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Response of fenugreek (*Trigonella foenum-graecum*) genotypes to planting geometry, agro-chemicals and sulphur levels

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ABSTRACT

A field experiment was conducted at Udaipur during winter seasons of 2005-07 to evaluate the effect of two genotypes of fenugreek (*Trigonella foenum-graecum* L.) (indeterminate type 'Rmt 1' and determinate type 'Rmt 305'), two crop geometry (30 cm × 10 cm and 20 cm × 15 cm), three agro-chemicals levels [Control, thiourea 1,000 ppm and thioglycolic acid (TGA) 100 ppm] and two levels of sulphur (0 and 40 kg S/ha) on the productivity and nutrient uptake. Results indicated that the determinate type 'Rmt 305' recorded higher seed yield and N, P and S uptake, while the indeterminate type 'Rmt 1' was found superior in respect to haulms and biological yields. The crop geometry of 20 cm × 15 cm exhibited higher seed yield (1.32 t/ha) and haulms yield (5.29 t/ha), which were 7.20 and 4.75% higher, over the crop geometry 30 cm × 10 cm respectively. Crop geometry of 20 cm x 15 cm also enhanced uptake of N, P and S. Foliar application of thiourea 1,000 ppm and TGA 100 ppm at flower initiation and 15 days thereafter and application of sulphur at the recommended dose resulted significant improvement in yield and N, P and S uptake of seed, haulms and total uptake over control.

Key words : Agro-chemicals, Crop geometry, Nutrient uptake, Sulphur fertilization, Thioglycolic acid, Thiourea

Fenugreek is mainly used for culinary and medicinal purposes and continues to be important winter season legume spice in India. Being, an important *rabi* spice crop, farmers largely include it in their cropping plan. The seeds contain an alkaloid 'Trigonellin' (0.12 to 0.38%) is thought to reduce glycosuria in diabetes. Fenugreek seed helps not only reducing blood sugar levels with its high concentration of phytochemicals, but also reduced low density cholesterols and triacylglycerols. The seeds are used in treatment of flatulence, dysentery, diarrhoea, dyspepsia, chronic cough, dropsy, enlargement of liver and spleen, rickets, gout, diabetes and arthritis. Diosgenin, the main sapogenin, is an estrogen precursor, and may help in managing menopause. Its concentration varies from 0.86 to 2.2% in seeds (Sanvaire and Baccon, 1976).

The lack of suitable plant type for prevailing agro-climatic conditions is a major constraint to harness the better yield. Adoptions of improved varieties have been reported by various workers for better growth and yield. Proper plant rectangularity is first and prime cultural operation to augment productivity of fenugreek. Optimum plant density with their proper arrangement on ground surface is necessary for reducing intra and inters plant competitions. To realize the maximum production for existing varieties, it is necessary that the chemical reactions takes place in the plants are in balanced and efficient manner which help in formation of quality seed. The bioregulators act as chemical catalyst in plants and improve physiological and reproductive efficiency in the plant. These bioregulators possibly improve the gene expression for efficient sucrose transport and increase dry matter partitioning for grain production (Werdan *et al.,* 1975). The deficiency of secondary nutrients also a major limiting factor for higher productivity. Sulphur has many important functions in plant growth and metabolism. It is directly involved in the catalytic or electrochemical functions of the molecules of which it is a component. S is a vital part of the ferredoxin, which participates in oxidoreduction processes by transferring electrons and has a significant role in nitrite reduction, sulfate reduction, the assimilation of N_2 by root nodule bacteria and free living N-fixing soil bacteria. Thus, S fertilization improves crop quality through reductions in the N/S ratio (Tisdale *et al.,* 1997). Therefore, the present investigation was carried out to test the suitability of fenugreek plant types to crop geometry, agro-chemicals and sulphur fertilization for realizing higher yield.

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MATERIALS AND METHODS

The field experiment was carried out during 2005-07 at Rajasthan College of Agriculture, Udaipur (Rajasthan) which is situated at 24º31' north latitude and 73º42' east longitude at an altitude of 582.17 m above mean sea level. This region has a typical subtropical climate with average rainfall of 637 mm. The soil of experimental field was clay loam in texture and alkaline in reaction (pH 8.06) with medium fertility having available nitrogen, phosphorus and sulphur of 240, 22.3 and 20.4 kg/ha, respectively.

