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Effect of Phosphorous and Sulphur Fertilization on Seed Yield of Fenugreek (*Trigonella foenum-graecum* L.)

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Abstract: *A research work 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 seed yield of fenugreek (cv. BARI Methi-1). Recorded data were analysed by using ANOVA technique and the mean differences were adjudged by DMRT at 5% level of probability. 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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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.

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).

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 @ 26 kg P (60 kg P_2O_5) ha^{-1} (Bhairagi, 2014; Purbey and Sen, 2005). Sharma et al. (2014) obtained maximum number of 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 kg S ha^{-1} produced the highest 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 kg S ha^{-1} which was statistically similar to 30 kg S ha^{-1}; whereas Nehara *et al.* (2006) got the highest seed yield from 25 kg S ha^{-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 observe the influence of phosphorous and sulphur on seed yield attributes of fenugreek.
ii. To find out the suitable combination of phosphorous and sulphur for higher seed yield of fenugreek.

II. Review Of Literature

Improvement work on fenugreek is limited in Bangladesh. However, a good number of investigations were taken 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. Lal *et al*. (2015) carried out an experiment to study the effects of sulphur and zinc nutrients on the yield of fenugreek and found that the number of pods per plant around 51 with maximum seed yield (1571.53 kg ha^{-1}) by the soil application of 30 kg sulphur per hectare. Sharma *et al.* (2014) investigated the effect of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) on yield attributes, yield and seed quality of fenugreek (*Trigonella foenum-graecum* L.) and found that the application of phosphorus up to 40 kg P_2O_5 ha^{-1} resulted in significantly higher number of pods per plant, seeds per pod and seed yield. Bairagi (2014) also found maximum thousand seed weight (18 g) and seed yield (1575 kg ha^{-1}) with the application of 60 kg P_2O_5 ha^{-1}. He also found that 60 kg P_2O_5 ha^{-1} coupled with a row spacing of 30 cm ensure highest yield of good quality fenugreek seed in North Indian conditions. Godara *et al.* (2013) also studied the response of *Kasuri Methi* (*Trigonella corniculata* L.) to phosphorus and sulphur. Result showed that the growth parameters and yield of dried leaves of the crop increased almost linearly with increasing levels of phosphorus. Verma *et al.* (2013) conducted an experiment to study the effect of vermicompost and sulphur on yield and nutrient uptake of fenugreek. Results indicated that 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 to study response of phosphorus and bio-fertilizers on fenugreek and found that the application of 20 kg N and 40 kg P_2O_5 ha^{-1} gave significantly higher seed, straw and biological yields, respectively. Tuncturk (2011) examined the effects of nitrogen and sulphur applications on the yield and quality of fenugreek and found highest seed yields (853.0 and 815 kg ha^{-1}) by the application of 90 kg N ha^{-1} and 20 kg S ha^{-1}. Nehara *et al.* (2006) conducted an experiment 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}) and sulphur (0, 25 and 50 kg S ha^{-1}) application. Result indicated that an increase in phosphorus 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 of fenugreek. Jat and Shakwat (2001) analyse the pods $plant^{-1}$, seeds pod^{-1} and test weight of fenugreek (*Trigonella foenum-graecum* L.) and found that, those outcomes increase significantly with increasing dose of phosphorous up to 80 kg P_2O_5 ha^{-1}. Yield estimates of fenugreek also responded significantly to sulphur application up to 100 kg ha^{-1}.

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 $23^o41'$ 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.

