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Response of fenugreek *(Trigonella foenum-graecum)* to phosphorus, sulphur and plant-growth regulators under semi-arid eastern plains zone of Rajasthan

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ABSTRACT

A field experiment was conducted 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), sulphur (0, 25 and 50 kg S/ha) 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 and sulphur up to 50 kg S/ha 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, except the P and S content in seed and straw, where significant increase was recorded only up to 25 kg P_2O_5/ha and 25 kg S/ha. Among different growth-regulators, the application of NAA @ 20 ppm proved significantly better than the control, tricontanol and etheophon.

Key words : Fenugreek, Phosphorus, Sulphur, Plant-growth regulators, Nutrient content and uptake

Fenugreek or *methi (Trigonella foenum-graecum)* is an important leguminous crop grown in winter season *(rabi).* It is cultivated mainly in northern India as an important spices crop.

It has great export potential. Application of tricontanol-based plant-growth regulators naphthalene acetic acid (NAA) and ethrel induce higher physiological efficiency including photosynthetic ability of plants. It leads to better growth and yield of several vegetables and agronomic crops without substantial increase in the cost of production. These increase ethylene formation in plants, which facilitates the efficient translocation of phytosynthates from source to sink. Therefore the present investigation was carried out to study the response of fenugreek as influenced by P, S and plant-growth regulators.

MATERIALS AND METHODS

A field experiment was conduced during winter season *(rabi)* of 2001-02 and 2002-03 on a loamy-sand soil at Jobner in Rajasthan. The soil was low in organic carbon (0.34%), available nitrogen (133.3 kg/ha), available phosphorus (17.5 kg P_2O_5/ha) and available potassium (150.5 kg K_2O/ha), and was slightly alkaline in reaction. The experiment was laid out in split-plot design consisting of a combination of three levels of phosphorus (0, 25 and 50 kg P_2O_5/ha) through diammonium phosphate (DAP) and three levels of sulphur (0, 25 and 50 kg S/ha) through gypsum in main plot, and four levels of plant-growth regulators (control, tricontanol @ 2 ppm, NAA @ 20 ppm and etheophon @ 100 ppm) in subplot, with four replications. Fenugreek cv 'RMt 1' was sown on 14 November 2001 and 10 November 2002, using seed rate 20 kg/ha, in rows spaced 30 cm apart. Nitrogen was estimated by digesting the plant samples with sulphuric acid and hydrogen peroxide. Nitrogen was estimated by colorimetric method using Spectronic-20 after development of colour with Nesseler's reagent (Snell and Snell, 1939), and expressed as percentage. Phosphorus was estimated by digesting the plant samples with di-acid mixture of HNO_3 and $HClO_4$ and was estimated by Vanadomolybdo phosphate yellow-colour method. Sulphur was estimated by turbidimetric method (Tabatabai and Bremner, 1970). Plant samples were digested with triacid mixture (nitric acid, perchloric acid and hydrochoric acid) using gelatin barium chloride solution for development of turbidity. The turbidity was measured by colorimeter and S content was expressed in percentage on dry-weight basis. The total uptake of nitrogen, phosphorus and sulphur by fenugreek crop at harvest was computed by summing up the nutrient uptake of seed as well as straw.

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RESULTS AND DISCUSSION

Effect of phosphorus

An increase in P level significantly improved the yield-attributing characters like number of pods/plant, seeds/pod and test weight up to 50 kg P_2O_5/ha. The seed, straw and biological yields and the net returns of fenugreek also increased significantly with successive increase in P level up to 50 kg P_2O_5/ha, but harvest index remained at par under 25 kg P_2O_5/ha as well as 50 kg P_2O_5/ha, though increasing significantly over the control (Table 1). It might be attributed to the favourable stimulatory effect of P on its shoot growth. Nodulation and dry weight of nodules brought about substantial improvement in yield attributes, viz. pods/plant, seeds/pod and test weight, and ultimately the seed and straw yields. There was highly significant positive correlation between yield attributes and seed yield. Significantly higher values of yield attributes and seed yield of fenugreek were reported from different locations at 40 to 50 kg P_2O_5/ha (Jat *et al.,* 2001; Khiriya and Singh, 2003).

The nitrogen and phosphorus contents of fenugreek in seed and straw and their total uptake increased significantly with increase in the level of applied phosphorus up to 50 kg P_2O_5/ha. The S content in seed and straw increased significantly only up to 25 kg P_2O_5/ha, whereas increase in P levels significantly improved the total S uptake of fenugreek, and consequently the highest uptake of sulphur was recorded under 50 kg P_2O_5/ha (Table 2). It was because the application of phosphorus improved the overall nutritional environment in the rhizosphere as well as in the plant system resulting in increased nodulation and dry weight of nodules, which might have increased the availability of N and P and of some other nutrients from deeper layers and larger surface area on account of better root development and proliferation. Thus the favourable influence of P on proper root and shoot development on higher nutrient absorption, greater photosynthetic efficiency and production of assimilates and their efficient partitioning into different sinks led to higher content of N, P and S in seed and straw and ultimately in higher uptake due to significant increase in both seed and straw yields. Singh and Bishnoi (1996) also reported similar results in fenugreek due to application of phosphorus.

