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Interrelationship in hybrids and segregants of faba bean (*Vicia faba* L.) under sodic soil

Amit Kumar Chaudhary, Shiva Nath, OP Verma and Hamsa Poorna Prakash

Abstract
A field experiment with 65 genotypes of faba bean (15 lines x 3 testers along with 2 checks) was evaluated at Genetics and Plant Breeding Research Farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during *rabi* 2017-18 to 2019-20. The experiment was laid out on Randomized Complete Block Design with three replications to record thirteen yields and yield contributing traits of faba bean *viz.*, days to 50 per cent flowering, days to maturity, chlorophyll content, plant height (cm), number of branches per plant, pod length (cm), number of pods per plant, number of seeds per pod, biological yield per plant (g), harvest-index (%), 100-seed weight (g), protein content (%) and grain yield per plant (g). The physico-chemical characteristic was the soil of pH-9.2, EC-3.2 dSm^{-1}, ESP-45%, sandy loam, low in organic carbon, nitrogen, phosphorus and rich in potash. In order to grow good crops, all the recommended cultural practices follow. The analysis of variance revealed that all the quantative traits were highly significant indicating a wide range of variability in the existing parents, hybrids, and sergeants. The grain yield per plant was found positively and significantly associated with biological yield per plant followed by number of pods per plant, harvest index, and number of seeds per pod in F_1's while in F_2's; biological yield per plant followed by number of pods per plant and harvest index. Besides, few quantitative traits were intercorelated to each other in hybrids and as well as in the segregating population. Hence, emphasis should be given to select the above traits to enhance the production and productivity of faba bean.

Keywords: Interrelationship, faba bean, hybrid, segregant and sodic soil

Introduction
Pulses have great importance for human nutrition considering their richness in proteins, carbohydrates and minerals. India has been a frontrunner in production yet as a consumption of pulses within the world. Total Pulses production throughout 2019-20 was 23.02 million tonnes (Anonymous, 2020) [2]. Faba bean is an annual legume (Fabaceae family) botanically known as *Vicia faba* L. The protein content of faba bean ranges from 20% to 35% of the seed dry matter, making it the most protein-rich major pulse crop. Faba bean is assigned to the Central Asian, Mediterranean, and South American centers of Diversity and believes to be a native to North Africa and southwest Asia, and extensively cultivated elsewhere (Harlan, 1969; Zohary and Hopf, 2000) [6, 18]. The main faba bean growing countries are China (1.80 Mt), Ethiopia (0.93 Mt), Australia (0.37 Mt), Germany (0.19 Mt), France (0.19 Mt), Egypt (0.11 Mt) Sudan (0.11 Mt). China is the leading producer with 37% share of the world's total faba bean production (FAOSTAT, 2019) [4]. Faba bean has been recognized as a potential grain legume by the National Agricultural Research System of the country and has been included in the 'All India Coordinated Research Network on Potential crops'. It has also been known as one of the eight major food legumes by the CGIAR research program. In the Bihar, it has become a traditional legume crop. It is also being grown on a small scale in Jharkhand, Eastern Uttar Pradesh, Chhattisgarh, Odisha, Madhya Pradesh, and Haryana. Yield improvement is a major breeding objective of most crop improvement programs (Ghobary and Abd-Allah, 2010) [5]. Yield in faba bean, just like the other crops, is a complex trait and constitute by many morphological and physiological traits. Seed yield is affected by genotype and environmental factors because it is a quantitative attribute. Victimization as selection criteria of characters, direct relationship with seed yield increases the success of selection in plant breeding (Karasu and Oz, 2010) [11]. Therefore, the progress of breeding in such traits is primarily conditioned by the magnitude and nature of variation and interrelationships among them (Raffi and Nath, 2004) [12]. This selection criterion takes into account the information on the interrelationship

among agronomic characters, their relationship with grain yield as well as their direct influence on grain yield. Since the scope of genetic improvement in any crop plants depends mainly on the selection of tolerant genotypes against biotic and abiotic stresses along with the traits association of different seed yield and its contributing components to enhance the yield potential in salt-affected soil. Work on faba bean improvement under salt-affected soil is meagre. Hence, we have discussed to improve the faba bean under sodic soil.

