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Effects of genotype and environment on seed and forage yield in fenugreek (*Trigonella foenum-graecum* L.) grown in western Canada

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Abstract

Fenugreek is being developed as a forage legume crop in western Canada, as it has desirable agronomic and forage quality traits. The objective of the present study was to determine if genotype x environment interactions have an impact on seed and forage yield when plants are grown under the short growing season of western Canada. Two studies were conducted: one with up to 83 accessions grown under rain-fed and irrigated conditions at Lethbridge, Alberta for two years and the other had five selected genotypes grown under seven environments scattered over Alberta and British Columbia over five years. In the first study significant ($P < 0.01$) location and year effects were observed for forage yield and 1000 seed weight respectively, while for seed yield effect of year, genotype, year X location and year X genotype were significant ($P < 0.01$). In the second study significant ($P < 0.01$) genotype, environment and their interaction effects were observed for forage and seed yield. These studies indicate that improvement through phenotypic selection for forage and seed yield is possible but, will require use of multiple locations and years. Improvement in seed yield can be achieved through selection for less variable seed size and/or early maturity.

***Keywords*:** accessions; environment; fenugreek; genotype; interaction; irrigated; legume; rain-fed; *Trigonella foenum-graecum*

***Abbreviations*:** **AAFC**_Agriculture and Agri-Food Canada; **AAFRD**_Alberta Agriculture, Food and Rural Development; **G x E**_Genotype by Environment interaction; **LRC**_Lethbridge Research Centre; **PGRC**_Plant Genetic Resource Canada

Introduction

Fenugreek (*Trigonella foenum-graceum*) is an annual legume crop whose seed is traditionally used as a spice, in artificial flavoring and in the production of hormones (Duke 1981; Jorgensen 1988; Jongebloed 2004; McCormick et al. 2006; Acharya et al. 2006 a,b; 2007 a,b, 2008). The crop is currently grown in India and parts of west Asia, north Africa, Mediterranean Europe, Australia, Argentina, United States of America and Canada (Acharya et al. 2006 a). Some genotypes of this species are adapted for growth under the rain-fed conditions found in western Canada (Acharya et al. 2007 b, 2008). However, earlier fenugreek cultivar development activities in western Canada were mainly focused on development of early maturing and high seed yielding genotypes for the spice market (Dr. A.E. Slinkard, pers. comm. 2007). Recent studies indicate that fenugreek developed in western Canada can also be used as a forage crop since the plant maintains high nutritional quality irrespective of its maturity and the forage does not cause bloat in ruminants (Mir et al. 1997 a,b). Fenugreek is an important source of diosgenin and soluble fibre (Fazil and Hardman 1968;

Taylor et al. 1997; Basu et al. 2008) both of which contribute to its medicinal properties. The occurrence of diosgenin in livestock feed can enhance carcass weight (Acharya et *al*., 2006 a; 2007 a,b, 2008) and as an annual legume it is easy to incorporate into short term rotations where perennial forage legumes do not fit. Despite the fact that fenugreek has been identified as a forage crop, few adapted cultivars/ lines are available for successful forage production on the Canadian prairies. Tristar is the first forage fenugreek cultivar developed by Agriculture and Agri-Food Canada (AAFC) at the Lethbridge Research Centre (LRC), Alberta, for its ability to produce high biomass yield consistently over the years and locations. This cultivar is suited for intensive production of silage and hay in western Canada especially in regions with warm summers (Moyer et al. 2003; Acharya et al. 2006 b, 2008). However, Tristar fenugreek is slow to mature under adverse conditions, making it difficult to obtain seed for ongoing commercial production. In recent years, collaborative research between AAFC, University of Lethbridge and Alberta Agriculture, Food and Rural Development (AAFRD) has focused on use of a mutation breeding approach to identify new, early maturing fenugreek lines to help address this problem. It is widely accepted that genotype (G), growing conditions (E) and their interaction (G x E) are key factors in optimization of phenotypic traits in agricultural crops. However, if significant environmental effects exist, individual environmental parameters may be examined for their correlation to phenotypic traits (Moore et al. 2006). Eberhart and Russell (1966) proposed a model to test the stability of plant varieties under various environments, and defined a stable variety as having unit regression over environments and minimum deviation from regression. Adaptability of a genotype over diverse environments is usually tested by the degree of its interaction with different environments under which it is planted. A genotype or variety is considered to be more adaptive or stable if it has high mean yield but a low degree of fluctuation in yielding ability when grown over diverse environments (Muhammad et al. 2003). Genotype x environment interactions for various traits have previously been studied by different researchers in various crops including chickpeas (Jain and Panya 1998; Muhammad et al. 2003), dry beans (Balasubramanian et *al.*1999), hard winter wheat (Moore et al. 2006) and sunflowers (Leon et al. 2003). However, information on seed and forage yield of fenugreek lines is extremely limited. This study was conducted to elucidate the effect of G, E, and G x E on seed and forage yield of newly identified fenugreek lines, by quantifying their individual contributions to yield variance.