The benefit : cost (B : C) ratio of fenugreek increased significantly under application of 25 kg P_2O_5/ha over the control, but further increase in P level did not show any significant improvement (Table 1).

Effect of sulphur

This increase in S level significantly improved the yield-attributing characters like number of pods/plant and seeds/pod up to 50 kg S/ha, but the test weight increased only up to 25 kg S/ha. Seed yield and net returns also increased with increase in S level up to 50 kg S/ha, but the straw yield and harvest index increased significantly up to 25 kg S/ha. However, the application of 25 kg S/ha remained at par with that of 50 kg S/ha (Table 1), because the application of S increased the availability of most of the plant nutrients in rhizosphere as well as nutritional environment in the plant system due to greater absorption of

Table 1. Effect of phosphorus, sulphur and plant-growth regulators on yield attributes and economics of fenugreek (pooled data of 2 years)

Treatment	Pods/ plant	Seeds/ pod	Test weight (g)	Seed yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index	Net returns (Rs/ha)	B : C ratio
P_2O_5 (kg/ha)									
P_0	34.8	15.7	11.9	14.00	38.56	52.56	26.6	16,248	1.55
P_{25}	36.5	17.2	12.2	16.23	42.13	57.97	27.8	19,496	1.77
P_{50}	37.9	17.7	12.5	17.15	44.18	61.49	27.9	20,591	1.78
CD (P=0.05)	0.6	0.3	0.2	0.43	1.34	1.45	0.4	534	0.05
S (kg/ha)									
P_0	35.0	15.8	11.9	14.02	30.62	52.47	26.7	15,887	1.47
P_{25}	36.5	17.2	12.3	16.31	42.50	58.01	27.6	19,668	1.77
P_{50}	37.7	17.7	12.4	17.05	43.76	60.73	28.0	20,781	1.83
CD (P=0.05)	0.6	0.3	0.2	0.43	1.34	1.45	0.4	534	0.05
Plant-growth regulators									
Control	34.7	16.3	11.9	15.09	39.65	54.58	27.3	17,703	1.64
Tricontanol @ 2 ppm	36.6	16.9	12.3	15.83	41.72	57.58	27.4	18,626	1.69
NAA @ 20 ppm	37.9	17.4	12.4	16.52	43.60	60.03	27.8	20,232	1.77
Etheophon @ 100 ppm	36.4	16.9	12.2	15.73	41.52	57.16	27.2	18,532	1.66
CD (P=0.05)	0.6	0.3	0.2	0.40	1.25	1.58	NS	478	0.04

NS = Non-significant

nutrients and ultimately the metabolism and photosynthetic activity, resulting in better growth and development of the plant. Further, the efficient partitioning of photosynthates to different reproductive structures (pod development and seed formation) and later on at seed-development stage led to higher number of pods, seeds/pod and test weight. The seed yield, primarily being the function of yield attributes, increased significantly due to application of 50 kg S/ha over the control. The significant increase in straw yield of fenugreek up to 25 kg S/ha was probably because of greater translocation of photosynthates from source to reproductive sinks, i.e. seed, resulting in lesser increase in straw yield, which could nor reach up to the level of significance. This effect also seemed responsible for higher harvest index (HI) under 50 kg S/ha, as the increase in economic yield was comparatively more than the total biomass produced. Jat *et al.* (2001) also reported significant increases in yield attributes and yield due to application of sulphur in fenugreek.

There was significant increase in N and S content of grain and NPS content in straw up to 50 kg S/ha, but P content of fenugreek seed increased significantly up to 25 kg S/ha only (Table 2). S improved the overall nutrient availability due to reduced pH, creating favourable environment in the rhizosphere for greater absorption of nutrients by the plant. The increased photosynthesis, production of metabolites and efficient partitioning of these metabolities into different sinks resulted in higher content especially of N, P and S as well as of other nutrients, as observed in the present study. Thus the higher content of these nuteients with improved growth and development of plant resulted in higher uptake, which is the function of nutrient concentration in seed and straw and their total yield. Jat *et al.* (1998) also reported similar results due to application of sulphur in fenugreek.

Thus there was significant increase in B : C ratio of fenugreek with the successive increase in the level of applied sulphur, and consequently the application of 50 kg S/ha recorded the highest B : C ratio, registering an increase of 27.59 and 4.52% over the control and 25 kg S/ha respectively (Table 1).

Effect of plant-growth regulators

The application of PGRs recorded significantly higher number of pods/plant, seeds/pod and test weight of fenugreek over the control. However, NAA proved significantly better than Tricontanol and etheophon (Table 1) due to the stimulatory effect of the former, which induced larger number of reproductive sinks, leading to greater activity of carboxylating enzyme (ribose-1, 5-diphosphate carboxylase) and thus resulting in higher photosynthetic rate with greater translocation and accumulation of metabolites in the sinks, and ultimately in higher seed yield. The favoruable hormonal balance maintained at cellular level on NAA application might also have greater photosynthetic efficiency and enzymatic activity through the production of endogenous auxin (Nehara *et al.*, 2004).

