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APPLICATION OF PHOSPHATE FERTILIZER AND HARVEST MANAGEMENT FOR IMPROVING FENUGREEK (*Trigonella foenum-graecum* L.) SEED AND FORAGE YIELD IN A DARK BROWN SOIL ZONE OF CANADA

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ABSTRACT

Fenugreek (*Trigonella foenum-graecum* L.) is an annual legume crop. Recently a new forage cultivar, Tristar, was released for use by western Canada producers. Experiments were conducted to determine appropriate cultural practices for maximizing forage and seed production in this crop. Annual variation in climate and soil moisture conditions significantly affected forage and seed yield of fenugreek. Application of phosphate fertilizer (@ 0, 30, 40, 50 and 60 kg/ha) also had a significant effect on forage and seed yield. For seed yield 40 to 50 kg/ha of phosphate application was effective while high forage yield was obtained when 50 to 60 kg/ha of phosphate was applied. Combining seed after swathing yielded significantly more seed in Tristar fenugreek than direct combining (p <0.001). These experiments indicate that the uses of appropriate agronomic practices are necessary to maximize forage and seed production of this new crop cultivar in dark brown soil zones of the Canadian prairies.

KEYWORDS: fenugreek, *Trigonella foenum-graecum* L., phosphate fertilizer, swathing

1. INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an annual, self pollinating, legume crop, believed to be native to the Mediterranean region but now, is widely cultivated in India and other parts of the world [1]. Fenugreek seed is used in foods as a spice, in artificial flavoring of maple syrup, as a condiment and, in the production of steroid and other hormones for the pharmaceutical industry [2]. Fenugreek is a dryland crop but responds well to minimum application of irrigation [1, 3]. The first North American forage fenugreek cultivar, Tristar, was developed for growth on the Canadian prairies and was released in 2004. As feed for livestock, it is a bloat free crop containing growth promoting steroidal compounds, produces a good amount of high quality forage, can be grown efficiently for hay or silage and, can be used for incorporation into short term rotations with other crops [4-6].

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Agronomic studies conducted in different agro-climatic zones of India and in some parts of Egypt suggest that optimum productivity of fenugreek can be enhanced when seed is spaced 20 to 30 cm apart and planted in early October or November [7-10] with a seeding rate of up to 30 kg/ha [11]. Lal *et al.* [12] has suggested that optimization of sowing dates and forage cutting, can increase fenugreek yields. Well-drained loam soils with a pH range of 8-8.5 provide good conditions for this crop while, heavy and wet soils limit crop growth [13]. Potash has been used at a depth of 6"-12" to adjust soil pH to increase nutrient uptake of fenugreek [14] and, application of organic and inorganic fertilizers, farmyard manure, nitrogen and phosphorus has been found to be effective in increasing fenugreek yield [15-17].

Fenugreek is a late maturing crop, requiring about 140 days to mature [18]. Tristar fenugreek matures in about 120 days when grown in Western Canada [1]. However, on an average only 100 frost free days are available for crop production in this area. So, the primary goal for this study was to develop suitable agronomic practices for growing fenugreek in the Canadian prairies. Specific objectives were to determine the most effective harvesting methods (swath versus direct combining) on seed production and the effect of phosphate fertilizer application on seed and forage yield as well as on days to maturity.

2. MATERIALS AND METHODS

2.1 Source of fenugreek seed

The lines used in this study were taken from the Lethbridge Research Center (LRC) Agriculture and Agri-Food Canada seed collection and included Tristar, Amber, F86, F80 and F70.

2.2 Environment

The study site was at Lethbridge, Alberta, Canada and the trials were planted under two growing conditions; *i.e.*, rain fed and irrigation (considered as two separate environments). The trials were planted over a two year period (2004 and 2005) and, the years also were considered different environments. Hence, the locations, growing conditions and years provided different environments; each of these was considered a random effect for statistical purposes.

Lethbridge (49º 45' N and 112º 45' W) is located in a semi-arid zone of southern Alberta, Canada with an average elevation of 900 m above mean sea level (MSL) [19]. The soil type is Orthic Dark Brown Chernozem [20]. GPS coordinates for the LRC irrigated field were 49º 42' 24.98" N and 112º 45' 47.77" W and for the rain fed field were 49º 42' 19.80" N and 112º 45' 59.02" W.

In the field trials, a standard *Rhizobium* legume soil inoculant (The Nitragin Company, USA) was used to optimize legume plant growth [21]. The code for this inoculant was "N" and the dosage applied was @ 0.3 g/120 seed. For weed control, Edge (Dow AgroScience Canada Inc.), Odyssey (BASF Canada), and Embutox 625 (Nufarm Canada) were used in the field experiments and a Reglone (Syngenta Crop Protection Canada Inc.) desiccant was used for the seed yield trials.

