Genotype x Environment Effect on Galactomannan Content and Seed Yield of Fenugreek (*Trigonella foenum-graecum* L.)

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Abstract

Galactomannan (GLM) is a cell-wall storage polysaccharide, found in the fenugreek seed endosperm. Studies have shown that consumption of GLM from fenugreek, decreases cholesterol levels in the liver and blood plasma, and also decreases cholesterol synthesis in the liver. A study was conducted to examine the impact of growing environment (E) on seed galactomannan content (GC) and seed yield (SY) of fenugreek genotypes, with the objective of selecting lines for high GLM productivity. Fourteen fenugreek genotypes were grown in replicated trials at four different growing environments (Es) representing irrigated and rainfed conditions in southern Alberta, Canada. Results indicated that E, genotype (G) and E x G interaction accounted for 48.9 %, 19.4% and 31.6% of the treatment sum squares, respectively for GC and 38.6%, 39.5% and 21.9%, respectively for SY. Both G x E interaction effects for GC and SY were highly significant ($P< 0.0001$), suggesting that GLM and seed production potential of fenugreek genotypes varied across Es. The GC of fenugreek genotypes ranged from 12.2% to 23.5%, and SY ranged from 527 kg/ha to 4040 kg/ha, indicating SY variation across Es was higher than that of GC (1.9-fold for GC vs. 7.7-fold for SY). Consequently, fenugreek genotypes F 17, F 86, F 75 and L 3312 were selected for cultivar development because of their high seed yield and moderate GC when grown under rainfed conditions. .

Media Summary

Selection of well-adapted high yielding fenugreek genotypes with high galactomannan content will result in development of fenugreek cultivars to use as a source for functional food ingredient.

Key Words

Fenugreek, galactomannan, genotypes, growing environment, seed yield,

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is a self-pollinating, annual leguminous crop, native to the Indian subcontinent and the Eastern Mediterranean region (Petropoulos 2002). It has been historically utilized as a medicinal plant in various parts of the world. Seeds of the plant are used as a spice to impart flavor, color and aroma to foods while the leaves are consumed as leafy vegetables. Recent scientific studies and clinical trials have evidenced the role of fenugreek galactomannan in the lowering of plasma cholesterol and triglyceride levels, as well as reducing cholesterol synthesis in the liver (Madar and Shomer 1990; Sauvaire et al. 1996; Broca et al. 2000). During the past several years, we have tested over 100 fenugreek genotypes originating from different regions of the world in western Canada for early maturity and higher seed yields. However, evaluation of their bioactive compound content in to allow enhancement of the crop for use as a functional food. The purpose of this study was to evaluate the most promising fenugreek genotypes under four growing environments for the phenotypic adaptability and stability of seed yield and galactomannan content using the model suggested by Eberthart and Russell (1966) which facilitates discrimination of stability and adaptability of genotypes grown in different environments. This information would be useful to select most productive and stable genotype/s of fenugreek that can be for use as a functional food under different growing conditions in western Canada.

Methods

The fenugreek genotypes used in this study were *Trigonella foenum-graecum* L. which were previously selected for higher productivity in Alberta, Canada based on early maturity traits and high seed yield. The fourteen genotypes used in this study were grown in a Randomized Complete Block Design (RCBD) with two replicates per environment, at four different environments (Es) representing both rainfed and irrigated growing conditions in southern Alberta, Canada. Each plot was 4.5 m long and consisted of four rows spaced 30 cm apart. The crop was grown using recommended cultural practices. At maturity, seeds were mechanically harvested, cleaned and plot seed weights determined. All seed was stored in a dry and cool environment until further use. Galactomannan contents (GCs) for mature seed were determined using a commercially available assay kit (Megazyme Int., Bray, Ireland) which utilized sequential enzymatic hydrolysis of the galactomannan molecule to release free galactose into solution. Quantification was achieved through a redox reaction with nicotinamide adenine dinucleotide (NAD+) yielding NADH and the lactone form of galactose, followed by UV detection ($\lambda = 340$ nm) of NADH to calculate the galactomannan content assuming a galactose/mannose ratio of 1:1.

