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Association of characters and their direct and indirect contribution for seed yield in fenugreek (*Trigonella foenum graecum* L.) germplasms

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ABSTRACT : Seed yield plant^{-1} had highly significant and positive association with days to 50 per cent flowering, days to 75 per cent maturity, petiole length and number of primary branches plant^{-1}. Path co-efficient analysis of different traits contributing towards seed yield plant^{-1} showed that days to 50 per cent flowering recorded the highest positive direct effect followed by petiole length, days to 75 per cent maturity, number of pods plant^{-1}, number of seeds pod^{-1} and vegetative yield.

KEY WORDS : Fenugreek, Correlation, Path co-efficient

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Fenugreek (*Trigonella foenum graecum* L.) is an annual, self-pollinating legume (sub family: Papilionaceae; family: Fabaceae). Most plants are diploid (2n=16) and grown as a spice as well as forage crop. According to the National Center for Complementary and Alternative Medicine, fenugreek was first mentioned in "an Egyptian papyrus" dating back to 1500 B.C. According to Rosengarten (1969) the Romans, who got the plant from Greece where it was a very common crop in ancient times, gave it this name. It is also called 'ox horn' or 'goat horn' because of the pods projecting in opposite directions usually from the nodes of the stem base that resembles ox or goat horns. It is believed to be native to the Asia rather than Southern Europe. Fenugreek is an old medicinal plant and has been commonly used as a traditional spice and medicine. It is known to have hypoglycemic and hypocholesterolaemic effects. Recent research has identified fenugreek as a valuable medicinal plant with potential for multipurpose uses and also as a source for preparing raw materials of pharmaceutical industry, especially steroidal hormones. The leaves and seeds of fenugreek are consumed in different countries around the world for different purposes such as medicinal uses (anti-diabetic, lowering blood sugar and cholesterol level, anti-cancerous, anti-microbial etc.), making food (stew with rice in Iran, flavour cheese in Switzerland, syrup and bitter run in Germany, mixed seed powder with flour for making flat bread in Egypt, curries, dyes, young seedlings eaten as vegetables etc.), roasted grain as coffee-substitute (in Africa), controlling insects in grain storages, perfume industries etc. In India, it is mainly used as a lactation stimulant (Tiran, 2003). Fenugreek seed in powder or germinated form exhibits anti-diabetic properties (Broca *et al.*, 2004 and Devi *et al.*, 2003). It is also utilized as a source for preparing raw materials of pharmaceutical industry, especially steroidal hormones.

RESEARCH METHODS

The present investigation was conducted during the year 2009-10 and 2010-11 at Vegetable Farm, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). The experimental material consisted of 102 genotypes of fenugreek in a Randomized Block Design which was replicated thrice. Each genotype was planted in a spacing of 30x10cm between two consecutive row and plant. Correlation co-efficients were calculated for all quantitative characters combinations at phenotypic, genotypic and environmental level by the formula given by Miller *et al.* (1958). The direct and indirect contributions of various characters to yield were calculated through path co-efficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). Later the path co-efficients were rated based on the scales given by Lenka and Mishra (1973).

RESEARCH FINDINGS AND DISCUSSION

Correlation analysis provides a good measure of the linear association between character(s) and helps to identify the most important character(s) to be considered for effective selection for increasing yield. In the present investigation correlations were worked out both at phenotypic and genotypic levels for all possible character combinations. In general, genotypic correlation co-efficients were higher in magnitude than phenotypic correlation co-efficients (Lal *et al.*, 1983) in the same direction and magnitude indicated that there is a strong inherent association between each pair of character(s) which might be due to masking or modifying effect of the environment.