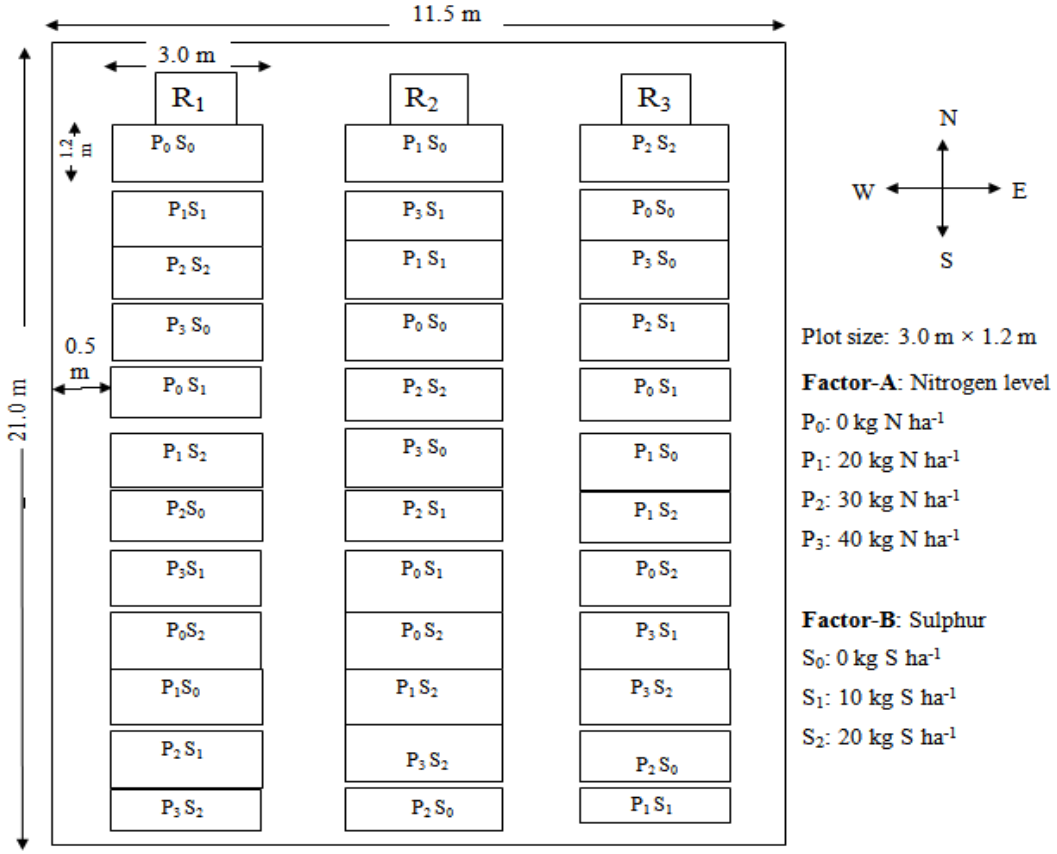

Fig. 1. A field layout of the experiment having four levels of phosphorus and three levels of sulphur

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
Potassium	Potassium 67 kg ha^{-1}	MoP
Cowdung	5 t ha^{-1}	Well rotten cowdung
Nitrogen	80 kg ha^{-1}	Urea
Phosphorus	As per treatment	TSP
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. Number of pods $plant^{-1}$
2. Weight of seeds pod^{-1} (mg)
3. 1000 seed weight (g)
4. Weight of single pod (g)
5. Weight seeds $plant^{-1}$ (g)
6. Number of seeds pod^{-1}
7. Weight of straw $plot^{-1}$ (g)
8. Number of plants $plot^{-1}$ at harvest
9. Seed yield $plot^{-1}$ (g)
10. Seed yield (kg ha^{-1})

3.11.1 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.

3.11.2 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.

3.11.3 1000 seed weight (g): 1000 seed weight was measured by Electric Balance in gram (g). 1000 seed from each treatment were counted then weighed.

3.11.4 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.

3.11.5 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}.

3.11.6 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.

3.11.7 Weight of straw plot^{-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}.

3.11.8 Number of plant plot^{-1} at harvest: Number of plant was counted during final harvesting of fenugreek plant

3.11.9 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$^{-1.}$

3.11.10 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 in respect of growth and yield components were statistically analyzed to find out the significance of the experimental results. The means of all the treatments were calculated and the analysis of variance for each of the characters under study was performed by F test. The difference among the treatment means was evaluated by DMRT (Gomez and Gomez, 1984) at 5% level of probability.

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 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 kg P ha^{-1} and 20 kg S ha^{-1} (Table 3). The second highest but identical pods plant^{-1} (20.93) was observed from the application of 40 kg P ha^{-1} and 10 kg S ha^{-1}. But the third most pods plant^{-1} (17.13) was counted from the application dose of 30 kg P ha^{-1} and 10 kg S ha^{-1} closely followed by the combination of 20 kg P ha^{-1} and control of sulphur (16.53) was observed. But the nearest pods plant^{-1} (15.60) was counted from the application dose of 20 kg S ha^{-1} and control of Phosphorus. The lower pods plant^{-1} (12.00) was observed from the application of fertilizer with the dose of 40.0 kg P ha^{-1} and 0.0 kg S ha^{-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 20 kg S ha^{-1}. Our findings were in harmony with the results of Nehara *et al.* (2006).