The seed, straw and biological yields and the net return yield of fenugreek increased significantly due to foliar application of growth-regulators. However, NAA proved the best, and tricontanol remained at par with etheophon (Table 1). These increases in yield appeared to be due to

Table 2. Effect of phosphorus, sulphur and plant growth regulators on N, P and S content and total uptake of fenugreek (pooled data of two years)

Treatment	N content		P content		S content		Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total S uptake (kg/ha)
	Seed	Straw	Seed	Straw	Seed	Straw			
Phosphorus (P_2O_5 kg/ha)									
P_0	3.20	1.14	0.375	0.113	0.220	0.199	88.81	9.68	10.72
P_{25}	3.27	1.18	0.417	0.135	0.226	0.207	102.67	12.61	12.35
P_{50}	3.32	1.20	0.430	0.146	0.225	0.210	109.70	14.17	13.17
CD (P=0.05)	0.03	0.01	0.005	0.003	0.004	0.005	2.25	0.43	0.33
Sulphur (kg/ha)									
S_0	3.21	1.14	0.404	0.121	0.207	0.190	89.29	10.55	10.25
S_{25}	3.26	1.18	0.413	0.133	0.218	0.210	103.48	12.59	12.50
S_{50}	3.31	1.20	0.414	0.140	0.236	0.216	108.40	13.45	13.49
CD (P=0.05)	0.03	0.01	0.005	0.003	0.004	0.005	2.25	0.43	0.33
Plant-growth regulator									
Control	3.20	1.15	0.402	0.128	0.215	0.198	93.78	11.37	11.11
Tricontanol @ 2 ppm	3.27	1.18	0.410	0.131	0.225	0.206	100.92	12.16	12.17
NAA @ 20 ppm	3.32	1.20	0.424	0.137	0.232	0.212	106.80	13.28	13.11
Etheophon @ 100 ppm	3.26	1.17	0.406	0.130	0.222	0.205	100.05	11.98	11.93
CD (P=0.05)	0.02	0.01	0.005	0.003	0.004	0.004	1.91	0.45	0.33

improvement in growth and yield attributes on application of PGRs, as evidenced by highly significant positive correlation between yield attributes and seed yield observed in the present study. Jain *et al.* (1988) also reported such associations between yield attributes and seed yield of fenugreek.

The application of growth-regulators significantly improved the content of N, P and S in seed and straw and their total uptake over the control. However, NAA proved significantly better than Tricontanol and etheophon (Table 2). The sustained photosynthetic efficiency for longer duration and increased metabolic activity due to application of NAA resulted in greater production of metabolites and their efficient partitioning into different vegetative and reproductive sinks, leading to higher nutrient content. The uptake, being the function of nutrient concentration in seed and straw and their total yield, also increased significantly with increase in all these parameters. These results get support from the findings of Patel *et al.* (1991).

The application of NAA (G_2) recorded significantly higher B : C ratio (12.88, 12.20 and 10.84% more than the control, Tricontanol and ethephon respectively) of fenugreek; the other growth-regulators were on a par with each other (Table 1).

Interaction of P × S on mean seed yield

Irrespective of the level of sulphur, the increase in level of phosphorus was associated with significant increase in seed yield of fenugreek. Similarly, irrespective of the level of phosphorus, the increase in level of sulphur significantly improved the seed yield, except that in the presence of phosphorus (P_{50}) the increase in seed yield under sulphur (S_{50}) was non-significant compared with that of S_{25}. The combined application of P_{50} + S_{25} (P_{50}+S_{25}), remaining at par with P_{50} + S_{50}, recorded significantly higher seed yield than the rest of the combinations of P and S (Table 3). Both P and S, being the constituents of several metabolic compounds, play an important role in photosynthesis, protein, carbohydrate and chlorophyll synthesis and biological energy transformations, which in turn favourably influence the plant growth. Both P and S had synergistic effect up to certain level in promoting the dry-matter, seed, straw and biological yields, uptake of N, P and S and net return of fenugreek. The highly significant positive correlation between seed yield, and the uptake of N, P and S strongly support their interdependence on each other.

Table 3. Interactive effect of phosphorus and sulphur (P×S) on pooled mean of seed yield (q/ha)

Phosphorus (P_2O_5 kg/ha)	Sulphur (S kg/ha)		
	S_0	S_{25}	S_{50}
P_0	11.23	14.84	15.94
P_{25}	14.96	16.51	17.21
P_{50}	15.86	17.57	18.00
CD (P=0.05)			0.73

The synergistic effect of P and S in the present study improved the overall nutritional environment in the whole plant system and improved the plant growth by promoting meristematic activity and dry-matter accumulation. The increase in seed and straw yields was probably due to improvement in source and sink relationship. The assimilates produced in abundance and their efficient partitioning into different sinks, particularly the seed as evidenced by high HI in the present study, increased the seed yield significantly (Jat *et al.*, 2001).

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