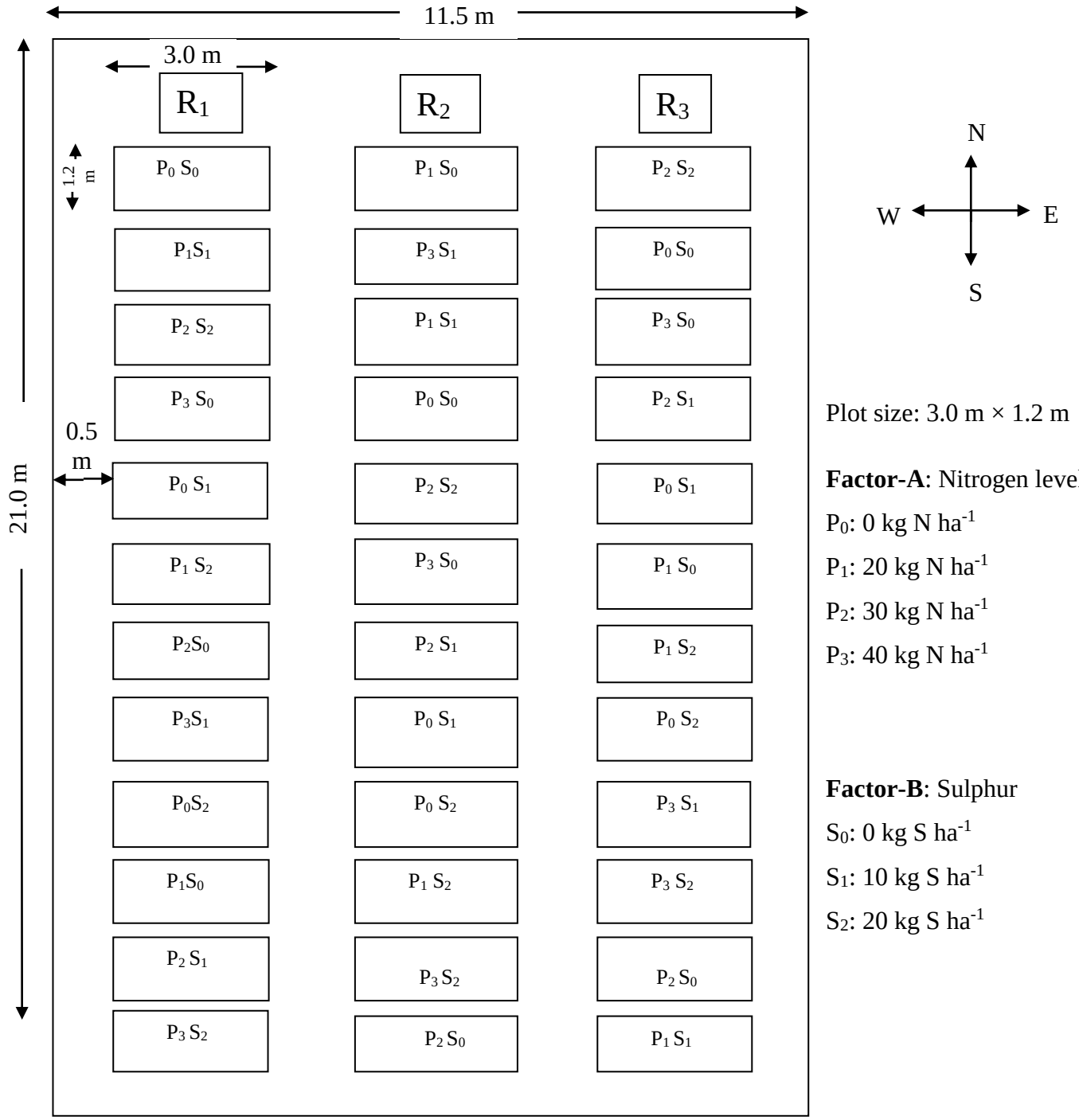

Fig. 1. A field layout of the experiment having four levels of phosphorus and three levels of sulphur

3.6 Land preparation

The land was opened by disc plough 15 days before seeding. Thereafter, the land was prepared thoroughly by ploughing and cross ploughing followed by laddering and harrowing to have good tilth. Weeds and stubbles of the previous crops were collected and removed from the field during land preparation. Soil clods were broken and plots were prepared as 15 cm raised seed bed so that irrigation and rain water easily could drain out and seeds could easily be germinated.

3.7 Fertilizer application

Manures and fertilizers were applied at the following doses Anon. (2010).

Nutrient/Fertilizer	Rate (Dose)	Fertilizer applied
Cowdung	5 t ha^{-1}	Well rotten cowdung
Nitrogen	80 kg ha^{-1}	Urea
Phosphorus	As per treatment	TSP
Potassium	Potassium 67 kg ha^{-1}	MoP
Sulphur	As per treatment	Gypsum

The entire amount of cowdung, phosphorus from TSP and potassium from MoP, sulphur from gypsum and one-half of nitrogen from urea were applied during final land preparation. The rest of the nitrogen was top dressed in two equal splits at 30 and 60 days after sowing.

3.8 Sowing

Fenugreek seeds were soaked in water for 6 hours to enhance germination. Seeds were also treated with Bavistin at the rate of 2 g per kg of seeds before sowing. The seeds were sown in rows 25 cm apart continuously by hand @ 15 kg/ha (Anon., 2010). To allow uniform sowing in rows seeds were mixed with some loose soil (about four to five times of weight of seeds). The seeds were covered with good pulverized soil just after sowing and gently pressed by hands. The sowing was done on November 25, 2016 with slight watering just to supply sufficient moisture needed for quick germination. Seedlings of the plots were thinned later to maintain 10 cm intra spacing (plant to plant distance) 25 days after sowing (DAS).

3.9 Intercultural operations

The desired population density was maintained by thinning plants 20 DAS. Irrigation, mulching, weeding and plant protection measures etc. were performed for better crop establishment and proper plant growth.

3.9.1 Weeding

The field was kept free by hand weeding. First weeding was done after 2 days after sowing (DAS). Plant thinning was also done at the time of weeding. Second and third weeding was done after 35 and 50 DAS, respectively.

3.9.2 Irrigation

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

3.10 Harvesting

Seeds were harvested on 26 March, 2017 when pod color changed into yellowish brown in color (Anon., 2010). To avoid shattering of fruits, harvesting of seed plant was cut to the base by sickles in the early morning. Then the stalks with seeds were dried in the sun. Seeds (grains) were separated by beating with sticks and cleaned by winnowing and dried properly (10% moisture of seed).