The two plant types, i.e. indeterminate type 'Rmt 1' and determinate type 'Rmt 305' were planted at the planting geometry of 30 cm × 10 cm and 20 cm × 15 cm and applied two levels, i.e. no sulphur and 40 kg S/ha through elemental sulphur and supplemented with two foliar sprays of thiourea 1,000 ppm and thioglycolic acid (TGA) 100 ppm at flower initiation and 15 days thereafter. The crops were planted on 7 November, 2005 and 5 November, 2006 using 25 kg seed/ha. The crop was fertilized with recommended doses of nitrogen and phosphorus. The crop was harvested on 20 March during 2006 and 17 March during 2007. Primary soil samples were drawn randomly from each plot at depth of 0-15 cm before the commencement of the experiment and after harvesting of crop during both the years. A representative composite sample was prepared and subjected to available nutrient analysis using standard methods for nitrogen, phosphorus and sulphur. The methods used for soil analysis were acid digestion for nitrogen, vanadomolybdo-phosphoric yellow color method for phosphorus and barium chloride turbiditimetric method for sulphur. The total uptake of N, P and S by crop at harvest in each treatment was computed by multiplying N, P and S content in seed and haulms with the respective dry weight and expressed as kg/ha using following relationship. Total uptake of N, P and S (kg/ha) =[% N, P and S in seed × seed yield (kg/ha)] + [%N, P and S in haulms × haulms yield (kg/ha)].

Based on apparent gain and loss of nutrients, an attempt was made to establish fate of nutrients available in soil, added through different treatments and crop removals were usually taken into account during the course of fenugreek crop of two consecutive years. The nutrient balance sheet was worked out. All the data obtained with regards to the yield attributes, yield, nutrient content and uptake was analyzed statistically using the analysis of variance technique. The correlation and regression studies were done to establish cause and effect relationship.

RESULTS AND DISCUSSION

Yield and yield attributes

The determinate type 'Rmt 305' fenugreek produced significantly higher seed yield (1.34 t/ha) over indeterminate type 'Rmt 1' (1.19 t/ha) (Table 1). Seed yield recorded by 'Rmt 305' was 12.36% higher over the indeterminate

Table 1. Effect of plant types, crop geometry, agro-chemicals and sulphur fertilization on yield attributes and yield of fenugreek (Pooled data of 2 years)

Treatment	Pods/branch	Pod length (cm)	Seeds/pod	Test weight (g)	Seed yield (t/ha)	Haulms yield (t/ha)	Harvest index (%)
Genotype							
'Rmt 1'	7.80	9.22	15.14	9.99	1.19	5.37	18.05
'Rmt 305'	10.07	10.78	17.75	12.06	1.34	4.97	21.17
SEm±	0.12	0.08	0.11	0.08	0.01	0.05	0.20
CD (P=0.05)	0.34	0.22	0.30	0.22	0.03	0.13	0.56
Crop geometry (cm)							
30 × 10	8.68	9.74	16.12	10.98	1.22	5.05	19.39
20 × 15	9.19	10.27	16.78	11.07	1.31	5.29	19.83
SEm±	0.12	0.08	0.11	0.08	0.01	0.05	0.20
CD (P=0.05)	0.34	0.22	0.30	NS	0.03	0.13	NS
Agro-chemical (ppm)							
No spray	8.36	9.53	15.71	10.75	1.18	4.87	19.43
Thiourea (1,000)	9.23	10.25	16.83	11.20	1.31	5.33	19.77
Thioglycolic acid (100)	9.22	10.23	16.79	11.13	1.30	5.31	19.63
SEm±	0.146	0.096	0.132	0.096	0.01	0.06	0.243
CD (P=0.05)	0.41	0.27	0.37	0.27	0.04	0.16	NS
Sulphur (kg S/ha)							
0	8.51	9.65	15.82	10.77	1.17	4.84	19.46
40	9.36	10.35	17.07	11.28	1.36	5.50	19.76
SEm±	0.119	0.078	0.107	0.078	0.01	0.05	0.198
CD (P=0.05)	0.34	0.22	0.30	0.22	0.03	0.13	NS

type 'Rmt 1'. While the haulms yield were recorded significantly higher in indeterminate type 'Rmt 1'. The marked variation in growth could be ascribed on account of their genetic capabilities to exploit available resources for their growth and development. Observed marked increase in seed yield appears to be a resultant of remarkable improvement in different yield attributes. Seed yield, in turn, was found strongly correlated with the mean number of branches/plant, number of pods/branch, pod length, number of seeds/pod, test weight and harvest index. Respective correlation coefficients were 0.618, 0.782, 0.930, 0.917, 0.655 and 0.827 (Table 6). Such close associationship of seed yield with different yield attributes was also observed by Bhati and Prasad (2004).