Materials and methods

Fenugreek seed material

The lines used in this study were taken from LRC seed collections and fenugreek seed collected from spice markets in India. The LRC collection includes seed from AAFRD, Plant Genetic Resource Canada (PGRC), Saskatoon and some personal collections of Dr. S.N. Acharya (LRC) from India. All of the lines used were *Trigonella foenum-graecum* L., with the exception of lines L3673 and L3674, which were *Trigonella caerulea* (L.) Ser. (Thomas et al. 2006).

Environments

The environments tested in the field experiments are described in Table 1. In the Lethbridge area the long term average annual precipitation is 375 mm out of which ~250 mm comes in the form of rain during the growing season (May to September).

Impact of growing conditions (rain-fed and irrigated) on genotype performance

This study was done at the LRC research field in 2004 and 2005. In 2004, depending on the seed availability 65 and 83 fenugreek accessions were seeded under rain-fed (mean precipitation for the May to September growing season was ~ 250 mm - Table 1) and irrigated (supplemental irrigation was added during the season as per Table 3) conditions, respectively. However, based on their seed yield performance in 2004, only 72 lines were seeded both under rain-fed and irrigated conditions in 2005. The 2004 rain-fed test was seeded on May 4 while the irrigated test was seeded on May 20. In 2005 both of the tests were seeded on May 25. It should be noted that in 2004, precipitation for the months May to September was 108, 73, 48, 38 and 21 mm, respectively while for 2005 precipitation for the period May to September was 13, 269, 13, 80 and 137 mm, respectively. Each genotype was planted in plots consisting of single 2 m long rows using 120 seeds from each line; rows were spaced 1 m apart. Each row (genotype) was considered as an experimental unit and was arranged as in a randomized complete block design (RCBD) with two replicates under each growing condition in 2004 and 2005. Despite the fact that the total number of genotypes used was 83, due to limitations in seed supply and ability to produce seed under Lethbridge conditions, an ANOVA was done on only 45 genotypes that were common among the two years and the two growing seasons. In calculating the correlation coefficients, data from all of the geno-

Table 1. Description of the environments under which the fenugreek tests were grown