On the basis of pooled analysis (Table 1) of two years the seed yield plant^{-1} had highly significant and positive association with days to 50 per cent flowering (0.388), days to 75 per cent maturity (0.251), petiole length (0.119) and number of primary branches plant^{-1} (0.107). Significant and positive correlation of vegetative yield was recorded with chlorophyll content at 60 DAS (0.264), test weight (0.182), plant height at maturity (0.149) and days to 50 per cent flowering (0.120). Plant height at maturity showed significant and positive association with days to 50 per cent flowering (0.162), pod length (0.158), vegetative yield (0.149) and chlorophyll content (0.121). Chlorophyll content at 60 DAS was positively correlated with vegetative yield (0.264), pod length (0.205) and days to 75 per cent maturity (0.122). Petiole length showed a positive and highly significant correlation with nodulation at 60 DAS (0.127) and seed yield plant^{-1} (0.119). Correlation of nodulation at 60 DAS was significant and positive with number of primary branches plant^{-1} (0.225) and days to 50 per cent flowering (0.169). However, association was observed significant and negative with pod length (-0.136) and days to 75 per cent maturity (-0.122). The findings corroborated the earlier reports of Kole and Mishra (2006), Mathur (1996) and Sharma and Sastry (2008).

Number of primary branches plant^{-1} was significantly and positively associated with number of pods plant^{-1} (0.291), days to 50 per cent flowering (0.137), days to 75 per cent maturity (0.120) and seed yield plant^{-1} (0.107). Number of seeds pod^{-1} showed positive and significant association with test weight (0.139), while it was negatively associated with days to 75 per cent maturity (-0.128). Test weight had high significant and positive correlation with vegetative yield (0.182). The correlation co-efficient of days to 50 per cent flowering was significant and positive with seed yield plant^{-1} (0.338), days to 75 per cent maturity (0.379) and vegetative yield (0.120). Whereas, days to 75% maturity was observed to have a positive and significant correlation with seed yield plant^{-1} (0.251). These findings were in agreement to those of Banerjee and Kole (2004), Kole and Mishra (2006), Kumar and Choudhary (2002) and Sharma and Sastry (2008).

Genotypic and environmental factors have extensive affects on growth and yield of fenugreek. Most of the characters of interest to breeders are complex and are result of the interaction of a number of components (Sarawgi *et al.*, 1998). The study of relationships among quantitative traits is important for assessing the feasibility of joint selection for two or more traits instead of selection of secondary traits on genetic gain for the primary trait under consideration (Ezeeku and Mohammed, 2006). Path co-efficient analysis is a statistical tool which has been used to organize and present the causal relationships between predictor variables and response variables through a path diagram that is based on experimental results (Samonte *et al.*, 1998). In agriculture path analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Milligan *et al.*, 1990).

The highest positive direct effects (Table 2) was recorded for days to 50 per cent flowering (0.3380) on seed yield plant^{-1} followed by petiole length (0.2447), days to 75 per cent maturity (0.2068), number of pods plant^{-1} (0.0880), number of seeds pod^{-1} (0.0801) and vegetative yield (0.0143). Chlorophyll content at 60 DAS (-0.1241) exhibited the highest negative direct effect on seed yield plant^{-1} followed by number of primary branches plant^{-1} (-0.0726), pod length (-0.0251), plant height at maturity (-0.0146) and nodulation at 60 DAS (-0.0130). The positive direct effect was observed for chlorophyll content at 60 DAS via., petiole length (0.0112) and nodulation at 60 DAS (0.0078), while vegetative yield (-0.0351), pod length (-0.0318), number of pods plant^{-1} (-0.0164), days to 75 per cent maturity (-0.0156), plant height at maturity (-0.0152) and test weight (-0.0125) were found to be negative. This indicates true relationship with seed yield plant^{-1} and direct selection for these traits would result in higher breeding efficiency for improving yield. Thus these traits might be reckoned as the most important component trait of seed yield plant^{-1} in fenugreek. The results are in propinquity with Ayanoglu *et al.* (2004), Balai *et al.* (2006), Dash and Kole (2000), Mathur (1996) and Singh and Pramila (2009).