Crop geometry 20 cm × 15 cm exhibited significantly higher seed and haulms yields of 1.31 and 5.29 t/ha, respectively (Table 1) which was 7.20 and 4.75% higher over 30 cm × 10 cm respectively. The marked increase in seed yield appears to be a resultant of remarkable improvement in different yield attributes, which was brought about due to adoption of this crop geometry. Improvement in seed yield as result of remarkable improvement in different growth and yield components due to adoption of different crop geometries was also reported by Yadav *et al.* (1990). The regression analysis also validated these finding (Table 6).

Foliar spray of thiourea and thioglycolic acid (TGA) gave significantly higher seed and haulms yields as compared to that of control. The mean seed yield of 1.31 t/ha and 1.30 t/ha were produced with application of foliar spray of thiourea and TGA, respectively with their corresponding increase of 11.03 and 10.01% over that recorded with control (Table 1). The foliar spray of thiourea and TGA increased the plant photosynthetic efficiency and canopy photosynthesis due to presence of - SH group as an integral constituent of these thiols. Thiourea is known to increase dark fixation of CO_2 in embryonic tissues of chickpea as the - SH group has diverse biological activities. Its beneficial effect in the present study, secondly appears to be due to delayed senescence of both vegetative and reproductive organs as thiourea has cytokinin like activity particularly on delaying senescence (Halmann, 1980). Thiourea is also known to increase photosynthetically active leaf surface during grain filling period in cereals (Sahu *et.al.* 1993).

Application of sulphur at recommended dose exhibited significantly higher seed and haulms yields over no sulphur application. The mean seed yield of 1.36 t/ha was produced which was 15.9% higher than that recorded without sulphur application (Table 1). Sulphur is a constituent of S containing amino acids, thus influence the synthesis of chlorophyll, proteins and vitamins, required for large number of physiological and metabolic processes. Remarkable improvement in different yield param-

Table 2. Effect of plant types, crop geometry, agro-chemicals and sulphur fertilization on N, P and S content of fenugreek grown in clay loam soil in the southern part of Rajasthan (Pooled data of 2 years).

Treatment	Nitrogen (%)		Phosphorus (%)		Sulphur (%)	
	Seed	Haulms	Seed	Haulms	Seed	Haulms
Genotype						
'Rmt 1'	3.35	1.25	0.41	0.17	0.25	0.21
'Rmt 305'	3.37	1.25	0.41	0.18	0.25	0.21
SEm±	0.01	0.003	0.001	0.001	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Crop geometry (cm)						
30 × 10	3.36	1.25	0.41	0.17	0.25	0.21
20 × 15	3.36	1.25	0.41	0.18	0.25	0.21
SEm±	0.01	0.003	0.001	0.001	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Agro-chemical (ppm)						
No spray	3.33	1.24	0.41	0.17	0.25	0.21
Thiourea (1,000)	3.38	1.26	0.41	0.18	0.26	0.21
Thioglycolic acid (100)	3.37	1.26	0.41	0.18	0.25	0.21
SEm±	0.01	0.004	0.001	0.001	0.001	0.001
CD (P=0.05)	0.03	0.01	NS	NS	NS	NS
Sulphur (kg S/ha)						
0	3.34	1.24	0.41	0.17	0.25	0.21
40	3.39	1.27	0.42	0.18	0.26	0.21
SEm±	0.01	0.003	0.001	0.001	0.001	0.001
CD (P=0.05)	0.02	0.01	NS	NS	0.001	0.002

eters seems to be due to significant increase in dry matter production. These results corroborates with the findings of Tiwari *et.al.* (1997).