Fig. 2. Showing the number of pods plant^{-1} at maturity stage

4.2 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 40 kg P ha^{-1} and 10 kg S ha^{-1} (Table 3). The second highest weight (4.10 g) was found when the field was fertilized with the dose of 40 kg P ha^{-1} and 20 S 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.

Table 1. 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}

4.3 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 40 kg P ha^{-1} and 10 kg S ha^{-1} closely followed by the combination of 40 kg P ha^{-1} and 20 kg S ha^{-1} (15.13) and 30 kg P ha^{-1} and 20 kg S ha^{-1} (Table 3). The identical number of seeds pod^{-1} (14.60) was also found when the field was fertilized with the dose of 40 kg P ha^{-1} and 0.0 kg S ha^{-1} and the dose of 30 kg P ha^{-1} and 20 kg S ha^{-1}.

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

Table 2. 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}

4.4 Thousand (1000) seed weight (g)

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

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

Sharma *et al*. (2014) reported 1000 seed weight (test weight) increased with the successive levels of applied phosphorous (0, 20 and 40 kg P_2O_5 ha^{-1}) but difference could not reach level of significance. But Bairagi (2014) obtained the maximum 1000 seed weight from 60 kg P_2O_5 ha^{-1}. Nehara *et al.* (2006) stated that yield contributing characters of fenugreek were significantly increased up to 50 kg S ha^{-1}. Tuncturk *et al.* (2011) obtained the maximum 1000-seed weight from 20 kg S ha^{-1}.

4.5 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 40 kg P ha^{-1} and 10 kg S ha^{-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 40 kg P ha^{-1} and 30 kg S ha^{-1}. And then the nearest weight of seeds pod^{-1} (14.53 mg) was found from the application of 30 kg P ha^{-1} with 20 kg S ha^{-1}. But the weight of seeds pod^{-1} (13.60 mg) was recorded from the application dose of 30 kg P ha^{-1} and 10 kg S ha^{-1} and 30 kg P ha^{-1} and 0.0 kg S ha^{-1} whereas the weight seeds pod^{-1} (13.03 mg) was observed from the application dose of fertilizer of 40 kg P ha^{-1} with the control of sulphur.

When the field was fertilized dose of 20 kg P 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 kg P_2O_5 ha^{-1}.

4.6 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 kg P ha^{-1} and 10 kg S 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 40 kg P ha^{-1} and 20 kg S ha^{-1}. The third highest weight of seeds plant^{-1} (3.14 g) was found from the application of 30 kg P ha^{-1} and 0.0 kg S ha^{-1}. But the seed weight plant^{-1} (3.10 g) was recorded from the application dose of 20 kg P ha^{-1} and control of sulphur, whereas the weight of seeds palnt^{-1} (3.01 g) was observed from the application dose of fertilizer of 20 kg P ha^{-1} and 20 kg S ha^{-1}.

When the field was fertilized with the dose of 30 kg P ha^{-1} and 20 kg S ha^{-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 kg P ha^{-1} and 10 kg S ha^{-1}. The lowest weight of seeds plant^{-1} was recorded from the combination of 0.0 kg P ha^{-1} and 0.0 kg S ha^{-1} i.e. when the plot received no P and no S.

4.7 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.

4.8 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 40 kg P ha^{-1} and 20 kg S ha^{-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 40 kg P ha^{-1} and 10 kg S ha^{-1}. And then the nearest weight of straw plot^{-1} (168.78 g) was found from the application of 20 kg P ha^{-1} with the control of sulphur. But the weight of straw plot^{-1} (165.83 g) was recorded from the application dose of 20 kg P ha^{-1} and 10 kg S ha^{-1}, whereas the straw weight plot^{-1} (164.04 g) was observed from the application dose of fertilizer of 30 kg P ha^{-1} and 0.0 kg S ha^{-1}. Application of 40 kg P_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 20 kg P_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 3. 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 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}

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

The maximum seed yield was obtained from the combination of 40 kg P ha^{-1} and 10 kg S ha^{-1} (277.2 g) closely followed by the combination of 30 kg P ha^{-1} and 20 kg S ha^{-1} (276.2 g) and 40 kg P ha^{-1} and 20 kg S ha^{-1} (275.5 g) (Table 6). Application of 20 kg P ha^{-1} in combination with 20 kg S ha^{-1} gave the seed yield plot^{-1} (248.5 g) which was identical with 30 kg P ha^{-1} and 0.0 kg S ha^{-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 kg P_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 4. 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 = 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}