3.11 Data collection

Ten (10) plants from each plot were selected randomly and were tagged for the data collection. Some data were collected from sowing to harvesting with 10 days interval and some data were collected at harvesting stage. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and straw yield per plot were recorded after cleaning and drying those properly in the sun. Data were collected on the following parameters:

1. Plant height (cm) at 30 and 60 days after sowing (DAS)
2. Number of primary branches plant^{-1} at 30 and 60 DAS
3. Plant spread (cm) at first flowering
4. Number of pods plant^{-1}
5. Weight of seeds pod^{-1} (mg)
6. 1000 seed weight (g)
7. Weight of single pod (g)

8. Weight seeds plant^{-1} (g)
9. Number of seeds pod^{-1}
10. Weight of straw plot^{-1} (g)
11. Number of plants plot^{-1} at harvest
12. Seed yield plot^{-1} (g)
13. Seed yield (kg ha^{-1})

3.11. 1 Plant height(cm)

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

3.11. 2 Number of leaves plant^{-1}

Number of leaves plant^{-1}was counted two times at 30 days interval such as 30 and 60 DAS of fenugreek plants. Mean values of data were calculated and recorded.

3.11.3 Number of primary branches plant^{-1}

Number of branches was counted from randomly selected ten plants from each plot and mean values were calculated and recorded.

3.11. 4 Plant spread (cm)

At first the measurement was made in centimeter North-South (N-S) direction of the plant canopy of randomly selected ten plants at first flowering stage. Again the measurement was made in centimeter East-west (E-W) direction of the plant canopy of randomly selected ten plants.

Average plant spread (cm) was measured by adding those two values and dividing by two.

3.11.5 Number of pods plant^{-1}

Pods of ten randomly selected plants of each replication were counted and then the average number of fruits for each plant was determined. It was done at final harvest.

3.11.6 Weight of seeds pod^{-1}(mg)

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

3.11.7 1000seed weight (g)

1000seed weight was measured by Electric Balance in gram (g). 1000 seed from each treatment were counted then weighed.

3.11.8 Weight of single pod (g)

Pod weight was measured by Electric Precision Balance in gram (g).Ten randomly fruits from each of the treatment were weighted and then divided by ten to get single individual pod weight.

3.11.9 Number of seeds pod^{-1}

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

3.11. 10 Weight of seeds plant^{-1} (g)

Seed weight pod^{-1} was measured by Electric Balance in milligram (g). Seeds from each treatment were counted and then weighed.

3.11.11 Weight of strawplot^{-1} (g)

After seed collection all plant of each unit plot were dried in the sun. Then total plants of each unit plot were weighed to get weight of straw plot^{-1}.

3.11.12 Number of plant plot^{-1} at harvest

Number of plant was counted during final harvesting of fenugreek plant

3.11.13 Seed yield plot^{-1} (g)

After maturity seeds of all plants except 10 selected plants were harvested and cleaned. Then seed was measured with electric balance in gram. Then this weight was added to seed weight of 10 selected plants to obtain seed yield plot$^{-1.}$

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

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

3.12 Statistical analysis

The data obtained for different parameters will be statistically analyzed following computer based software XLSTAT 2016 (AddinSoft, 2016) and mean separation was be done by DMRT at 5% level of significance.

CHAPTER IV

RESULT AND DISCUSSION

The result obtained with different levels of phosphorous (P), sulphur (S) and their combinations were presented and discussed in this chapter. Data on morphological parameters, yield contributing characters and seed yield of fenugreek were in both tables and figures and analyses of variance and corresponding degrees of freedom had been shown in Appendices.

4.1 Plant height

The application of different phosphorous (P) and sulphur (S) levels had significant effects on fenugreek plant height at different days after sowing (DAS) (Table 1)**.** The highest plant height (26.73 cm) was found when the field was fertilized with the dose of 40 kgha^{-1} of phosphorous and 10 kg ha^{-1} of sulphur at 30 days after sowing (DAS). At 30 DAS, the second highest but identical plant height was observed as 25.89 cm with the application of 40 kgPha^{-1} and 20 kgSha^{-1}**,** but the third highest plant height (25.35 cm) was found with the application of 30 kg P ha^{-1} and zero (0) kg S ha^{-1}. The lowest plant height (23.19 cm) was observed from the control (P_0S_0) at 30 days after sowing.

The plant height increased with increasing the age of the plants. The highest plant height (32.47 cm) was obtained when the field was fertilized with the dose of 40 kg ha^{-1} of phosphorus and 20 kg ha^{-1} of sulphur at 60 days after sowing (DAS). The second nearest height was observed as 30.83 cm with the application of 40kgPha^{-1} and 10 kgS ha^{-1}**.** But the third most plant height was found as 29.81 cm with the application dose of 30 kg Pha^{-1} and 10 kgS ha^{-1}. The lowest plant height (26.67 cm) was observed from the application dose of zero (0) kgPha^{-1} and 10 kgSha^{-1},

whereas the second lowest plant height 27.91cm was found from the control at 60 days after sowing. Application of 40 kgP_2O_5/ha gave significantly higher plant height at all the growth stages (Metha *et al.*, 2012)

A **B**

Fig. 2. Plant height at 30 (A) and 60 (B) days after sowing

Table 1. Combined effect of phosphorus and sulphur on the height of fenugreek plant at different days after sowing (DAS)

Treatment	Plant height (cm)	
	30 DAS	60 DAS
P_0S_0	23.19 e	27.91 de
P_0S_1	23.98 cde	26.67 e
P_0S_2	23.72 de	26.87 e
P_1S_0	24.05 cde	27.77 de
P_1S_1	25.22 b	28.24 cde
P_1S_2	24.75 bcd	27.98 cde
P_2S_0	25.35 b	29.35 bcd
P_2S_1	21.93 f	29.81 bc
P_2S_2	25.07 bc	27.12 e
P_3S_0	24.03 cde	29.05 bcd
P_3S_1	26.73 a	30.83 ab
P_3S_2	25.89 ab	32.47 a
CV (%)	8.07	7.79

Means with uncommon letter(s) are significantly different at 5% probability level by DMRT.