Nutrient content and uptake

The nitrogen, phosphorus and sulphur content in seeds and haulms did not vary significantly in different plant types and crop geometries. Agro-chemicals and sulphur fertilization significantly improved the nitrogen content in seed and haulms. The mean improvement was 1.55 and 1.19% in seed and 1.69 and 1.77% in haulms by thiourea and TGA, respectively over the control. The application of sulphur recorded 0.257% sulphur content in seed and 0.214% in haulms, which was 2.4 and 1.9%, higher over the control respectively (Table 2).

The determinate type 'Rmt 305' resulted higher uptake of N, P and S in seed by 12.92, 12.77 and 12.54% over indeterminate type, 'Rmt 1' respectively (Table 3). The significant increase in N, P and S uptake by seed of plant type 'Rmt 305' might be due to higher seed yield, as nutrient uptake by the crop is primarily depends on dry matter production and secondarily their content in plant parts. The correlation and regression analysis indicated that nutrient uptake by seed was closely associated with seed yield (Fig. 1). The results are in close conformity with findings of Nehara *et. al.* (2006). Crop geometry 20 cm × 15 cm enhanced N uptake by 7.02, 5.01 and 5.80%, P uptake by 7.72, 5.11 and 6.06% and S uptake by 7.07, 5.23 and 5.58% by seed, haulms and total uptake, respectively over that recorded with the crop geometry 30 cm × 10 cm. Greater uptake of N, P and S under the crop geometry 20 cm × 15 cm was evident from increased yield under this crop geometry. The correlation studies showed positive interrelationship between N, P and S uptake by seed, haulms and total uptake and seed and haulms yields (Table 6 and Fig. 1).

The increase in N, P and S uptake by seed with application of thiourea was 12.8, 10.2 and 10.0% and by the application of TGA was 11.3, 10.2 and 10%, respectively over control (Table 3). Foliar sprays of thiourea and TGA might have enabled the plant to produce proliferated roots having greater physiological activity as a result of presence of -SH group in these chemicals, as metabolic role of - SH group in root physiology is well recognized. Thus, plant treated with these thiols appears to have greater power for nutrient absorption as well as for their utilization in efficient way (Solanki, 2003).

The sulphur application enhanced nitrogen uptake by 15.6, 15.9 and 16.6%, phosphorus uptake by 16.7, 14.6 and 15.4% and sulphur uptake by 19.0, 16.4 and 16.9% in seed, haulms and total uptake, respectively over no sulphur application. The remarkable improvement in nutrient uptake by application of sulphur seems to be due to maintenance of congenial nutritional environment at the cellu-

Table 3. Effect of plant types, crop geometry, agro-chemicals and sulphur fertilization on N, P and S uptake of fenugreek grown in clay loam soil in the southern part of Rajasthan (Pooled data of 2 years).

Treatment	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Sulphur (kg/ha)		
	Seed	Haulms	Total	Seed	Haulms	Total	Seed	Haulms	Total
Genotype									
'Rmt 1'	40.0	67.3	107.3	4.9	9.3	14.2	3.0	11.3	14.4
'Rmt 305'	45.1	62.6	107.8	5.6	8.7	14.2	3.4	10.6	14.0
SEm±	0.38	0.62	0.72	0.05	0.09	0.10	0.03	0.10	0.11
CD (P=0.05)	1.07	1.73	NS	0.14	0.25	NS	0.08	0.28	0.30
Crop geometry (cm)									
30 × 10	41.1	63.4	104.5	5.0	8.8	13.8	3.1	10.7	13.8
20 × 15	44.0	66.5	110.6	5.4	9.2	14.6	3.3	11.2	14.5
SEm±	0.38	0.62	0.72	0.05	0.09	0.10	0.03	0.10	0.11
CD (P=0.05)	1.07	1.73	2.03	0.14	0.25	0.28	0.08	0.28	0.30
Agro-chemical (ppm)									
No spray	39.4	60.5	99.9	4.9	8.4	13.3	3.0	10.2	13.3
Thiourea (1,000)	44.4	67.3	111.7	5.4	9.3	14.7	3.3	11.3	14.7
Thioglycolic acid (100)	43.9	67.1	111.0	5.4	9.2	14.6	3.3	11.3	14.6
SEm±	0.46	0.75	0.88	0.06	0.11	0.12	0.03	0.12	0.13
CD (P=0.05)	1.31	2.12	2.49	0.17	0.31	0.35	0.10	0.35	0.37
Sulphur (kg S/ha)									
0	39.1	60.2	99.3	4.8	8.4	13.2	2.9	10.1	13.1
40	46.0	69.7	115.8	5.6	9.6	15.3	3.5	11.8	15.3
SEm±	0.38	0.61	0.72	0.04	0.09	0.10	0.02	0.10	0.10
CD (P=0.05)	1.07	1.73	2.03	0.14	0.25	0.28	0.08	0.28	0.30