Materials and methods

The experiment was conducted at the Department of Genetics and Plant Breeding Research Farm of the Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, during *Rabi* 2017-18, *Rabi* 2018-19 and *Rabi* 2019-20. The 65 genotypes possessing 45 crosses (F_1's and F_2's) were generated by crossing 15 lines with 3 testers during *Rabi* 2017-18 and 2018-19, respectively. The final experiment with 65 diverse genotypes with two checks (Vikrant and HFB 1), was evaluated in Randomized complete block design with 3 replications during *Rabi* 2019-20 to record 15 characters *viz.*, days to 50 per cent flowering, days to maturity, chlorophyll content (spad. value), plant height (cm), number of branches per plant, pod length (cm), number of pods per plant, number of seeds per pod, biological yield per plant (g), harvest-index (%), 100-seed weight (g), protein content (%) and grain yield per plant (g). Each plot had two rows of 4 m length with inter and intra-row spacing of 30 cm and 10 cm, respectively. All the recommended cultural practices were followed to raise a good crop. The observations were recorded on five randomly selected competitive plants of a genotype in a plot in each replication for thirteen characters. The mean values of observations recorded on five plants of each plot were used for analysis. Data were subjected to statistical analyses. The simple correlation coefficient between different characters was estimated according to Searle (1961) [14]. Grain yield per plant was assumed to be the dependent variable (effect) which was influenced by the thirteen characters, the independent variables (causes), directly as well as indirectly through other characters. The variation in grain yield per plant unexplained by the thirteen causes was presumed to be contributed by a residual factor (x) which is uncorrelated with other factors.

Results and discussion

Analysis of variance was carried out concerning thirteen characters to test the significance of differences between various treatments (genotypes) *viz.*, fifteen lines, three testers, forty five F_1's and F_2's, and two checks (Vikrant and HFB 1) under sodic soil as depicted in 'Table 1'. The mean squares due to treatments were highly significant for all the thirteen characters which showed significant differences, indicating the presence of sufficient variability in the materials of hybrids and segregants generation. The variances due to replications were found significant for six characters *viz.*, chlorophyll content, plant height, number of branches per plant, biological yield per plant, protein content, and grain yield per plant in F_1's while four characters *viz.*, days to maturity, chlorophyll content, plant height, grain yield per plant in F_2's and non-significant for rest of the characters in F_1's and F_2's. This indicated the presence of substantial variability in the parents, hybrids, and segregants and validated further statistical and genetical analysis.

The magnitude of correlation coefficients among various traits considering the possibility of high yield through yield attributes, as a key interest in crop improvement is crucial. Grain yield or economic yield, in almost all the crops, is the complex character that manifests from multiplicative interactions of several other characters that are termed as yield components. The genetic makeup of grain yield in faba bean as well as in other crops is based on the balance or overall net effect produced by various yield components directly or indirectly by interacting with each other. Therefore, selection for yield *per se* alone would not matter much as such unless accompanied by the selection for various component characters responsible for conditioning it. Therefore, identifying key elements and information about their association with yield and with each other is very useful for developing an efficient breeding strategy for modifying high yielding varieties/hybrids and segregants. The correlation coefficient is the measure of the degree of symmetrical association between two variables or characters that helps to understand the nature and magnitude of the association between yield and yield components.

In the present investigation, phenotypic and genotypic correlation coefficients of thirteen traits both of F_1's (with parents) and F_2's generations (with parents) are presented in 'Table 2 and 3'. Grain yield per plant showed a very strong positive correlation with biological yield per plant (0.741), followed by number of pods per plant (0.679), harvest index (0.490), and number of seeds per pod (0.267) in F_1's while in F_2's; biological yield per plant (0.584), followed by number of pods per plant (0.451) and harvest index (0.270). It was negatively associated with days to 50% flowering (-0.380) and days to maturity (-0.277) in F_1's; while, days to 50% flowering (-0.285), days to maturity (-0.195), and chlorophyll content (-0.187) in F_2's. Therefore, these characters emerged as the most important associates of grain yield in faba bean under sodic soil.

The grain yield per plant was found to be positive and significant with number of seed per pods in F_2's. The highly significantly and negatively associated with days to 50% flowering, days to maturity in F_1's; while days to 50% flowering, days to maturity, and chlorophyll content in F_2's. Therefore, these characters emerged as the most important associates of grain yield in faba bean. The findings of the present study are in full agreement with those of Kumar *et al*. (2013) [9] who reported a highly significant and positive correlation of seed yield per plant with number of branches per plant, number of pods per plant, number of seeds per pod, biological yield per plant and harvest index. Verma *et al*. (2015) [16] also found a highly significant and positive correlation of seed yield per plant with harvest index and biological yield per plant. Singh *et al*. (2015) [15] reported similar results for plant height and days to maturity. Positive and significant correlation of grain yield with 100-seed weight and number of pods in the main branch, as reported by Yadav *et al*. (2016) [17] also supported the findings of the present study. Kumar *et al*. (2017) [8] reported positive significant correlation of all the traits with seed yield except plant height validates the results of the present study. Lal *et al*. (2019) [10] reported grain yield per plant showed a very strong positive correlation with biological yield per plant, followed by the number of pods per plant, harvest index, number of branches per plant, 100-seed weight, plant height, number of seeds per pod and pod length. The negative but non-significant correlation coefficient for days to maturity with grain yield per plant conforms to Salem (1982) [13] and Bora *et al*. (1998) [3].