Data analysis was performed using a RCBD model by considering replicates and growing environment as random factors and genotypes as fixed factors. An LSD-test was carried out to compare the environment (E), genotype (G) and E x G interaction. Furthermore, both galactomannan content and seed yield were subjected to stability analysis using the model suggested by Eberthart and Russell (1966).

Results

Pooled analysis of variance indicated highly significant differences among environments (Es) for both seed yield (SY) and galactomannan content (GC), and among genotypes (Gs) only for seed yield (Table 1). The environment (E), genotype (G) and G x E interaction accounted for 48.9 %, 19.4% and 31.6% of the treatment sum squares, respectively for GC, and 38.6%, 39.5% and 21.9%, respectively for SY. Both G x E interaction effects for GC and SY were highly significant ($P< 0.0001$), suggesting that GLM and seed production potential of fenugreek genotypes varied across Es. The GC of fenugreek genotypes ranged from 12.2% to 23.5%, and SY ranged from 527 kg/ha to 4040 kg/ha, indicating that SY variation across Es was higher than that of GC (1.9-fold for GC vs. 7.7-fold for SY). Thus, these results further suggest that the variability in seed yield of fenugreek genotypes due to environmental factors is relatively higher than that of GLM. We have used a parametric model based on a simple linear regression analysis suggested by Eberhart and Russell (1966), which interprets the linear regression coefficient (bi) as a measure of cultivar adaptability and the variance of the regression deviation (s_{di}^2) as a measure of stability. By definition, the regression line for the most consistent cultivar should have a slope of one (b_i) with deviations from linearity (s_{di}^2) close to zero. Positive and negative values of the environment index indicate the favorable and unfavorable environmental conditions respectively, for these traits (Table 2). Results show that on average, genotypes F 75, L 3312, L 3308 and F 86 had significantly higher in seed yield compared to that of named genotypes such as Tristar and AC Amber, but that galactomannan contents were comparable among genotypes. In respect to SY, among the genotypes tested, F 86, L 3312 and F 80 were the most adaptable genotypes (b_i ranged

1.02 to 1.17) and F 96, L 3312 and Tristar were the most stable genotypes (s_{di}^{2}) across the environments tested (Table 3). The genotypes L 3308, and F80 were the most adaptable and Quatro MP, L 3308 and F 75 were most stable genotypes in terms of GC, across Es tested (Table 3). Since the seed yield is relatively more of an influencing factor for galactomannan yields (seed yield x galactomannan content) than GC, we have identified F 75, L 3312, F 86 and F 17 as the most productive genotypes. However, further evaluations are in progress which use different growing environments in southern Alberta.

Conclusions

Fenugreek has sufficient variability to allow its adaptation for use as a rainfed crop in semi-arid regions of the Canadian prairies. We conclude that environmental factors were influential in the productivity of the fenugreek genotypes tested. Seed yield variability was also four times higher than that of galactomannan content, again reinforcing our position that productivity of the genotypes was heavily dependent upon environmental influences. From the perspective of growers, the galactomannan productivity (GLM yield /unit area) is of greater importance than GC per se. Acknowledging the fact that seed yield is a relatively greater influence on galactomannan yield than GC, we have identified F 75, L3312, F 86 and F 17 as the most productive genotypes, but further evaluations are in progress under diverse growing environments in southern Alberta. They demonstrate that levels of SY and GC in seeds can be optimized for potential marketing of the plants as a functional food for use to regulate cholesterol levels in human.

Table 1. Pooled analysis of variance for seed yield and galactomannan content (%) of fourteen fenugreek genotypes grown in four environments in southern Alberta in 2006.