P_0 = 0.0 kg ha^{-1} (control), P_1 = 20 kg ha^{-1}, P_2 = 30 kg ha^{-1} and P_3 = 40 kg ha^{-1}; S_0 = 0.0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2 = 20 kg ha^{-1}

4.2 Number of primary branches plant^{-1}

The maximum number of primary branches plant^{-1} (4.60) was found from the application of fertilizer with the dose of 40 kgPha^{-1} and 20kgSha^{-1} at 30 days after sowing (DAS) (Table 2). The identical nearest number of primary branches plant^{-1} (4.53) was observed from the application of 40 kgPha^{-1} and 10kgha^{-1} of sulphur. The lowest primary branches plant^{-1} (2.80) was observed from the application 0.0kgPha^{-1} and 0.0kgSha^{-1} at 30 DAS. Jat and Shaktawat (2001) and Nehara *et al.* (2006) stated that there was relation between the phosphorous and sulphur applications. Nehara *et al.* (2006) obtained the highest number of branches with increasing phosphorous (P_2O_5) levels up to 50kgha^{-1} and sulphur levels 50kgha^{-1}. Jat and Shaktawat (2001) got the highest primary branches plant^{-1} from the application of 80kgP_2O_5 ha^{-1}. At 60 DAS, the maximum number of branches plant^{-1} was observed (5.37) from the dose of 40 kgP ha^{-1} and 20 kg Sha^{-1}. The nearest number of branches (4.47) was observed with the dose of 40kgP ha^{-1} and 10 kgS ha^{-1} at 60 DAS. And the lowest branch number (3.00) was counted from the control.

Table 2. Combined effect of phosphorus and sulphur on number of primary branches plant^{-1} at different days after sowing (DAS) and plant spread of fenugreek

Treatment	Number of primary branches plant^{-1}		Plant spread at first flowering (cm)
	30 DAS	60 DAS	
P_0S_0	2.80 f	3.00 h	2.96 e
P_0S_1	3.87 bc	3.00 h	4.06 cd
P_0S_2	4.08 b	4.06 d	4.47 c
P_1S_0	3.07 ef	3.47 f	3.54 de
P_1S_1	3.47 cde	4.27 c	4.16 cd
P_1S_2	3.33 de	3.73 e	4.28 c
P_2S_0	3.13 ef	3.53 f	3.49 de
P_2S_1	3.67 bcd	3.71e	5.67 b
P_2S_2	3.73 bcd	3.26 g	2.96 e
P_3S_0	3.13 ef	3.20 g	3.95 cd
P_3S_1	4.53 a	4.47 b	6.74 a
P_3S_2	4.60 a	5.73 a	6.76 a
CV (%)	9.87	8.92	9.75

Means with uncommon letter(s) are significantly different at 5% probability level by DMRT.

P_0 = 0.0 kg ha^{-1} (control), P_1 = 20 kg ha^{-1}, P_2 = 30 kg ha^{-1} and P_3 = 40 kg ha^{-1}; S_0 = 0.0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2 = 20 kg ha^{-1}

4.3 Plant spread (cm) at first flowering

The maximum plant spread at first flowering (6.76 cm) was found from the application of fertilizer with the dose of 40kgP ha^{-1} and 20kgSha^{-1} (Table 2). The second highest plant spread at first flowering (6.74 cm) was observed from the application of 30 kgP ha^{-1} and 10kgSha^{-1}. But the third most plant spread (5.67 cm) was recorded from the application dose of 30kgPha^{-1} and 10kgSha^{-1}. The nearest amount of plant spread (4.47 cm) was found from the control of phosphorus and with the dose of 20kgSha^{-1}. The lowest plant spread (2.96 cm) was observed from the application of fertilizer with the dose of 0.0kgPha^{-1} and 0.0kgSha^{-1}.

Fig. 3. Showing plant spread (cm^2) at first flowering

4.4 Number of pods plant^{-1}

The maximum number of pods plant^{-1} (23.08) was observed from the application of fertilizer with the dose of 40 kgP ha^{-1} and 20kgSha^{-1} (Table 3). The second highest but identical pods plant^{-1} (20.93) was observed from the application of 40kg Pha^{-1} and 10kgSha^{-1}. But the third most pods plant^{-1} (17.13) was counted from the application dose of 30kgP ha^{-1} and 10kgSha^{-1} closely followed by the combination of 20kgPha^{-1} and control of sulphur (16.53) was observed. But the nearest pods plant^{-1} (15.60) was counted from the application dose of 20kgSha^{-1} and control of Phosphorus. The lower pods plant^{-1} (12.00) was observed from the application of fertilizer with the dose of 40.0kg Pha^{-1} and 0.0kgSha^{-1}. Whereas, the lowest pods plant^{-1} (11.60) was counted from the control.

Nehara *et al.* (2006) reported that the highest number of pods (8.5 plant^{-1}) was obtained from 20kgSha^{-1}. Our findings were in harmony with the results of Nehara *et al.* (2006).

Fig. 4. Showing the number of pods plant^{-1} at maturity stage

4.5 Weight of single pod (g)

The highest weight of single pod (4.40 g) was observed from the application of fertilizer with the dose of 40kgP ha^{-1} and 10kgSha^{-1} (Table 3). The second highest weight (4.10 g) was found when the field was fertilized with the dose of 40kgP ha^{-1} and 20kgSha^{-1}.

The lowest weight of single pod (2.80 g) was observed from no phosphorous and no sulphur fertilizer was applied to the field.

Table 3. Combined effect of phosphorus and sulphur on number of pods plant^{-1}, weight of single pod and number of seeds pod^{-1} of fenugreek

Treatment	Number of pods plant^{-1}	Weight of single pod (g)	Number of seeds pod^{-1}
P_0S_0	11.60 f	2.80 hi	12.80 d
P_0S_1	15.60 b-e	2.87 h	14.40 bc
P_0S_2	16.33 bcd	3.67 d	12.73 d
P_1S_0	16.53 bc	3.87 bc	13.73 c
P_1S_1	13.10 def	2.87 h	14.47 abc
P_1S_2	13.47 c-f	3.20 e	13.80 c
P_2S_0	14.75 b-f	3.01 fg	12.73 d
P_2S_1	17.13 b	3.20 e	15.13 ab
P_2S_2	12.80 ef	3.40 de	14.60 abc
P_3S_0	12.00 f	3.10 f	14.60 abc
P_3S_1	20.93 a	4.40 a	15.33 a
P_3S_2	23.08 a	4.10 b	15.13 ab
CV (%)	11.13	3.79	10.25

Means with uncommon letter(s) are significantly different at 5% probability level by DMRT.

P_0 = 0.0 kg ha^{-1} (control), P_1 = 20 kg ha^{-1}, P_2 = 30 kg ha^{-1} and P_3 = 40 kg ha^{-1}; S_0 = 0.0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2 = 20 kg ha^{-1}

4.6 Number of seeds pod^{-1}

The highest number of seeds pod^{-1} (15.33) was observed from the application of fertilizer with the dose of 40kgPha^{-1} and 10kgSha^{-1} closely followed by the combination of 40kgPha^{-1} and 20kgSha^{-1} (15.13) and 30kgPha^{-1} and 20kgSha^{-1} (Table 3). The identical number of seeds pod^{-1} (14.60) was also found when the field was fertilized with the dose of 40kgPha^{-1} and 0.0kgSha^{-1} and the dose of 30kgPha^{-1} and 20kgSha^{-1}.