2.3 Harvest methods

To determine the effect of harvest methods on seed production, the study was conducted using five genotypes including Tristar, Amber, F86, F80 and F70 fenugreek, under two growing conditions at Lethbridge; *i.e*., rain fed and irrigation (50 mm X 4) over two years (2004 and 2005). For the purpose of analysis the two growing conditions and the two production years were considered as four environments. The plot size used was 1.8 m X 6.0 m with 18 cm row spacing. The plots were arranged as in a four times replicated randomized complete block design (RCBD) in each environment. The seeding rate used was 15 kg/ha. For both years, seeds were planted in the first week of May and harvested in mid October. The data obtained were subjected to a mixed model Analysis of Variance (ANOVA) using environment as a random effect and the genotype as a fixed effect. For the mixed model ANOVA there was no direct F test for the interactions involving environment and so the probabilities of F value are not shown.

2.4 Effect of phosphate fertilizer

This study was conducted under rain fed and irrigated (50 mm X 4) conditions at LRC in 2004 and 2005 (considered four environments) on five fenugreek genotypes Tristar, Amber, F86, F80 and F70. An initial soil survey was done in each year to make sure that the field selected for the trial had low phosphate levels. The soil survey indicated that the average phosphate level for the 2004 plot varied between 36-37 kg/ha, whereas that in 2005 varied between 24-44 kg/ha. The plot size for these experiments, under both rain fed and irrigated conditions was 1.8 m X 6.0 m with 18 cm spacing between the rows. The seeding rate used was 15 kg/ha. The rate of application for the phosphate fertilizer (Westco Fertilizer, Edmonton) used was 0, 30, 40, 50 and 60 kg/ha at the reported depth of 6"-12". The plots were arranged as in a four times replicated RCBD in each environment. For both years seeds were planted in the first week of May and harvested in mid October. The data obtained were subjected to a mixed model ANOVA as described above using environment as random and the rate of phosphate application (P rate) as a fixed effect.

2.5 Statistical analysis

For all analyses Agrobase 99 [22] software was used. All means and standard errors used in the study were generated using this software.

3. RESULTS AND DISCUSSION

3.1 Assessment of swathing and direct combining of seed

Fenugreek seed yield was affected significantly ($p<0.05$) by genotype and, highly significantly ($p<0.001$) by the environment under which the seed was produced and the harvest methods (Table 1). The interaction effect of genotype X harvest method was not significant.

Among the genotypes, F70 produced a significantly higher seed yield than the others included in the test. The seed yield of F70 was recorded as 1068 kg/ha, followed by F86 (1003 kg/ha). The superiority of F70 in seed production (1,245 kg/ha) was also observed in earlier studies by our group [1, 4, 23].

The four environments produced mean seed yields of 1,582 and 1,289 kg/ha under 2004 irrigation and rain fed conditions and, 539 and 338 kg/ha under 2005 irrigation and rain fed conditions, respectively. At Lethbridge the 2004 growing season was better for seed production than the 2005 growing season and this was reflected by their respective mean seed yields of 1435 and 438 kg/ha. The reason for a higher yield in 2004 compared to 2005 may have been due to higher precipitation during the growing season (May to September) in 2004 (286 mm) compared to 2005 (102.8 mm).

Between the two seed harvest methods swathing yielded significantly ($p < 0.001$) more seed (mean over 2 years = 975 kg/ha) than direct combine methods (mean over 2 years = 898 kg/ha). This was expected as swathing normally is practiced as a method of seed harvest to force rapid seed maturity and to reduce loss due to seed shatter [18]. This practice will help the fenugreek seed harvest as it expedites seed maturation in crops having an indeterminate growth habit.

Table 1 Effect of environment, genotype, harvest method and their interactions for fenugreek seed yield was determined by using a mixed model ANOVA*1. Mean square (MS), degrees of freedom (df) and probability (Pr) of F value for seed yield (kg/ha) from swath and direct combined plots was calculated by using five genotypes (as fixed effect) and four environments (as random effect)

Source	df	MS	Pr of F
Total	119		
Replication	3	49.5	
Environment	3	3050.4	0.000
Genotype	4	44.3	0.002
Environment*Genotype[2]	12	18.1	--
Harvest method (HM)	1	165.6	0.000
Environment*HM[2]	3	73.1	--
Genotype*HM	4	8.5	0.472
Environment*Genotype*HM[2]	12	6.2	--
Residual	77	9.5	
CV		10.6	
R^2		0.9	

1ANOVA was done on square root transformed data.
2 For the mixed model ANOVA there was no direct F test used for the interactions that included environment and, so the probabilities are not shown. For the determination of the F values for Genotype, Harvest Method and Genotype* Harvest Method; Environment*Genotype, Environment*Harvest Method and Environment*Genotype*Harvest Method were used as denominators, respectively. F values are significant when Pr of F = 0.05 or less.