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

The maximum seed yield (770.0 kg ha^{-1}) was observed from the application of fertilizer with the dose of 40 kg P ha^{-1} and 10 kg S ha^{-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 30 kg P ha^{-1} with 20 kg S ha^{-1} closely followed by the combination of 40 kg P ha^{-1} with 20 kg S ha^{-1} (765.3 kg ha^{-1}) and 30 kg P ha^{-1} with 10 kg S ha^{-1} (757.2 kg ha^{-1}), and then the nearest seed yield (690.3 kg ha^{-1}) was recorded from the application of 20 kg P ha^{-1} with 30 kg S ha^{-1}. But the seed yield of 684.4 kg ha^{-1} was found from the application dose of 30 kg P ha^{-1} with 0.0 kg S ha^{-1}, whereas the seed yield (623.0 kg ha^{-1}) was observed from the application dose of fertilizer of 40 kg P ha^{-1} with 0.0 kg S ha^{-1}. Bhragava *et al.* (1989) while working at Durgapura (Jaipur) reported that application 30 kg P_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 20 kg P ha^{-1} with 10 kg S ha^{-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 kg ha^{-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 kg P ha^{-1} + 20 kg S ha^{-1} (50.51%) and 40 kg P ha^{-1} + 20 kg S 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 sulphur levels. The R^2 value indicated that 93.2% seed yield was attributed due to sulphur levels.

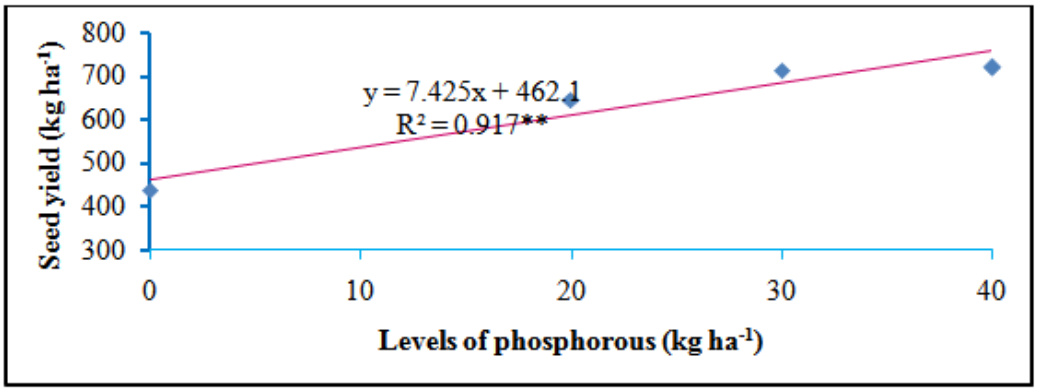

Fig. 3. Response of seed yield of fenugreek to different levels of phosphorus

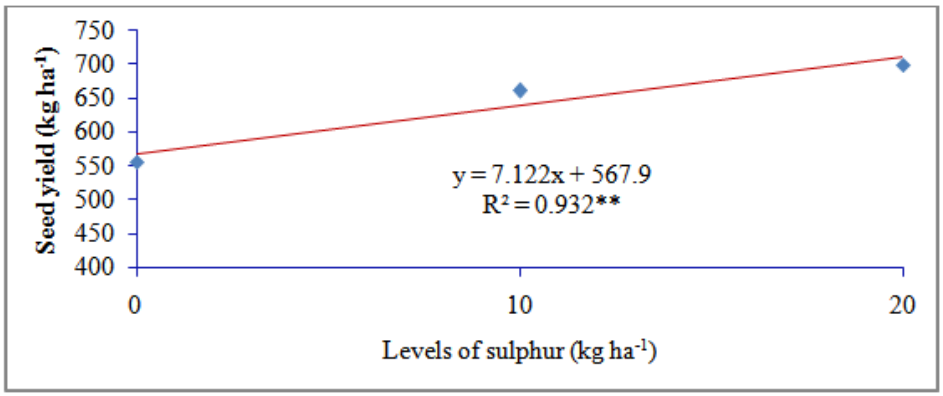

Fig. 4: Response of fenugreek seed yield to different levels of sulphur

V. Conclusion

Data on different growth parameters and seed yield attributes were recorded and analysed. Based on the findings of the present study, the following conclusion might be drawn:

1. Application of 40 kg P ha^{-1} in combination with 10 kg S ha^{-1} gave the maximum plant height at 30 DAS, single pod weight, weight of seeds pod^{-1} and number of seed pod^{-1}.
2. The maximum seed yield was obtained from the combination of 40 kg P ha^{-1} and 10 kg S ha^{-1} closely followed by the combination of 30 kg P ha^{-1} and 20 kg S ha^{-1} and 40 kg P ha^{-1} with 20 kg S ha^{-1}.