Environment	Location description	Soil type	Mean max and min temperatures May to Sept.[A]	Mean precipitation May to Sept.*	References
Edmonton, Alberta	53° 29' 30.27" N and 113° 31' 53.82" W.	Black Chernozem	9.8 °C / 20.8 °C	248 mm	Harsh 1985
Fairview, Alberta	56° 02' 56.03" N and 118° 23' 14.01" W.	Gray Luvisol	8.3 °C / 19.7 °C	263 mm	Harsh 1985 www.calverley.ca/Part16-Alberta%20Peace/16-16.html
Brooks, Alberta	50º 31' 23.14" N and 111º 47' 18.84" W.	Orthic Brown Chernozem	8.4 °C / 23.2 °C	184 mm	Harsh 1985; Wyatt et al, 1939
Lethbridge, Alberta	Rain-fed field: (49º 42' 19.80" N and 112º 45' 59.02" W) Irrigated field: (49º 42' 24.98" N and 112º 45' 47.77" W)	Orthic Dark Brown Chernozem	8.5 °C / 22.8 °C	199 mm	Harsh 1985; Wyatt et al. 1939
Creston, British Columbia	49 ^{0} 06 ' 27.39 " N and 116 ^{0} 34 ' 05.62 " W	Stone-free alluvial deposit of Carbonated Rego Gleysol (composed of silt loam and silty clay loam) with poor to moderately poor drainage	10.0 °C / 23.8 °C	194 mm	Harsh 1985; Wittneben and Sprout 1971

[A] 30 year mean (1971–2000) – Environment Canada.

Table 2. Mean square (MS), degrees of freedom (df) and probability (P) of F value for forage yield, seed yield and 1000 seed weight as determined by a fixed model ANOVA. For the purpose, 45 genotypes were tested at two locations (Lethbridge rain-fed and irrigation) over two years (2004 and 2005)

Source	df	Forage yield (kg/ha)		Seed yield (kg/ha)		1000 Seed Weight (g)	
		MS	P of F	MS	P of F	MS	P of F
Total	359						
Replication	1	617.6	0.13	26.1	0.55	0.3	0.04
Year	1	51.7	0.66	1241.2	0.00	22.7	0.00
Location	1	22451.4	0.00	36.8	0.48	0.0	0.62
Genotype	44	416.8	0.02	275.6	0.00	0.1	0.26
Year*Location	1	2576.7	0.00	4690.1	0.00	0.1	0.31
Year*Genotype	44	170.8	0.96	126.5	0.01	0.1	0.13
Location*Genotype	44	323.9	0.19	72.5	0.51	0.1	0.71
Year*Location*Genotype	44	261.8	0.51	67.2	0.63	0.1	0.88
Residual	179	265.7		73.8		0.1	
CV (Coefficient of variation)		16.5		21.1		6.0	

Table 3. Grand Mean (GM) ± Standard Error (SE) of all world accessions and Tristar included in the Lethbridge study grown under two growing conditions (rain-fed and irrigated) over two years (2004 and 2005) and available moisture for the two locations

Yield parameters	Rain-fed (2004)		Irrigation (2004)[A]		Rain-fed (2005)		Irrigation (2005)	
	GM±SE	Tristar	GM±SE	Tristar	GM±SE	Tristar	GM±SE	Tristar
Seed yield (kg/ha)	1990 ± 104	2268	1254 ± 64	1478	1749 ± 78	2335	2283 ± 111	3544
Forage yield (kg/ha)	9073 ± 410	10235	12306 ± 786	11671	7957 ± 174	13154	12173 ± 375	16440
1000 seed weight (g)	19 ± 0.3	17	19 ± 0.3	14	23 ± 0.1	22	24 ± 0.1	22
Available moisture (mm)	288		150		512		95	

[A] Irrigated plots received supplemental irrigation in addition to the precipitation for the area.

types were used resulting in a high "df" for each 'r' determined; *i.e.*, 130 or 144).