The biological yield per plant showed highly significant and positive association with the number of pods per plant, number of seed per pods in F_1's, while in F_2's; number of pods per plant. The above characters had strong positive association with grain yield which augurs well for providing correlated response during selection for improving these characters. The above observations of strong positive associations between biological yield per plant and other yield components are in agreement with the available literature in faba bean reported by earlier workers Kumar *et al.* (2013) [9], Verma *et al.* (2015) [16], Singh *et al.* (2015) [15], Yadav *et al.* (2016) [17], Kumar *et al.* (2017) [8] and Lal *et al.* (2019) [10].

In the present study, the majority of significant estimates of correlations between yield and yield components were positive in nature. This represents a highly favourable situation for obtaining high response to selection in improving yield and yield components in faba bean. Thus, selection practiced for improving these traits individually or simultaneously would bring improvement in other yield contributing components due to correlated response. The higher estimates of genotypic correlation coefficients than the corresponding phenotypic correlations, indicating inherent associations among the traits confirm with those of Kalia and Sood (2004) [7] and Abhay *et al.* (2009) [1]. This suggested that selection would be quite efficient in improving yield and yield components in the context of hybrids and segregants.

Table 1: Analysis of variance for randomized block design for 13 characters in faba bean (*Vicia faba* L.) under sodic soil

S. N.	Characters	Sources of variation					
		Replications		Treatments		Error	
	d.f.	2		64		128	
		F_1's	F_2's	F_1's	F_2's	F_1's	F_2's
1.	Days to 50% flowering	1.98	0.76	58.63**	55.26**	0.93	0.69
2.	Days to maturity	0.00	9.18*	42.64**	35.76**	2.41	2.06
3.	Chlorophyll content	0.95**	1.30**	2.17**	2.10**	0.17	0.21
4.	Plant height (cm)	203.44**	220.27**	49.77**	67.02**	18.05	17.13
5.	Number of branches per plant	0.79**	0.25	0.73**	0.85**	0.12	0.11
6.	Number of pods per plant	6.46	10.47	31.17**	23.91**	3.85	4.15
7.	Pod length (cm)	0.69	0.64	1.07**	1.10**	0.44	0.37
8.	Number of seeds per pod	0.04	0.07	0.34**	0.33**	0.11	0.11
9.	Biological yield per plant (g)	44.44*	30.21	134.08**	109.60**	11.06	11.98
10.	Harvest index (%)	0.44	0.30	46.73**	42.33**	5.30	8.17
11.	100- seed weight (g)	0.17	0.19	12.90**	12.89**	0.43	0.41
12.	Protein content (%)	4.42*	1.85	10.18**	10.69**	1.12	1.14
13.	Grain yield per plant (g)	6.94*	5.21*	27.38**	10.61**	1.77	1.28

*, ** Significant at 5% and 1% probability levels, respectively.

Table 2: Estimates of phenotypic and genotypic correlation coefficients F_1's amongst 13 metric traits in faba bean (*Vicia faba* L.) under sodic soil