The lowest number of seeds pod^{-1} was recorded when no phosphorous and no sulphur was applied to the field.

Table 4. Combined effect of phosphorus and sulphur on 1000 seed weight, weight of seeds pod^{-1} and weight of seeds plant^{-1} of fenugreek

Treatment	1000-seed weight (g)	Weight of seeds pod^{-1} (mg)	Weight of seeds plant^{-1} (g)
P_0S_0	8.10 f	12.00 de	2.75 f
P_0S_1	8.37 e	11.67 e	2.81 ef
P_0S_2	8.33 e	12.33 cde	2.57 g
P_1S_0	8.76 d	12.53 cde	3.10 c
P_1S_1	9.16 c	12.47 cde	2.93 de
P_1S_2	9.79 a	12.73 cde	3.01 cd
P_2S_0	9.58 b	13.60 bc	3.14 c
P_2S_1	8.79 d	13.60 bc	2.79 ef
P_2S_2	9.84 ab	14.53 ab	2.93 de
P_3S_0	8.31 e	13.03 cd	2.31 h
P_3S_1	9.85 ab	15.07 a	4.12 a
P_3S_2	9.98 a	14.60 ab	3.52 b
CV (%)	9.32	9.52	6.88

Means with uncommon letter(s) are significantly different at 5% probability level by DMRT.

P_0 = 0.0 kg ha^{-1} (control), P_1 = 20 kg ha^{-1}, P_2 = 30 kg ha^{-1} and P_3 = 40 kg ha^{-1}; S_0 = 0.0 kg ha^{-1} (control), S_1 = 10 kg ha^{-1}, S_2 = 20 kg ha^{-1}

4.7 Thousand(1000) seed weight (g)

The highest weight of 1000seeds (9.98 g) was observed from the application of fertilizer with the dose of 40kgPha^{-1} and 20kgSha^{-1} (Table 4). The second highest but identical 1000seed weight (9.85) was found when the field was fertilized with the dose of 40kgPha^{-1} and 10kgSha^{-1} which was statistically similar with 30kgPha^{-1} and 20kgSha^{-1}.

The lowest 1000seed weight (8.10 g) was observed from the application of fertilizer with the dose of 0.0kgP ha^{-1} and 0.0kgSha^{-1}.

Sharma *et al*. (2014) reported 1000 seed weight (test weight) increased with the successive levels of applied phosphorous (0, 20 and 40 kgP_2O_5 ha^{-1}) but difference could not reach level of significance. But Bairagi (2014) obtained the maximum 1000seed weight from 60kgP_2O_5 ha^{-1}. Nehara *et al.* (2006) stated that yield contributing characters of fenugreek were significantly increased up to 50kgSha^{-1}. Tuncturk *et al.* (2011) obtained the maximum 1000seed weight from 20kgSha^{-1}.

4.8 Weight of seeds pod^{-1} (mg)

The highest weight of seeds pod^{-1} (15.07 mg) was observed from the application of fertilizer with the dose of 40kgPha^{-1} and 10kgSha^{-1} (Table 4). The second highest but identical weight of seeds pod^{-1} (14.60 mg) was found when the field was fertilized with the dose of 40kgP ha^{-1} and 30kgSha^{-1}. And then the nearest weight of seeds pod^{-1} (14.53 mg) was found from the application of 30kgPha^{-1} with 20kgSha^{-1}. But the weight of seeds pod^{-1} (13.60 mg) was recorded from the application dose of 30kgPha^{-1} and 10kgSha^{-1} and 30kgPha^{-1} and 0.0kgSha^{-1} whereas the

weight seeds pod^{-1} (13.03 mg) was observed from the application dose of fertilizer of 40 kg Pha^{-1} with the control of sulphur.

When the field was fertilized dose of 20 kgP ha^{-1} with the different doses of sulphur, the weight of seeds pod^{-1}(12.73, 12.53, 12.47 mg) were observed. But the lowest weight of seeds pod^{-1} (12.00 mg) was observed when the plot received no phosphorous and no sulphur at all. Sharma *et al.* (2014) obtained the maximum weight of seeds pod^{-1} from the application of 40 kgP_2O_5 ha^{-1}.

4.9 Weight of seeds plant^{-1} (g)

The highest weight of seeds plant^{-1} (4.12 g) was observed from the application of fertilizer with the dose of 40 kgP ha^{-1} and 10kgS ha^{-1} (Table 4). The second highest weight of seeds plant^{-1} (3.52 g) was found when the field was fertilized with the dose of 40kgPha^{-1} and 20kgSha^{-1}. The third highest weight of seeds plant^{-1} (3.14 g) was found from the application of 30kgPha^{-1} and 0.0kgSha^{-1}. But the seed weight plant^{-1} (3.10 g) was recorded from the application dose of 20kgPha^{-1} and control of sulphur, whereas the weight of seeds palnt^{-1} (3.01 g) was observed from the application dose of fertilizer of 20kgPha^{-1} and 20kgSha^{-1}.

When the field was fertilized with the dose of 30 kgP ha^{-1} and 20kgSha^{-1}, weight of seeds palnt^{-1} (2.93 g) was observed. But the nearest weight of seeds palnt^{-1} (2.93 g) was found from the application dose of 20 kgP ha^{-1} and 10kgSha^{-1}. The lowest weight of seeds plant^{-1} was recorded from the combination of 0.0kgP ha^{-1} and 0.0 kgSha^{-1} i.e. when the plot received no P and no S.

4.10 Number of plants plot^{-1} at harvest

The combination of phosphorous and sulphur put no significant effects on number of plants plot^{-1} at harvest (Table 5). The range of number of plants plot^{-1} was 115.8 to 118.2.

4.11 Weight of straw plot^{-1} (g)

The highest weight of straw plot^{-1} (172.59g) was found from the application of fertilizer with the dose of 40kgPha^{-1} and 20kgSha^{-1} (Table 5). The second highest but identical weight of straw plot^{-1} (170.17 g) was found when the field was fertilized with the dose of 40kgP ha^{-1} and 10kgS ha^{-1}. And then the nearest weight of straw plot^{-1} (168.78 g) was found from the application of 20kgP ha^{-1} with the control of sulphur. But the weight of straw plot^{-1} (165.83 g) was recorded from the application dose of 20kgP ha^{-1} and 10kgSha^{-1}, whereas the straw weight plot^{-1} (164.04 g) was observed from the application dose of fertilizer of 30 kgP ha^{-1} and 0.0kgSha^{-1}. Application of 40kgP_2O_5/ha gave significantly higher straw yields (Metha *et al.*, 2012). Rathore and Manohar (1989) recorded the highest straw yields.