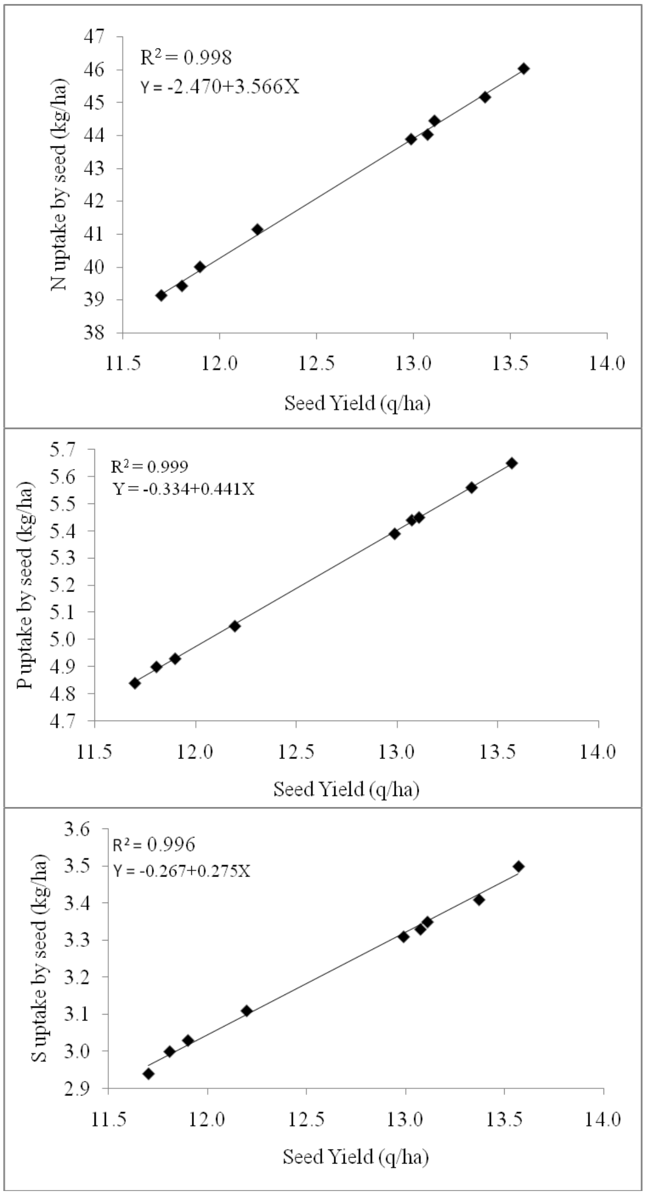

Fig. 1. Correlation between nitrogen, phosphorus and sulphur uptake by seed (kg/ha) and seed yield (q/ha) of fenugreek

lar level as well as in the *rhizosphere*, which might have led to greater availability of nutrients from soil mass. The correlation and regression analysis showed that nutrient uptake was found strongly correlated with yield (Table 6 and Fig. 1). Jat *et al.* (1998) and Nehara *et al.* (2006) also reported the increased N, P and S uptake due to application of sulphur in fenugreek.

Nutrient balance sheet

Plant types and crop geometry showed apparent gain in N and S content and actual gain in available P of experimental soils while resulted in apparent loss in P and actual loss in S status of soil. Agro-chemicals and sulphr fertilization resulted in apparent gain in N and S as well as ac-

Table 4. Nitrogen and phosphorus balance sheet of soil during crop season (kg/ha) of fenugreek (Pooled data of 2 years).