VI. 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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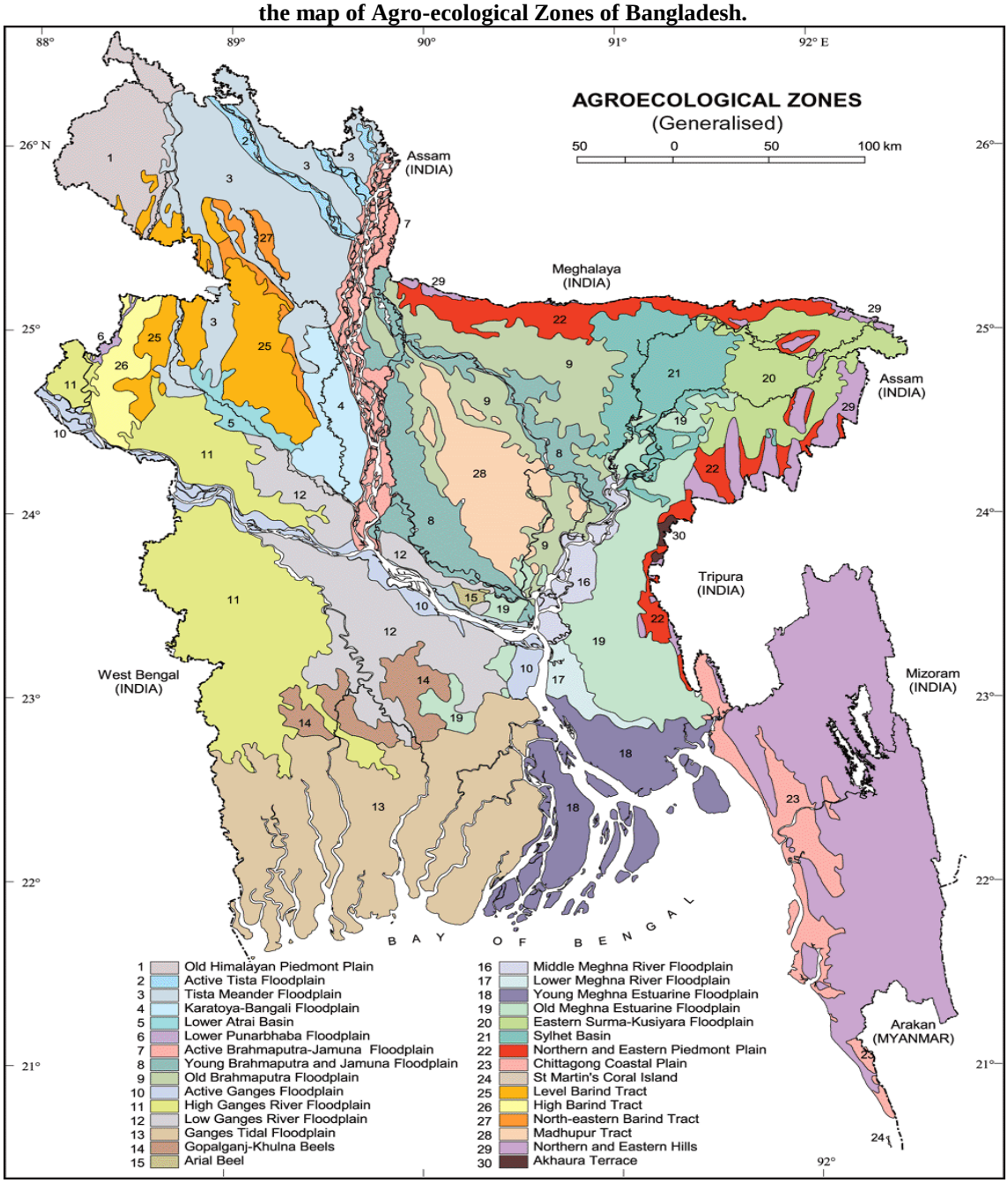
APPENDICES

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

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