Impact of location on the performance of 5 genotypes

Two separate location trials were done using the same five selected fenugreek genotypes; i.e., F70, F80, F86, Tristar and Amber. These genotypes were selected because of their ability to produce a high biomass yield in southern Alberta. In trial #1, each plot consisted of 10 rows (18 cm apart) and was 1.8 X 6 m^2 in size. Plots were arranged in a RCBD with 5 replicates at each environment. The seeding rate for each line in all the environments was 15 kg/ha. The tested environments were: Lethbridge rain-fed (49º 42' 19.80" N) and irrigated (49º 42' 24.98" N) for 2004 and 2005; and rain-fed conditions in Brooks (50º 31' 23.14" N) for 2004 and 2005 and, rain-fed conditions in Creston (49 ^{0} 06 ' 27.39 " N) for 2005. The 2004 test in Creston was damaged and so was not included in the analysis. For data analyses all seven growing conditions were considered separate environments and the environment effect was considered as random while the five selected genotypes were considered fixed. A separate trial consisting of the same five fenugreek lines (F70, F80, F86, Tristar and Amber) was performed at six locations; *i.e.*, Edmonton (rain-fed), Fairview (rain-fed) Lethbridge (rain-fed and irrigated) and Brooks (rain-fed and irrigated), over five years (2001-2005). The plots were arranged as in a RCBD and the data analyses used year as a random effect, and location and genotypes/lines as fixed effects. All trials were seeded during the first three weeks of May depending on the test site, the plots were harvested for forage yield in the first week of August to first week of September and, desiccated for seed harvest in the last week of September to October in different years and locations. Plants showing an average stand height of less than 15 cm and maturing within 90 days after seeding were considered to be 'determinate' in growth habit. In field trials, standard *Rhizobium* legume soil inoculants (The Nitragin Company, USA) were used to optimize legume plant growth. The code for this particular inoculant was "N" and the dosage applied was @ 0.3 g 120/seed. For weed control Edge (Dow AgroScience Canada Inc. 19.5 kg/ha), Odyssey (BASF Canada, 42 g/ha), and Embutox 625 (Nufarm Canada, 20 L/ha) were used in the field experiments and Reglone (Syngenta Crop Protection Canada Inc.) desiccant was used with Agral 90 surfactant (Syngenta Crop Protection Canada Inc., 1L/1000L mix) for the seed yield trials. For various reasons the plant numbers varied among some single row plots in 2004 and 2005 and so seed and forage yields were adjusted based on the proportion of surviving plants before analyses. The equation was: Adjusted yield = [(Observed yield X 100) / % stand after one month of growth in the field]

Statistical analysis

The mix procedure from SAS (SAS Institute Inc. 2005) was used to perform one fixed model ANOVA and two mixed model ANOVAs (one with environment as random and genotype as fixed and the other with year as random but genotypes and locations as fixed effects) were used for analyzing the data on studies dealing with multi-location trials. For study one with large number of world accessions the fixed effects ANOVA was performed on the seed and forage yield and 1000 seed weight. Data from 65 common lines grown under the two growing conditions in 2004 and 72 lines in 2005 were used for correlation analysis. All analyses were performed using the Agrobase 99 Statistical software program (Agronomix Software, Inc. 1999) which uses the SAS statistical package.

Table 4. Mean seed yield (kg/ha) of the top ten and bottom five lines from world accessions studied at two locations (LRC rain-fed and irrigation) over two years (2004 and 2005)

2004 Rain-fed		2004 Irrigation		2005 Rain-fed		2005 Irrigation	
Accessions	Seed yield	Accessions	Seed yield	Accessions	Seed yield	Accessions	Seed yield
PI 143504	4119	PI 211636	2881	L3708	7015	X92-23-3	6739
L3308	3952	L3312	2621	ZT-5	3866	L3068	6358
F18	3937	L3671	2452	L3308	3273	PI199264	4315
PI 138687	3320	L3720	2391	QUATRO	3079	L3375	4300
F86	3207	X92-23-3	2374	L3683	2979	AMBER	4057
L3312	3131	PI 143504	2342	L3678	2873	ZT-5	4051
F70	2980	PI 9095	2061	L3677	2808	F70	3994
L3703	2881	L3538	2004	PI211636	2755	L3683	3963
L3713	2564	L3308	1920	AMBER	2706	L3312	3945
L3707	2465	F86	1839	F70	2676	F18	3793
L3708	1032	L3678	261	L3714	994	L3679	1032
L3704	884	L3673	253	L3695	975	L3682	948
L3702	823	L3674	137	L3068	958	L3678	798
L3710	491	L3068	127	L3698	949	L3680	568
L3068	377	L3675	19	L3674	195	L3674	169