Jat and Sharma (2000) reported significantly higher straw yield of fenugreek under application of 20kgP_2O_5 ha^{-1} compared to control at Jobner. The lowest weight of straw plot^{-1} (156.90 g) was obtained from P_0S_0 (control).

Table 5. Combined effect of phosphorus and sulphur on number of plants plot^{-1} and straw yield plot^{-1} of fenugreek

Treatment	Number of plants plot^{-1} at harvest	Weight of straw plot^{-1} (g)
P_0S_0	118.0	156.90 f
P_0S_1	117.7	161.87 cde
P_0S_2	117.5	162.80 b-e
P_1S_0	118.1	168.78 abc
P_1S_1	116.9	165.83 a-d
P_1S_2	117.3	157.37 ef
P_2S_0	118.2	164.04 b-e
P_2S_1	117.2	160.14 def
P_2S_2	115.8	163.47 b-e
P_3S_0	117.4	158.83 def
P_3S_1	116.8	170.17 ab
P_3S_2	117.4	172.59 a
CV (%)	5.16	9.52

Means with uncommon letter(s) are significantly different at 5% probability level by DMRT.

P_0 = 0.0 kg ha^{-1} (control), P_1 = 20 kgha^{-1}, P_2 = 30kg ha^{-1} and P_3 = 40kgha^{-1}; S_0= 0.0kg ha^{-1} (control), S_1 = 10kg ha^{-1}, S_2 = 20kg ha^{-1}

4.12 Seed yield plot^{-1} (g)

The maximum seed yield was obtained from the combination of 40kgPha^{-1} and 10kgSha^{-1} (277.2 g) closely followed by the combination of 30kgPha^{-1} and 20kgSha^{-1} (276.2 g) and 40kgPha^{-1} and 20kgSha^{-1} (275.5 g) (Table 6). Application of 20kgPha^{-1} in combination with 20kgSha^{-1} gave the seed yield plot^{-1} (248.5 g) which was identical with 30 kg P ha^{-1} and 0.0kgSha^{-1}. The lowest seed yield plot^{-1} (136.7 g) was found when no phosphorous and no sulphur was applied to the field.

Application of 40 kgP_2O_5/ha gave significantly higher seed yield (Metha *et al.*, 2012). Seed yield increased with the increase of sulphur doses in Fenugreek (Tunctürk *et al*., 2011).

Table 6. Combined effect of phosphorus and sulphur on seed yield plot^{-1} and seed yield ha^{-1} of fenugreek

Treatment	Seed yield plot^{-1} (g)	Seed yield (kg ha^{-1})	Yield increase over control (%)
P_0S_0	136.7 f	379.7 g	-
P_0S_1	153.8 e	427.2 g	11.12
P_0S_2	182.7 d	507.5 f	25.18
P_1S_0	201.3 c	559.2 e	32.10
P_1S_1	217.5 c	604.2 d	37.16
P_1S_2	248.5 b	690.3 bc	45.00
P_2S_0	246.4 b	684.4 c	44.52
P_2S_1	272.6 a	757.2 a	49.85
P_2S_2	276.2 a	767.2 a	50.51
P_3S_0	224.3 c	623.0 d	39.05
P_3S_1	277.2 a	770.0 a	50.69
P_3S_2	275.5 a	765.3 a	50.39
CV (%)	3.63	4.32	-

Means with uncommon letter(s) are significantly different at 5% probability level by DMRT.

P_0 = 0.0 kg ha^{-1} (control), P_1 = 20kg ha^{-1}, P_2 = 30 kg ha^{-1} and P_3 = 40 kg ha^{-1}; S_0 = 0.0 kg ha^{-1} (control), S_1 = 10kg ha^{-1}, S_2 = 20kg ha^{-1}

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

The maximum seed yield (770.0 $kgha^{-1}$) was observed from the application of fertilizer with the dose of 40kgP ha^{-1} and 10kgSha^{-1}. (Table 6). The second highest but identical seed yield (767.2 kg ha^{-1}) was found when the field was fertilized with the dose of 30kgPha^{-1} with 20kgSha^{-1} closely followed by the combination of 40 kgP ha^{-1} with 20kgS ha^{-1} (765.3 kg ha^{-1}) and 30 kgP ha^{-1} with 10kgSha^{-1} (757.2 kg ha^{-1}), and then the nearest seed yield (690.3 kg ha^{-1}) was recorded from the application of 20kgPha^{-1} with 30kgSha^{-1}. But the seed yield of 684.4 kg ha^{-1} was found from the application dose of 30 kgPha^{-1} with 0.0kg Sha^{-1}, whereas the seed yield (623.0 kg ha^{-1}) was observed from the application dose of fertilizer of 40kgPha^{-1} with 0.0kgS ha^{-1}. Bhragava *et al*. (1989) while working at Durgapura (Jaipur) reported that application 30 kgP_2O_5 ha^{-1} significantly increased the seed yield of fenugreek by increasing the yield attributes like pods plant^{-1}, number of grains pod^{-1} and test weight (1000-seed weight).

When the field was fertilized dose of 20kgP ha^{-1} with 10kgSha^{-1}, the seed yield (604.2 kg ha^{-1}) was observed. The lowest seed yield (379.7 kg ha^{-1}) were observed from the control (P_1S_1). From researches it was reported that highest seed yields in fenugreek were obtained from maximum P applications (Bhati, 1993; Chaudhary, 1999; Halesh *et al.*, 2000; Mavai *et al.*, 2000; Ram and Verma, 2001; Dayanand, 2004; Thapa and Maity, 2004 and Khan *et al.*, 2005). Some researchers reported that an increase in the seed yield of fenugreek was obtained with P doses of 40 and 60 kg ha^{-1} (Khiriya *et al*., 2001; Khiriya *et al*., 2003 and Sheoran *et al*., 1999). Bhairagi (2014) obtained the highest seed yield per hectare from the application of 60 kg P_2O_5 ha^{-1}. Lal *et al*. (2015) reported that application of sulphur @ 30 $kgha^{-1}$ gave the maximum seed yield of fenugreek.

Application of 40 kg P ha^{-1} in combination with 10 kg S ha^{-1} increased maximum percentage of seed yield over control (50.69%) followed by 30 kgP ha^{-1}+ 20kgSha^{-1} (50.51%) and 40kgP ha^{-1}+ 20kgS ha^{-1} (50.39%).

There was highly significant correlation between seed yield of fenugreek and Phosphorus levels (Fig. 6). The relationship between seed yield and levels of phosphorus showed a linear equation as $y = 7.425x + 462.1$; $R^2 = 0.917^{**}$ which stated that seed yield increased at the rate of 7.425 kg ha^{-1} for per unit change of phosphorus levels. The R^2 value indicated that 91.7% seed yield was attributed due to phosphorus levels.