Plant height at maturity revealed a positive indirect effect through nodulation at 60 DAS (0.0019) and number of seeds pod^{-1} (0.0017). Indirect effect of petiole length via., nodulation at 60 DAS (0.0574), number of primary branches

Table 1: Estimates of genotypic and phenotypic correlation coefficient for yield and its contributing characters in fenugreek

Characters		Chl. content 60 DAS	Petiole length (cm)	Nodulation at 60 DAS	No. of primary branches	No. of pods/plant	Pod length (cm)	No. of seeds/ pod	Test seed weight	Days to 50% flowering	Days to 75% maturity	Vegetative yield (kg)	Seed yield/ plant (g)
Plant height maturity	G	0.122	-0.050	-0.127	0.019	0.112	0.201	-0.117	0.079	0.173	0.024	0.157	0.023
	P	0.121 *	-0.032	-0.095	0.016	0.092	0.158 **	-0.092	0.072	0.162 **	0.022	0.149 **	0.023
Chlorophyll content 60 DAS	G		-0.090	-0.063	-0.007	0.131	0.256	-0.010	0.100	0.046	0.125	0.282	-0.095
	P		-0.055	-0.041	-0.005	0.100	0.205 **	-0.006	0.093	0.046	0.122 *	0.264 **	-0.093
Petiole length (cm)	G			0.234	0.214	-0.092	-0.136	0.011	0.089	-0.039	-0.198	0.065	0.180
	P			0.127 *	0.103	-0.030	-0.136 *	0.001	0.054	-0.030	-0.122 *	0.029	0.119 *
Nodulation at 60 DAS	G				0.313	0.027	-0.097	0.062	0.071	0.234	-0.012	-0.058	0.121
	P				0.225 **	0.018	-0.028	0.072	0.042	0.169 **	-0.009	-0.031	0.087
No. of primary branches	G					0.450	-0.149	0.098	0.100	0.172	0.163	0.032	0.123
	P					0.291 **	-0.094	0.078	0.081	0.137 *	0.120 *	0.042	0.107 *
No. of pod/plant	G						0.090	0.057	0.091	0.096	-0.027	-0.064	0.044
	P						0.035	0.069	0.081	0.089	-0.034	-0.031	0.041
Pod length (cm)	G							-0.095	0.073	0.045	-0.024	-0.011	-0.069
	P							-0.087	0.038	0.034	-0.007	-0.006	-0.059
No. of seeds/ pod	G								0.164	-0.112	-0.179	0.099	0.009
	P								0.139 *	-0.080	-0.128 *	0.061	0.004
Test seed weight	G									0.127	-0.028	0.209	0.063
	P									0.096	-0.027	0.182 **	0.056
Days to 50% flowering	G										0.422	0.134	0.412
	P										0.379 **	0.120 *	0.388 **
Days to 75% maturity	G											0.099	0.266
	P											0.095	0.251 **
Vegetative yield (kg)	G												0.062
	P												0.061

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2: Genotypic and phenotypic path analysis showing direct and indirect effect on seed yield plant^{-1} of fenugreek (Pooled)