Treatment	Nitrogen							Phosphorus (P_2O_5)						
	Initial status A	Nutrient added B	Crop uptake C	Expected nutrient balance D=(A+B-C)	Actual nutrient balance E	Apparent gain/loss F=E-D	Actual gain/loss G=E-A	Initial status A	Nutrient added B	Crop uptake C	Expected nutrient balance D=(A+B-C)	Actual nutrient balance E	Apparent gain/loss F=E-D	Actual gain/loss G=E-A
Genotype														
'Rmt 1'	241	20	107	154	254	100	13	22.3	40	14.3	48.0	28.9	-19.1	6.6
'Rmt 305'	241	20	108	153	254	101	13	22.3	40	14.3	48.0	29.0	-19.0	6.7
Crop geometry (cm)														
30 × 10	241	20	105	156	254	98	13	22.3	40	13.8	48.5	29.0	-19.5	6.7
20 × 15	241	20	111	150	254	104	13	22.3	40	14.7	47.6	28.9	-18.7	6.6
Agro-chemical (ppm)														
No spray	241	20	100	161	254	93	13	22.3	40	13.3	49.0	28.2	-20.8	5.9
Thiourea	241	20	112	149	254	105	13	22.3	40	14.8	47.5	28.2	-19.3	5.9
TGA	241	20	111	150	254	104	13	22.3	40	14.7	47.6	28.2	-19.4	5.9
Sulphur (kg S/ha)														
0	241	20	99	162	254	92	13	22.3	40	13.2	49.1	26.5	-22.6	4.2
40	241	20	116	145	254	109	13	22.3	40	15.3	47.0	27.2	-19.8	4.9

Table 5. Sulphur balance sheet of soil during crop season (kg/ha) of fenugreek (Pooled data of 2 years)

Treatment	Initial status A	Nutrient added B	Crop uptake C	Expected nutrient balance D=(A+B-C)	Actual nutrient balance E	Apparent gain/loss F=E-D	Actual gain/loss G=E-A
Genotype							
'Rmt 1'	20.9	0	14.4	6.5	13.9	7.4	-7.0
'Rmt 305'	20.9	0	14.0	6.9	14.0	7.1	-6.9
Crop geometry (cm)							
30 × 10	20.9	0	13.8	7.1	13.8	6.7	-7.1
20 × 15	20.9	0	14.6	6.3	13.8	7.5	-7.1
Agro-chemical (ppm)							
No spray	20.9	0	13.3	7.6	13.0	5.4	-7.9
Thiourea	20.9	0	14.7	6.2	13.1	6.9	-7.8
TGA	20.9	0	14.6	6.3	13.1	6.8	-7.8
Sulphur (kg S/ha)							
0	20.9	0	13.1	7.8	13.7	5.9	-7.2
40	20.9	40	15.3	45.6	22.3	-23.3	1.4

Table 6. Correlation coefficient and regression equations showing relationship between independent variables (x) and dependent variables (y) on the basis of two years pooled data (** shows that correlation coefficient is significant at 1% level of significance).

Dependent variable (y)	Independent variables (x)	r	R^2	Y = a+bx
Seed Yield (q/ha)	Branches/plant	0.618**	0.382	Y = 6.815+0.671X
	Pods/branch	0.782**	0.611	Y = 1.892+1.202X
	Seeds/pod	0.917**	0.841	Y = -3.824+1.001X
	Pod length (cm)	0.930**	0.866	Y = -0.982+1.361X
	Test weight (g)	0.655**	0.429	Y = -1.602+1.291X
	Harvest index (%)	0.827**	0.685	Y = -3.067+0.801X
N uptake haulms (kg/ha)	Haulms yield (q/ha)	0.993**	0.986	Y = -9.250+1.435X
Total N uptake (kg/ha)	Biological yield (q/ha)	0.966**	0.933	Y = -23.201+2.032X
P uptake haulms (kg/ha)	Haulms yield (q/ha)	0.992**	0.984	Y = -0.857+0.190X
Total P uptake (kg/ha)	Biological yield (q/ha)	0.966**	0.934	Y = -2.501+0.260X
S uptake haulms (kg/ha)	Haulms yield (q/ha)	0.986**	0.973	Y = -1.710+0.245X
Total S uptake (kg/ha)	Biological yield (q/ha)	0.991**	0.982	Y = -2.694+0.262X

tual gain in N and P status of soil while apparent loss of P and actual loss of S status in soil (Table 4 and 5).

It is concluded that growing of determinate type 'Rmt 305' fenugreek at crop geometry 20 cm × 15 cm supplemented with foliar spray of TGA 100 ppm and sulphur application 40 kg S/ha was found beneficial in respect of seed yield and nutrient uptake.

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