There depicted a significant correlation between seed yield of fenugreek and sulphur levels (Fig. 7). The relationship between seed yield and levels of sulphur showed a linear equation as $y = 7.12x + 567.9$; $R^2 = 0.932^{**}$ which stated that seed yield increased at the rate of 7.12 kg ha^{-1} for per unit change of sulphurlevels. The R^2 value indicated that 93.2% seed yield was attributed due to sulphur levels.

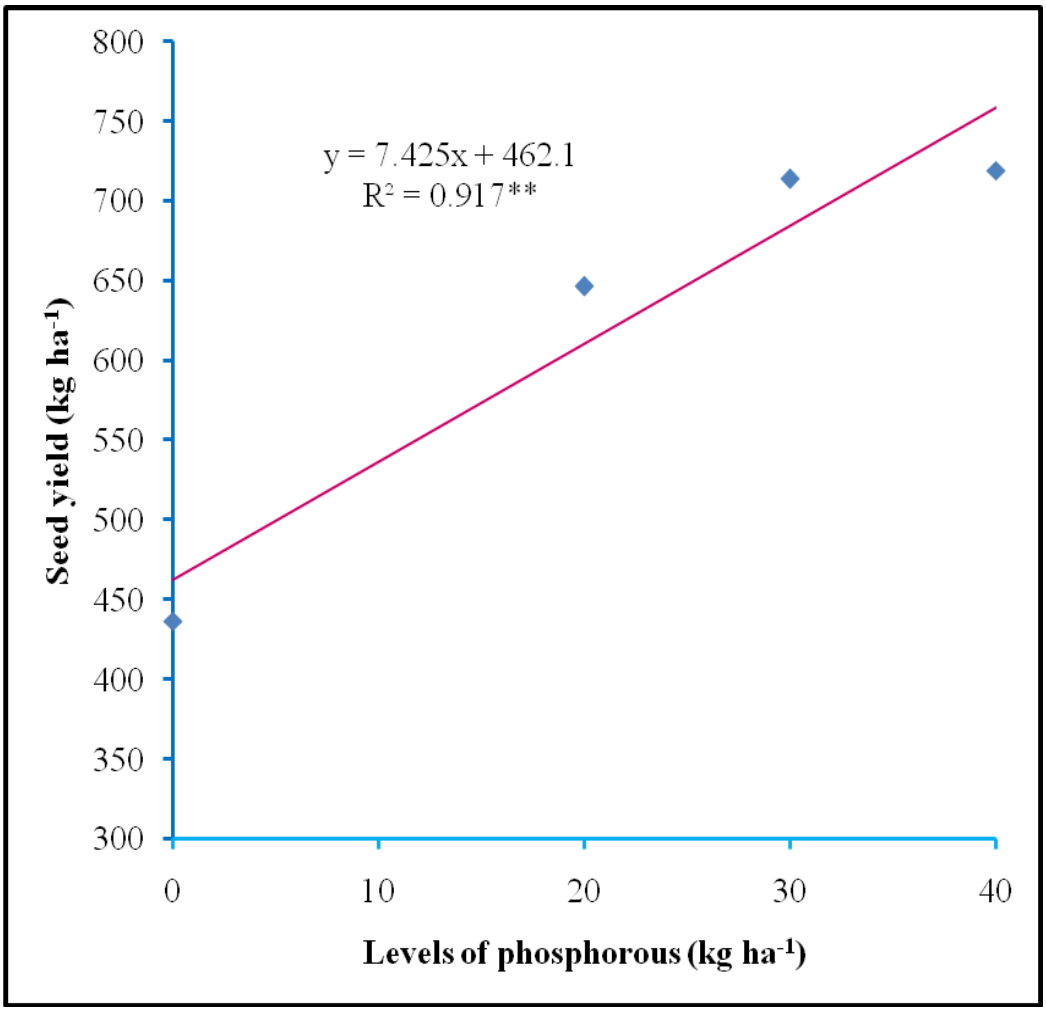

Fig. 5. Response of seed yield of fenugreek to different levels of phosphorus

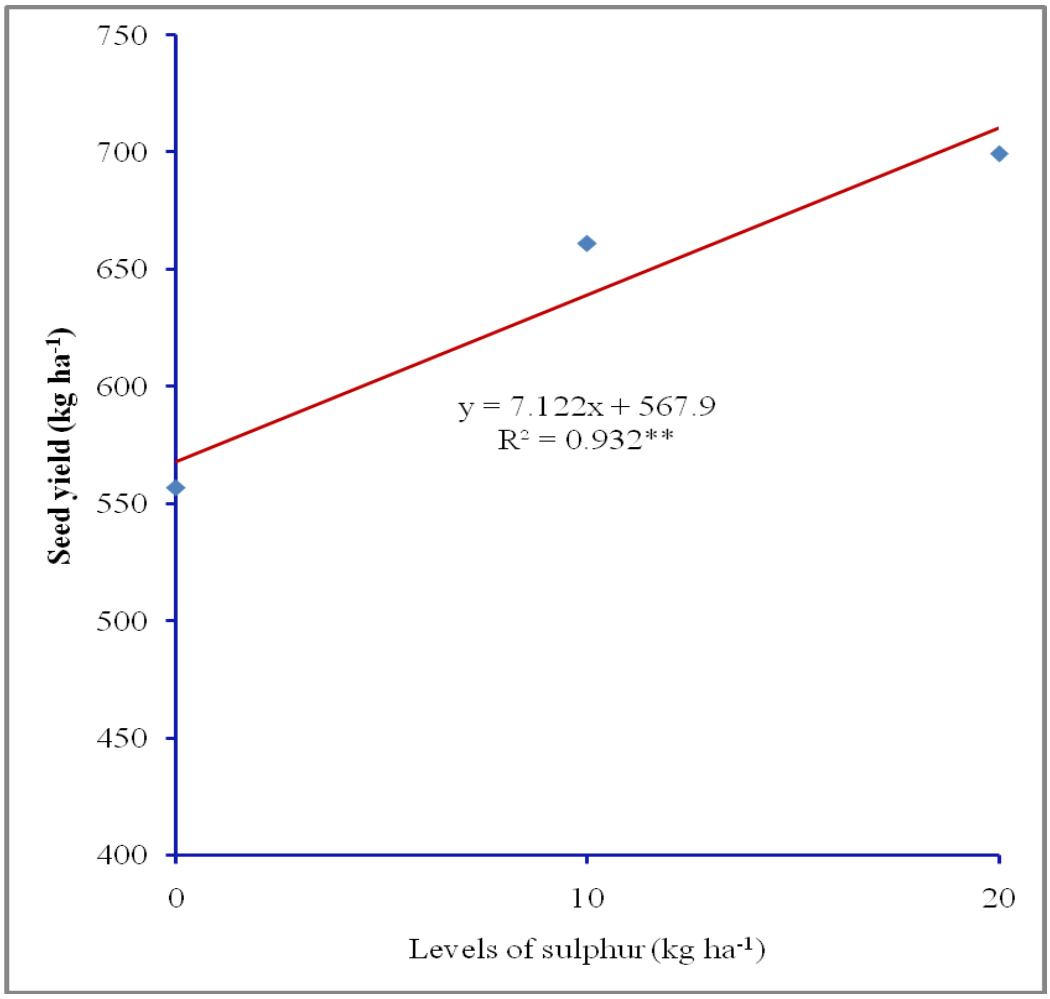

Fig. 6: Response of fenugreek seed yield to different levels of sulphur

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2016 to March 2017 to observe the effect of four levels of phosphorus *viz.*, 0, 20, 30, 40 kg P ha^{-1} and three levels of sulphur *viz*., 0, 10, 20 kg S ha^{-1} on growth, seed yield and yield attributes of fenugreek (cv. BARI Methi-1). Data on different growth parameters, seed yield attributes were recorded. Data analysis was done using ANOVA technique and the mean differences were adjudged by DMRT at 5% level of probability.

The highest plant height (26.73 cm) was found when the field was fertilized with the dose of 40 kg ha^{-1} of phosphorous and 10 kg ha^{-1} of sulphur at 30 days after sowing (DAS). At 30 DAS, the second highest but identical plant height was observed as 25.89 cm with the application of 40kgP ha^{-1} and 20kgS ha^{-1}. The maximum number of primary branches $plant^{-1}$ (4.60) was found from the application of fertilizer with the dose of 40kgP ha^{-1} and 20kgSha^{-1} at 30 days after sowing (DAS). The identical nearest number of primary branches $plant^{-1}$ (4.53) was observed from the application of 40 kgP ha^{-1} and 10 kg ha^{-1} of sulphur. The lowest primary branches $plant^{-1}$ (2.80) was observed from the application of 0.0 kg P ha^{-1} and 0.0kgS ha^{-1} at 30 DAS. At 60 DAS, the maximum number of branches $plant^{-1}$ was observed (5.73) from the dose of 40kgP ha^{-1} and 20kgSha^{-1}. The nearest number of branches (4.47) was observed with the dose of 40kg Pha^{-1} and 10kgSha^{-1} at 60 DAS. The maximum plant spread at first flowering (6.76 cm) was found from the application of fertilizer with the dose of 40kg Pha^{-1} and 20kgSha^{-1}. The second highest plant spread at first flowering (6.74 cm) was observed from the application of 40 kgP ha^{-1} and 10kgSha^{-1}. But the third most plant spread (5.67 cm) was