Source of variation	Degree of freedom	Sum of squares for seed yield	*P*	Sum of squares for galactomannan %	*P*
Environment	3	36738023	0.000	282.18	0.000
Replicate (Environment)	4	2061518	0.007	4.21	0.660
Genotype	13	37585127	0.000	111.98	0.071
Environment x genotype	39	20813220	0.000	182.44	0.000
Error	52	6785138		90.25	

Table 2. Mean seed yield and galactomannan content (%) of fourteen fenugreek genotypes grown in four environments in southern Alberta in 2006.

Genotype	Seed yield (kg ha^{-1})				Galactomannan content (%)			
	Env. 1[#] (+ 660)[!]	Env.2[x] (+ 256)	Env.3[y] (- 900)	Env. 4[z] (- 16)	Env. 1 (- 0.3)	Env.2 (- 1.3)	Env.3 (+ 2.6)	Env. 4 (- 1.0)
Tristar	3584	2618	1448	2629	17.6	20.7	22.5	19.3
Quatro MP	3634	2839	1658	3286	19.9	19.3	21.2	19.2
AC Amber	2575	1696	1705	1620	18.1	17.3	19.8	12.2
L 3308	3555	3038	1205	3587	20.0	19.0	22.1	18.7
F 17	4040	2693	1670	1905	19.8	15.6	23.2	20.1
F 70	3609	2098	1453	2070	19.8	17.0	20.3	17.9
F 96	3511	3264	1806	2637	17.6	17.4	22.4	16.8
F 75	3852	3443	1813	3847	19.2	16.4	23.5	17.5
ZT -92 -1	1958	1912	1377	527	16.1	17.9	21.4	16.1
Indian -T	1569	1645	1180	1006	16.9	15.6	21.0	17.8
ZT- 92-2	2262	1981	1467	1457	19.4	16.4	22.4	16.1
L3312	3619	3146	1788	3210	21.6	17.3	21.3	20.7
F 80	3190	3641	1613	2991	18.0	19.3	22.9	20.2
F 86	2676	3965	1540	3404	19.4	17.2	19.3	19.7
LSD ($P < 0.05$)	722				2.6			

CV%	14.7	6.9

Env. 1[#]= Brooks rainfed; Env.2[x] = Brooks irrigated; Env.3[y] = Bow Island rainfed; Env. 4[z] = Bow Island irrigated.
( )[!] = environment index.

Table 3. Mean values and estimates of stability parameters of Eberhart and Russell (1966) for seed yield and galactomannan content of fourteen fenugreek genotypes grown in four environments in southern Alberta in 2006.

Genotype	Seed yield (kg ha^{-1})			Galactomannan content (%)		
	$\bar{X}$	b_i	s_{di}^2	$\bar{X}$	b_i	s_{di}^2
Tristar	2570	1.29	57046	20.0	0.747	3.837
Quatro MP	2854	1.20	160430	19.9	0.515	0.042
AC Amber	1899	0.44	181455	16.8	1.200	9.455
L 3308	2863	1.46	373828	19.9	0.846	0.126
F 17	2577	1.39	448320	19.7	1.460	4.267
F 70	2308	1.20	313016	18.7	0.703	1.209
F 96	2805	1.13	26641	18.3	1.440	1.391
F 75	3239	1.32	268590	19.1	1.720	0.281
ZT -92 -1	1443	0.41	555580	17.8	1.210	2.525
Indian -T	1350	0.26	87257	17.8	1.200	1.045
ZT- 92-2	1792	0.50	72883	18.6	1.560	1.240
L3312	2941	1.17	55380	20.2	0.612	4.181
F 80	2856	1.17	243516	20.1	0.934	2.386
F 86	2896	1.02	957272	18.9	0.236	1.746
LSD *(P < 0.05)* for genotype	361			-		

$\bar{X}$ = mean values across environments; bi = regression coefficient; S^2 d = mean square of deviation from linear regression.

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