Results and discussion

Impact of growing conditions on genotypic performance

In addition to a significant genotypic effect, location and year x location effects were significant for forage yield (Table 2). In this case the two trials were fairly close to each other (Table 1) and the only difference between the two trials occurred when irrigation water was added to the plots. Fenugreek is known to be adapted to rain-fed growing conditions in western Canada, but its biomass production can be increased considerably (Table 3) by application of minimal irrigation in dry areas such as those found in southern Alberta. This study confirmed earlier observations in this regard (Mir et al. 1993; McCormick et al. 1998; Huang and Liang 2000). Seed yield of fenugreek was influenced significantly by genotype and environmental factors such as year and interaction effects of year x location, and year x genotype (Table 2). It is interesting to note that irrigation did not always improve seed yield. For example mean seed yield for plants grown under irrigation in 2004 (Table 3) was lower than that observed for plants grown under rain-fed conditions while the opposite was true in 2005. This type of interaction effect indicates that improvement in seed yield using selection of plants grown in different environments over a short term will be difficult and that genetic improvement using phenotypic selection will require selection under multiple locations and years. Higher seed yields were observed for lines grown under rain-fed conditions in 2004 (1990 kg/ha) compared to those grown under irrigation (1254 kg/ha). In contrast, mean seed yield of plants grown under irrigation (2283 kg/ha) in 2005 was higher than that observed for plants grown under rain-fed conditions (1828 kg/ha) (Table 3). Further examination of the trial details revealed that all growth conditions with the exception of irrigation were similar for the plots in 2005. However, in 2004 rain-fed plots were seeded 16 days ahead of the irrigated plots. This, along with good precipitation at seeding time (108 mm of rain in May 2004) may have contributed to the increased seed yield seen that year. In 2005, both of the tests were seeded on the same day and mean yield for seed and forage was higher as expected under irrigation in comparison to the rain-fed conditions. None of the genotypes tested made a list of the top 10 seed producers tested in all four environments (Table 4). However, accessions L3308 and F70 were among the top 10 seed yielding lines observed in three out of four environments, while accession X92-23-3 was among the top 10 seed yielding lines under irrigated conditions.

These three genotypes are good candidates for use as parent material in a hybridization program for seed yield improvement if the goal of the program is to produce a cultivar with high seed yield and adaptation to both rain-fed and irrigated conditions of western Canada. Among low yielding lines, accessions L3068 and L3674 were found to be consistently low yielding under all four growing conditions (Table 4). These two accessions belong to

Table 5. Correlation coefficient (r) for forage and seed yield, and 1000 seed weight determined for all lines included in the tests grown under rain-fed and irrigated conditions in 2004 and 2005

2004	Rain-fed		Irrigated	
	Forage yield	Seed yield	Forage yield	Seed yield
Forage yield	--		--	
Seed yield	0.60	--	0.34	--
1000 seed weight	0.95	0.59	0.81	0.41
2005				
Forage yield	--		--	
Seed yield	0.59	--	0.77	--
1000 seed weight	-0.03	0.06	-0.29	-0.15

Correlation coefficients greater than 0.23 are significant ($P < 0.01$)