recorded from the application dose of 30 kgPha^{-1} and 10kg Sha^{-1}. The maximum number of pods plant^{-1} (23.08) was observed from the application of fertilizer with the dose of 40kgPha^{-1} and 20kgS ha^{-1}. The highest weight of single pod (4.40 g) was observed from the application of fertilizer with the dose of 40kgP ha^{-1} and 10kgS ha^{-1}. The second highest weight (4.10 g) was found when the field was fertilized with the dose of 40kgP ha^{-1} and 20kgS ha^{-1}. The lowest weight of single pod (2.80 g) was observed from no phosphorous and no sulphur fertilizer was applied to the field. The highest number of seeds pod^{-1} (15.33) was observed from the application of fertilizer with the dose of 40kgP ha^{-1} and 10 kgSha^{-1} closely followed by the combination of 40kgP ha^{-1} and 20kgS ha^{-1} (15.13) and 30 kgP ha^{-1} and 20kgS ha^{-1}. The identical number of seeds pod^{-1} (14.60) was also found when the field was fertilized with the dose of 40 kgP ha^{-1} and 0.0 kgS ha^{-1} and the dose of 30 kgP ha^{-1} and 20kgSha^{-1}.

The highest weight of 1000 seeds (9.98 g) was observed from the application of fertilizer with the dose of 40kg P ha^{-1} and 20kgSha^{-1}. The second highest but identical 1000-seed weight (9.85) was found when the field was fertilized with the dose of 40kgPha^{-1} and 10kgSha^{-1} which was statistically similar with 30kgPha^{-1} and 20kgSha^{-1}. The highest weight of seeds pod^{-1} (15.07 mg) was observed from the application of fertilizer with the dose of 40kgPha^{-1} and 10kgSha^{-1}. The second highest but identical weight of seeds pod^{-1} (14.60 mg) was found when the field was fertilized with the dose of 40kg Pha^{-1} and 20kgSha^{-1}. And then the nearest weight of seeds pod^{-1} (14.53 mg) was found from the application of 30kgPha^{-1} with 20kgSha^{-1}. The highest weight of seeds plant^{-1} (4.12 g) was observed from the application of fertilizer with the dose of 40kgPha^{-1} and 10kgSha^{-1}. The second weight of seeds plant^{-1} (3.52 g) was found when the field was fertilized with the dose of 40kgPha^{-1} and 20kgS ha^{-1}.

The highest weight of straw plot^{-1} (172.59 g) was found from the application of fertilizer with the dose of 40kgP ha^{-1} and 20kgS ha^{-1}. The second highest but identical weight of straw plot^{-1} (170.17 g) was found when the field was fertilized with the dose of 40kgPha^{-1} and 10kgSha^{-1}. The maximum seed yield plot^{-1} was obtained from the combination of 40kgPha^{-1} and 10kgSha^{-1} (277.2 g) closely followed by the combination of 30kgPha^{-1} and 20kgSha^{-1} (276.6 g) and 40kg Pha^{-1} and 20kgSha^{-1} (275.5 g). Application of 20 kg P ha^{-1} in combination with 20kgSha^{-1} gave the seed yield plot^{-1} (248.5 g) which was identical with 30kgPha^{-1} and 0.0kgS ha^{-1}. The lowest seed yield (136.7 g/plot) was found when no phosphorous and no sulphur was applied to the field.