3.2 Effects of phosphate fertilizer

A highly significant (p<0.001) effect of environment and rate of phosphate application on both forage and seed yield was observed in this study (Table 2). Effect of P (phosphate) on yield attributes of fenugreek has been observed earlier [18]. The effect of genotype was significant for seed yield while the interaction effect for phosphate rate X genotype was significant (p<0.05) for forage and seed yield.

Since the interaction effect of P rate X genotype was significant, mean values for each treatment combination are presented in Table 3. High seed yield was obtained when 30-60 kg/ha of P was applied, optimal being at 40 kg/ha (independent of genotype used in the study). For high forage yield most genotypes required ~ 60 kg/ha of P fertilizer. Hence, our results indicate that application of higher dosages of phosphate to phosphate poor soil can improve fenugreek seed and forage yield in Southern Alberta, irrespective of the genotypes used. Similar observations have been made in India where significantly higher levels of seed and forage production were observed when increasing levels of P_2O_5 fertilizer (up to 60 kg/ha) were used (14, 16, 24]. Sheoran *et al.* [25] observed a 28.8 % increase in seed yield in response to phosphate application of up to 60 kg/ha.

The LRC plots used did not have high P levels (as indicated by our pre-trial soil surveys conducted in each year of the study) and this may have helped produce the pronounced response to P application seen in this study. By contrast, Randhawa *et al.* [11] observed no fenugreek response to phosphate application when soil in Punjab, India was rich in elemental P. Fenugreek roots have the ability to trap high levels of phosphorus and use it for growth and development of the plant [11]. But, if the soil is already rich is P, addition of P fertilizer will not be effective. For this study, although different plots were used in each of the two years and at different locations, the P levels were low according to our soil tests and so we observed a pronounced effect. These results are similar to those obtained in studies conducted in other environments on phosphate application and yield attributes of fenugreek [14, 16]. During the two years of this study in southern Alberta, reduction in days to maturity was not observed due to P application to the field plots. This observation is similar to that of Sheoran *et al.* [25] in a study conducted in India where floral initiation and maturity were not affected by P application.

Table 2 Effect of environment, rate of phosphate application, genotype and their interactions for forage and seed yield in fenugreek was determined using a mixed model ANOVA[1]. Mean square (MS), degrees of freedom (df) and probability (Pr) of F value for forage and seed yield on phosphate fertilizer treated plots was calculated using the five genotypes (as fixed effect) and four environments (as random effect)

Source	**df**	**Forage yield (kg/ha)**		**Seed yield (kg/ha)**	
		MS	**Pr of F**	**MS**	**Pr of F**
Total	399				
Replication	3	167.5		10.4	
Environment	3	27886.6	0.000	13092.9	0.000
Phosphate rate	4	159.1	0.000	654.1	0.000
Environment* P rate[2]	12	89.6	--	148.9	--
Genotype	4	36.1	0.147	52.6	0.0002
Environment*Genotype[2]	12	44.8	--	50.4	--
P rate* Genotype	16	39.6	0.022	19.9	0.005
Environment*P rate* Genotype[2]	48	46.1	--	19.9	--
Residual	297	21.1		9.2	
CV		8.9		12.0	
R^2		0.9		0.9	

[1]ANOVA was done on square root transformed data.
[2]For the mixed model ANOVA there was no direct F test used for the interactions that included environment and, so the probabilities are not shown. For the determination of the F values of P rate, Genotype and P rate*Genotype; Environment*P rate, Environment*Genotype and Environment*P rate*Genotype were used as denominators, respectively. F values are significant when Pr of F = 0.05 or less.

4. CONCLUSIONS

In conclusion, we suggest that agronomic improvement of fenugreek seed and forage yield under Canadian prairie conditions is possible. For Tristar fenugreek, swathing rather than direct combining can significantly improve seed recovery. Also, application of phosphate fertilizer can significantly improve both forage and seed yield under rain fed and irrigated conditions in Southern Alberta. However, further confirmation of the trends seen in these experiments needs to be obtained before more specific recommendations can be made.

Table 3 Two year mean seed and forage yield of fenugreek genotypes when treated with different amounts of phosphate fertilizer grown under rain fed and irrigated conditions at Lethbridge, Alberta

Genotypes	Seed yield[1] under rain fed (kg/ha)				
	0	**30**	**40**	**50**	**60**
F70	480	755	796	877	693
F80	647	805	969	830	795
F86	461	769	802	870	819
Amber	541	823	988	892	815
Tristar	415	786	942	782	746
Genotypes	**Forage yield[2] under irrigated (kg/ha)**				
	0	**30**	**40**	**50**	**60**
F70	3279	2706	3116	2862	3072
F80	2758	2830	2931	3149	3126
F86	2915	2870	2964	2830	3265
Amber	3060	2721	2824	2581	2834
Tristar	2990	2791	2775	2730	3237

[1] Overall mean = 764, LSD (Least Significant Difference) = 43.6 and CV (Coefficient of Variation) = 12.2; [2] Overall mean = 2929, LSD = 143.1 and CV = 8.9

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