a different species of fenugreek (*T. caerulea*; commonly called blue fenugreek) which has distinct flower color and plant characteristics. Of all the lines included in this study, only two (*i.e.*, L3172 and L3177) exhibited a determinate growth habit under both irrigated and rain-fed conditions in the two test years. This was expected as the determinate growth habit in fenugreek is a monogenic recessive trait; hence an indeterminate growth habit is the general norm (Choudhury and Singh 2001). The seed yield of the determinate lines, however, was considerably less than that of Tristar (an indeterminate line) and so, other than their use as parent material for transferring the determinate trait these accessions will be of little interest to producers.Since the year effect was highly significant for seed yield and 1000 seed weight, correlation coefficients (r) were calculated using seed yield and 1000 seed weight between the growing conditions (rain-fed and irrigation) for the two years separately. The "r" values for the 2004 lines were 0.54 and 0.61 ($P < 0.01$) for seed yield and 1000 seed weight, respectively; in 2005 the "r" values were 0.62 and 0.67, respectively ($P < 0.01$). Although significant "r" values indicate that many of the genotypes performed similarly under the two growing conditions (rain-fed and irrigation) within a year, all genotypes did not behave the same way for the two traits. In general dependence on single year data from multiple locations for selection purposes can be misleading for fenugreek and should not be used in the face of highly significant year and year x genotype effects. A wide range of variability with respect to mean seed yield, forage yield and 1000 seed weight was observed among different world accessions at the two locations during the two year (Table 3); this observation is encouraging from a genetic improvement stand point. Fenugreek accessions from the world collection exhibit extensive phenotypic variability when grown in western Canada. This variability has a genetic base, and so selection for improved forage and seed yield is possible. Raghuvanshi and Singh (1981) obtained high heritability estimates in fenugreek when they selected for a double pod trait. The double pod trait is known to be linked to diosgenin content and higher seed yields (Petropoulos 2002). From the large interaction effect observed in this study it is unlikely that heritability for the three traits studied will be high. The newly released cultivar Tristar was not among the top 10 seed yield producers observed under rain-fed or irrigated conditions in our two year study (Table 4). This was expected as Tristar was selected for its ability to produce high biomass and not seed yield. This cultivar has an indeterminate growth habit for which it produces high biomass and high quality forage throughout the growing period instead of letting early formed seed pods to mature. This, in fact, is one of the reasons why we are looking for high seed producing lines in areas with a short (~100 frost free days) growing season. Seed yield for Tristar was above the mean seed yield observed under all four growing conditions examined in this study but, the seed size of this cultivar was smaller than that of the mean seed size observed for all accessions examined under all four growing conditions (Table 3). It appears that it may be possible to increase seed yield by only increasing seed size; *i.e.*, as reported by Singh et al. (1973) and Dash and Kole (2000) for fenugreek, and by Raval and Dobariya (2003) for chickpea. Seed yield is known to be a complex trait governed by polygenes and therefore is influenced more by environmental factors, whereas the size component is governed by fewer genes in fenugreek (Singh and Singh 1974; Raghuvanshi and Singh 1981) and in other crops (Singh 1997; Raval and Dobariya 2003; Anbessa et al. 2006). It is expected that the size component for seeds will be less influenced by environmental factors (Petropoulos 1973; Fehr 1993; Bolaños-Aguilar et al. 2002) making phenotypic selection for

Table 6. Mean square (MS), degrees of freedom (df) and probability (P) of F value for forage and seed yield as determined by a mixed model ANOVA[A]. For this purpose, five genotypes were considered fixed and seven environments were considered random

Source		Forage yield (kg/ha)		Seed yield (kg/ha)	
	df	MS	P of F	MS	P of F
Total	174				
Replications	4			40.8	
Environment	6	885171264.4	0.00	7535.3	0.00
Genotypes	4	9106124.8	0.00	21.5	0.31
Environment*Genotypes	24	2551981.7		15.5	
Residual	136	1271287.1		17.8	
CV (Coefficient of variation)		15.0		13.9	

[A]ANOVA was done on square root transformed data. For the interaction term there is no direct F test and so the probability is not shown. To determination Environment and Genotype F values, MS for the Environment*Genotype calculation was used as the denominator.