The maximum seed yield (770.0 kgha^{-1}) was observed from the application of fertilizer with the dose of 40kgPha^{-1} and 10kgSha^{-1}. The second highest but identical seed yield (767.2 kg ha^{-1}) was found when the field was fertilized with the dose of 30kg Pha^{-1} with 20kgSha^{-1} closely followed by the combination of 40kgPha^{-1} with 20kgSha^{-1} (765.3 kg ha^{-1}) and 30kgPha^{-1} with 10kgSha^{-1} (757.2 kg ha^{-1}). Application of 40 kg P ha^{-1} in combination with 10kgSha^{-1} increased maximum percentage of seed yield over control (50.69%) followed by the combination of 30kgPha^{-1} and 20kgSha^{-1} (50.51%) and 40kgPha^{-1} and 20kgSha^{-1} (50.39%). The relationship between seed yield and levels of phosphorus showed a linear equation as $y = 7.425x + 462.1$; $R^2 = 0.917^{**}$ which stated that seed yield increased at the rate of 7.425 kg ha^{-1} for per unit change of phosphorus levels. The R^2 value indicated that 91.7% seed yield was attributed due to phosphorus levels. The relationship between seed yield and levels of sulphur showed a linear equation as $y = 7.12x + 567.9$; $R^2 = 0.932^{**}$ which stated that seed yield increased at the rate of 7.12 kgha^{-1} for per unit change of sulphurlevels. The R^2 value indicated that 93.2% seed yield was attributed due to sulphur levels.

Based on the findings of the present study, the following conclusion might be drawn:

1. The combined application of 40kgPha^{-1} and 20kgSha^{-1} produced the maximum plant height at 60 days after sowing (DAS), primary branches plant^{-1} both at 30 and 60 DAS, number of pods plant^{-1}, 1000-seed weight, straw yield plot^{-1}, which were identical with the combined application of 40kgP ha^{-1} and 10kgSha^{-1}.
2. Application of 40kg Pha^{-1} in combination with 10kgS ha^{-1} gave the maximum plant height at 30 DAS, single pod weight, weight of seeds pod^{-1} and number of seed pod^{-1}.
3. The maximum seed yield was obtained from the combination of 40kgP ha^{-1} and 10kgSha^{-1} closely followed by the combination of 30kgPha^{-1} and 20kgSha^{-1} and 40 kgP ha^{-1} with 20kgS ha^{-1}.

RECOMMENDATION

- Application of phosphorous @ 40 kg ha^{-1} in combination with sulphur @ 10 kg ha^{-1} is suitable for fenugreek cultivation.

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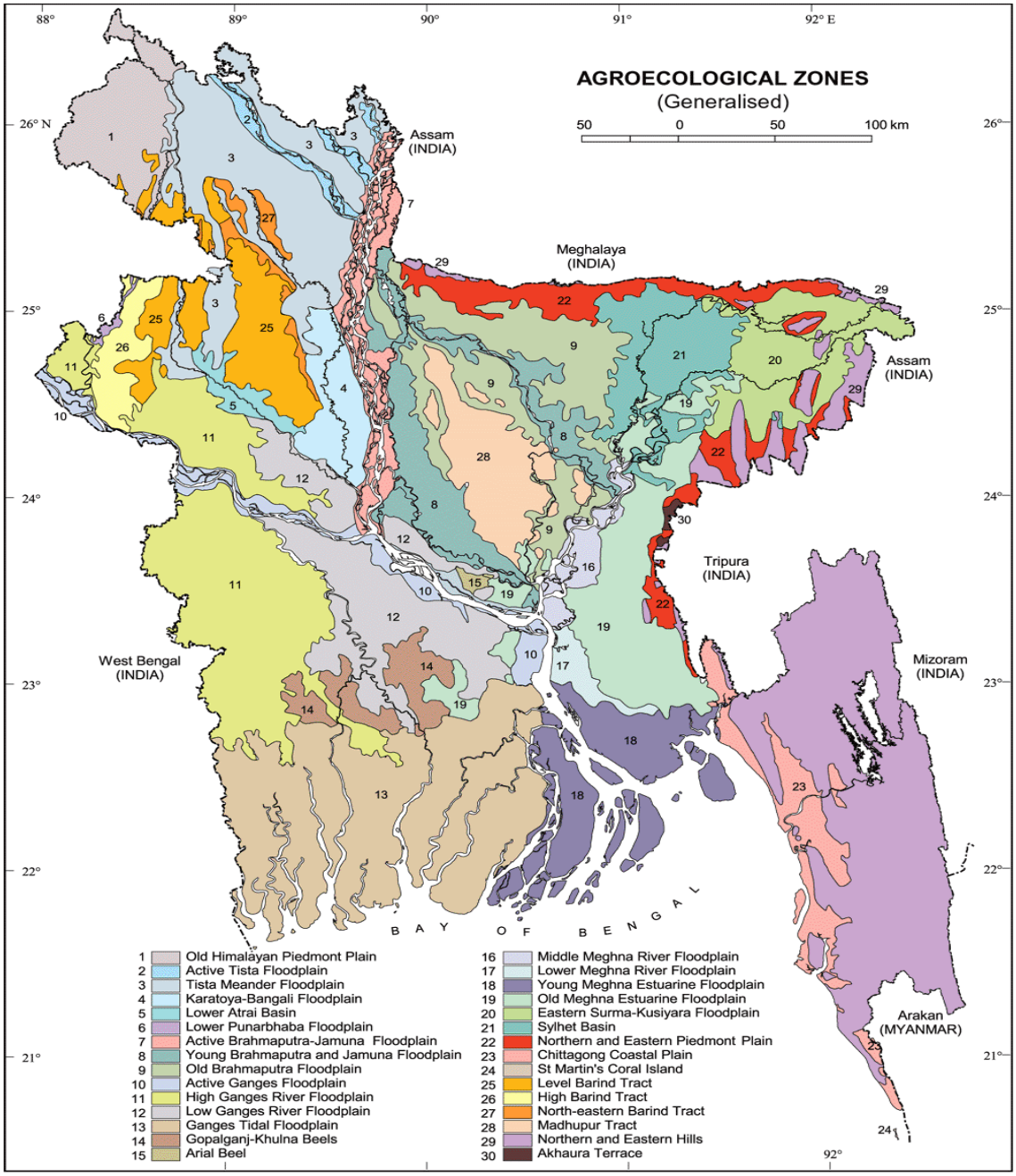
APPENDICES

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



Appendix II. Soil analysis of the experimental field prior to Experimentation

A. Morphological Characteristics

Morphological features	characteristics
Location	SAU Farm, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Mechanical analysis

Constituents	Percent
Sand	27
Silt	43
Clay	30

C. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.45
Total nitrogen (%)	0.03
Available P (ppm)	20
Exchangeable K (%)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from November to March 2016/2017

Months	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
November, 2016	31.6	21.4	68.2	33
December, 2016	30.2	20	59	11
January, 2017	29	12.8	46	09
February, 2017	30.8	15.9	47	15
March, 2017	33	17.9	48.6	42

Source: Bangladesh Meteorological Department, Agargaon, Dhaka-1207