Characters		Plant height at maturity (cm)	Chlorophyll content at 60 DAS	Petiole length (cm)	Nodulation at 60 DAS	Primary branches / plant	Pods/ plant	Pod length (cm)	Seeds/ pod	Test weight	Days to 50% flowering	Days to 75% maturity	Vegetative yield (kg)	"r" value of Seed yield/ plant (g)
Plant height at maturity (cm)	G	-0.0146	-0.0018	0.0007	0.0019	-0.0003	-0.0016	-0.0029	0.0017	-0.0012	-0.0025	-0.0004	-0.0023	0.0232
	P	-0.0164	-0.0020	0.0005	0.0016	-0.0003	-0.0015	-0.0026	0.0015	-0.0012	-0.0027	-0.0004	-0.0025	0.0238
Chlorophyll content at 60 DAS	G	-0.0152	-0.1241	0.0112	0.0078	0.0009	-0.0164	-0.0318	0.0013	-0.0125	-0.0057	-0.0156	-0.0351	-0.0957
	P	-0.0156	-0.1283	0.0071	0.0053	0.0006	-0.0129	-0.0263	0.0008	-0.0121	-0.006	-0.0157	-0.0339	-0.0935
Petiole length (cm)	G	-0.0123	-0.0222	0.2447	0.0574	0.0524	-0.0225	-0.0334	0.0028	0.0218	-0.0096	-0.0487	0.016	0.1803
	P	-0.0045	-0.0075	0.1359	0.0173	0.014	-0.0041	-0.0185	0.0001	0.0074	-0.0042	-0.0167	0.004	0.119
Nodulation at 60 DAS	G	0.0017	0.0008	-0.003	-0.013	-0.0041	-0.0004	0.0013	-0.0008	-0.0009	-0.003	0.0002	0.0008	0.1218
	P	-0.0002	-0.0001	0.0003	0.0026	0.0006	0	-0.0001	0.0002	0.0001	0.0004	0	-0.0001	0.0878
Primary branches/ plant	G	-0.0014	0.0005	-0.0156	-0.0227	-0.0726	-0.0327	0.0109	-0.0072	-0.0073	-0.0125	-0.0119	-0.0024	0.1239
	P	0.0002	-0.0001	0.0011	0.0025	0.0109	0.0032	-0.001	0.0009	0.0009	0.0015	0.0013	0.0005	0.1076
Pods/ plant	G	0.0099	0.0116	-0.0081	0.0024	0.0397	0.088	0.008	0.005	0.0081	0.0085	-0.0024	-0.0056	0.0448
	P	0.0027	0.0029	-0.0009	0.0005	0.0085	0.0291	0.001	0.002	0.0024	0.0026	-0.001	-0.0009	0.041
Pod length (cm)	G	-0.0051	-0.0064	0.0034	0.0025	0.0038	-0.0023	-0.0251	0.0024	-0.0018	-0.0011	0.0006	0.0003	-0.0696
	P	-0.0030	-0.0039	0.0026	0.0005	0.0018	-0.0007	-0.0191	0.0017	-0.0007	-0.0007	0.0001	0.0001	-0.059
Seeds/ pod	G	-0.0094	-0.0009	0.0009	0.005	0.0079	0.0046	-0.0076	0.0801	0.0131	-0.009	-0.0144	0.008	0.0097
	P	-0.0037	-0.0003	0	0.0029	0.0031	0.0028	-0.0035	0.0396	0.0055	-0.0032	-0.0051	0.0024	0.0043
Test weight (g)	G	0.0002	0.0002	0.0002	0.0001	0.0002	0.0002	0.0001	0.0003	0.0019	0.0002	-0.0001	0.0004	0.0638
	P	0.0015	0.0019	0.0011	0.0009	0.0017	0.0017	0.0008	0.0029	0.0207	0.002	-0.0006	0.0038	0.0567
Days to 50% flowering	G	0.0621	0.0165	-0.014	0.0839	0.0617	0.0345	0.0162	-0.0402	0.0456	0.358	0.1512	0.048	0.4124
	P	0.0543	0.0155	-0.0103	0.0565	0.046	0.03	0.0116	-0.0269	0.0322	0.3338	0.1267	0.0401	0.3883
Days to 75% maturity	G	0.005	0.026	-0.0411	-0.0026	0.0339	-0.0056	-0.005	-0.0371	-0.0059	0.0873	0.2068	0.0205	0.2668
	P	0.0036	0.0195	-0.0196	-0.0016	0.0192	-0.0055	-0.0011	-0.0205	-0.0044	0.0606	0.1597	0.0153	0.2516
Vegetative yield (kg)	G	0.0023	0.0041	0.0009	-0.0008	0.0005	-0.0009	-0.0002	0.0014	0.003	0.0019	0.0014	0.0143	0.0628
	P	0.0049	0.0087	0.001	-0.0011	0.0014	-0.001	-0.0002	0.002	0.006	0.004	0.0032	0.0331	0.0619

Genotypic residual effect = 0.2554 phenotypic residual effect = 0.2047 plant^{-1} (0.0524), test weight (0.0218) and vegetative yield (0.0160) were found to be positive whereas, it exhibited a negative indirect effect for days to 75 per cent maturity (-0.0487), pod length (-0.0334), number of pods plant^{-1} (-0.0225), chlorophyll content at 60 DAS (-0.0222) and plant height at maturity (-0.0123). Nodulation at 60 DAS had positive indirect effect on seed yield plant^{-1} via plant height at maturity (0.0017), pod length (0.0013), chlorophyll content at 60 DAS (0.0008), number of seeds per pod^{-1}(0.0008) and vegetative yield (0.0008). However, negative indirect effects were recorded in petiole length (-0.0030) and days to 50 per cent flowering (-0.0030). The findings of Ayanoglu *et al.* (2004), Shukla and Sharma (1978) and Singh and Raghuvansh (1989) are in close harmony to the present findings.