Table 7. Mean square (MS), degrees of freedom (df) and probability (P) of F value for forage and seed yield as determined by a mixed model ANOVA[A]. For this purpose, five genotypes were considered fixed and six environments were considered random

Source		Forage yield (kg/ha)		Seed yield (kg/ha)	
	df	MS	P of F	MS	P of F
Total	554				
Replication	4	2096.6		109.8	
Genotype	4	161.6	0.05	56.9	0.00
Year	4	37618.2	0.00	5527.3	0.00
Location	5	9560.6	0.00	9717.0	0.00
Genotype *Year	16	188.1		51.9	
Genotype* Location	20	176.9	0.00	37.6	0.00
Year*Location	20	2402.2		1312.5	
Genotype* Year*Location	80	55.9		4.8	
Residual	401	87.3		37.0	
CV (Coefficient of variation)		11.4		11.7	

[A] ANOVA was done on square root transformed data. For the interaction terms there were no direct F test and so the probability is not shown. All calculations were done according to the model discussed in the text.

it more effective (Rohewal and Kooper 1973; Raghuvanshi and Singh 1981; Sohoo and Bhardwaj 1986; Ahmed et al. 1989; McCormick et *al*.1998; Chandra et al. 2000; McCormick et al. 2001; Acharya et al. 2006 a, 2008). Another way to improve seed yield of fenugreek in areas with a limited growing period would be through production of short duration or early maturing cultivars, an approach which also is under study (Basu et al. 2007, 2008). This study generated a good data set to look for an association among forage yield, seed yield and seed weight. Since the environmental effect was significant, correlations coefficients were calculated for the three traits for each environment (Table 5). Forage yield and seed yield for the 65 and 72 accessions used in the trials were positively correlated in both years under the two growing conditions (rainfed and irrigated), whereas 1000 seed weight was only correlated with these traits in 2004. This means that selection for improvement in forage or seed yield likely will result in improvement in both of these traits, whereas selection for improved 1000 seed weight may not help improve forage or seed yield unless the study is done in multiple years.

Impact of location on the performance of five selected genotypes

The multi-environment study conducted in southern Alberta and British Columbia, Canada indicated a highly significant effect of environment on both forage and seed yield while only genotypic effects were significant for forage yield (Table 6). Although large variations in seed yield were noticed for the genotypes tested, a statistically significant effect for the interaction could not be determined in this mixed effects model analysis. Highest seed yield was observed in Tristar (1249 kg/ha), closely followed by F70 (1245 kg/ha). The lowest yield was observed for AC Amber (1103 kg/ha). As observed earlier, Tristar and F70 yielded a significantly higher forage yield (8083 and 8002 kg/ha) than F86, AC Amber and F80 (7381, 7183, 6921 kg/ha respectively) (Basu et al. 2004). A long term study conducted using the same five cultivars over five years at six environments (i.e., at Edmonton (53° 29' 30.27" N), Fairview (56° 02' 56.03" N), Lethbridge (irrigation and rain-fed), and Brooks (rain-fed and irrigation) exhibited significant G x E effects (Table 6). A mixed model ANOVA indicated a significant effect of genotype ($P < 0.05$), and a highly significant effect for year, location and genotype x location interaction ($P < 0.01$) on forage yield. For seed yield, genotype, year, location and genotype x location interaction effects were found to be highly significant ($P < 0.01$). Usually 2-3 years are necessary to acclimatize a plant species to a new environment, and then these species are subjected to further breeding manipulations to address the needs of local farming communities (Detoroja et al. 1995). This approach is crop specific, and some crops or plant species may have to be subjected to different types of acclimation depending upon their adaptability (Fehr 1993). A wide variability in yield performance due to the environmental variation and associated micro-environmental impact is an important consideration for a cultivar development program in fenugreek. In this experiment genotypes that were selected for their ability to produce a good amount of forage in western Canada were included and so these genotypes were grown in the area for 3-4 years. Therefore, variations observed for seed and forage yield cannot be attributed strictly to lack of acclimatization. The data indicated that development of fenugreek cultivars with wide adaptation (for the entire western Canada) will be difficult and breeding programs may have to develop cultivars for specific environmental conditions to maximize yield performance. Widely adapted cultivars such as Co-1, R Mt-1 or Pusa Early Bunching observed by Edison (1995) in India will require selection under multiple locations and years with some sacrifice in yield performance in specific agro-climatic zones.

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