High positive indirect effect of number of primary branches plant^{-1} on seed yield plant^{-1} was revealed through pod length (0.0109) and number of seeds pod^{-1} (0.0072), while it was observed to express negative indirect effects for number of pods plant^{-1} (-0.0327), nodulation at 60 DAS (-0.0227), petiole length (-0.0156), days to 50 per cent flowering (-0.0125) and days to 75 per cent maturity (-0.0119). Number of pods plant^{-1} exhibited the highest positive indirect effect via number of primary branches plant^{-1} (0.0397), chlorophyll content at 60 DAS (0.0116), plant height at maturity (0.0099), days to 50 per cent flowering (0.0085), test weight (0.0081) and pod length (0.0080). Indirect effects were observed through petiole length (-0.0081), vegetative yield (-0.0056) and days to 75 per cent flowering (-0.0024). Pod length expressed the highest positive indirect effect through number of primary branches plant^{-1} (0.0038), petiole length (0.0034), nodulation at 60 DAS (0.0025) and number of seeds pod^{-1} (0.0024). Its indirect negative effects were high via chlorophyll content at 60 DAS (-0.0064), plant height at maturity (-0.0051) and number of pods plant^{-1} (-0.0023). Ayanoglu *et al* (2004), Balai *et al.* (2006), Gurbuz *et al.* (2000), Singh and Kaur (2007) and Singh and Pramila (2009) recorded quite similar results.

Number of seeds pod^{-1} exhibited a positive indirect effect through test weight (0.0131), vegetative yield (0.0080), number of primary branches plant^{-1} (0.0079), nodulation at 60 DAS (0.0050) and number of pods plant^{-1} (0.0046). It showed a negative indirect effect through days to 75 per cent maturity (-0.0144), plant height at maturity (-0.0094), days to 50 per cent flowering (0.0090) and pod length (-0.0076). All the traits exhibited positive indirect effect except days to 75 per cent maturity in lower magnitude on seed yield plant^{-1} through test weight. Days to 50 per cent flowering expressed a high positive indirect effect through days to 75 per cent maturity (0.1512), nodulation at 60 DAS (0.0839), plant height at maturity (0.0621), number of primary branches plant^{-1} (0.0617), vegetative yield (0.0480), test weight (0.0456), number of seeds per pod (0.0402), number of pods plant^{-1} (0.0345), chlorophyll content at 60 DAS (0.0165) and pod length (0.0162), but it revealed negative indirect effect through petiole length (-0.0140). Days to 75 per cent maturity (0.0873) exhibited the highest positive indirect effect on seed yield plant^{-1} via days to 75 per cent maturity, followed by number of seeds per pod (0.0371), number of primary branches plant^{-1} (0.0339), chlorophyll content at 60 DAS (0.0260) and vegetative yield (0.0205). However, it was recorded negative indirect effect through petiole length (-0.0411), test weight (-0.0059), number of pods plant^{-1} (-0.0056) and pod length (-0.0050).

Vegetative yield revealed indirect effects through chlorophyll content at 60 DAS (0.0041), test weight (0.0030), plant height at maturity (0.0023) and days to 50 per cent flowering (0.0019). While, number of pods plant^{-1}, nodulation at 60 DAS and pod length expressed a negative effect in lower magnitude. The overall observation of path co-efficient analysis of seed yield plant^{-1} and its components *viz.*, petiole length, number of pods plant^{-1}, number of seeds pod^{-1}, days to 50 per cent flowering, days to 75 per cent maturity and vegetative yield were most important characters contributing towards seed yield plant^{-1}. The results were in consonance with Chandra *et al.* (2000), Dash and Kole (2000), Kumar and Chaudhary (2002 and 2003) and Raghuwanshi and Singh (1982).

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