S.N.	Characters		Characters												Corr. coeff. with grain yield (g)
			1	2	3	4	5	6	7	8	9	10	11	12	
1	Days to 50% flowering	P	1.000	0.371**	0.078	-0.016	0.371**	-0.386**	-0.095	-0.225**	-0.352**	-0.089	0.159*	-0.116	-0.380**
		G	1.000	0.365	0.095	0.006	0.445	-0.492	-0.156	-0.363	-0.419	-0.111	0.181	-0.143	-0.441
2	Days to maturity	P		1.000	-0.157*	-0.016	0.082	-0.191**	0.009	-0.105	-0.184**	-0.171*	0.070	0.033	-0.277**
		G		1.000	-0.199	-0.056	0.075	-0.277	-0.017	-0.195	-0.230	-0.231	0.080	0.019	-0.346
3	Chlorophyll content	P			1.000	-0.066	-0.132	0.010	0.079	-0.152*	-0.110	0.049	-0.147*	0.056	-0.057
		G			1.000	-0.022	-0.106	0.053	0.060	-0.314	-0.128	0.101	-0.170	0.056	-0.038
4	Plant height (cm)	P				1.000	-0.023	0.033	0.037	0.083	0.017	-0.131	-0.160*	0.057	-0.068
		G				1.000	-0.229	0.044	0.314	0.144	-0.072	-0.194	-0.307	0.132	-0.182
5	Number of branches per plant	P					1.000	-0.125	-0.127	-0.148*	-0.119	-0.045	0.163*	0.040	-0.136
		G					1.000	-0.509	-0.338	-0.192	-0.431	0.036	0.242	-0.044	-0.362
6	Number of pods per plant	P						1.000	0.042	0.012	0.692**	0.098	-0.223**	0.116	0.679**
		G						1.000	0.034	0.172	0.735	0.199	-0.262	0.100	0.749
7	Pod length (cm)	P							1.000	0.055	0.135	-0.043	0.039	-0.032	0.085
		G							1.000	0.427	0.186	0.055	0.053	-0.153	0.184
8	Number of seeds per pod	P								1.000	0.216**	0.102	-0.135	-0.037	0.267**
		G								1.000	0.413	0.236	-0.207	-0.036	0.517
9	Biological yield per plant (g)	P									1.000	-0.216**	-0.041	0.042	0.741**
		G									1.000	-0.134	-0.008	0.009	0.770
10	Harvest index (%)	P										1.000	0.199**	0.078	0.490**
		G										1.000	0.222	0.141	0.525
11	100- seed weight (g)	P											1.000	0.025	0.085
		G											1.000	0.044	0.119
12	Protein content (%)	P												1.000	0.098
		G												1.000	0.106

*, ** Significant at 5% and 1% probability levels, respectively

Table 3: Estimates of phenotypic and genotypic correlation coefficients F_2's amongst 13 metric traits in faba bean (*Vicia faba* L.) under sodic soil

S. N.	Characters		1	2	3	4	5	6	7	8	9	10	11	12	Corr. coeff. with grain yield (g)
1	Days to 50% flowering	P	1.000	0.248**	0.107	0.095	0.362**	-0.309**	-0.026	-0.144*	-0.241**	0.005	0.218**	-0.109	-0.285**
		G	1.000	0.251	0.131	0.165	0.439	-0.412	-0.008	-0.258	-0.301	0.038	0.238	-0.128	-0.332
2	Days to maturity	P		1.000	-0.146*	-0.107	-0.021	-0.105	0.087	-0.088	-0.061	-0.130	0.035	0.075	-0.195**
		G		1.000	-0.164	-0.048	-0.034	-0.165	0.083	-0.174	-0.079	-0.173	0.063	0.060	-0.244
3	Chlorophyll content	P			1.000	-0.022	-0.071	0.020	0.064	-0.110	-0.178*	0.031	-0.159*	0.005	-0.187**
		G			1.000	0.039	-0.081	0.090	0.071	-0.349	-0.179	-0.015	-0.189	0.037	-0.246
4	Plant height (cm)	P				1.000	0.066	-0.048	0.039	0.146*	-0.082	-0.084	-0.156*	-0.043	-0.174*
		G				1.000	0.144	-0.179	0.332	0.292	-0.178	-0.145	-0.277	-0.082	-0.351
5	Number of branches per plant	P					1.000	-0.110	-0.086	-0.038	-0.124	0.082	0.146*	0.015	-0.058
		G					1.000	-0.419	-0.151	-0.110	-0.393	0.277	0.203	-0.062	-0.231
6	Number of pods per plant	P						1.000	-0.103	-0.168*	0.542**	-0.180*	-0.290**	0.144*	0.451**
		G						1.000	-0.141	-0.175	0.554	-0.093	-0.382	0.160	0.560
7	Pod length (cm)	P							1.000	0.081	0.047	-0.018	0.022	-0.083	0.026
		G							1.000	0.381	0.131	-0.105	0.045	-0.220	0.055
8	Number of seeds per pod	P								1.000	0.096	0.043	-0.232**	-0.063	0.168*
		G								1.000	0.278	-0.041	-0.387	-0.106	0.314
9	Biological yield per plant (g)	P									1.000	-0.615**	-0.059	0.008	0.584**
		G									1.000	-0.596	-0.040	-0.051	0.657
10	Harvest index (%)	P										1.000	0.158*	0.063	0.270**
		G										1.000	0.180	0.156	0.209
11	100- seed weight (g)	P											1.000	0.015	0.087
		G											1.000	0.041	0.118
12	Protein content (%)	P												1.000	0.090
		G												1.000	0.093

*, ** Significant at 5% and 1% probability levels, respectively

Conclusion

Based on the results achieved in this study, it is concluded that yield components are interrelated with each other and they affect grain yield per plant directly or indirectly, positively or negatively, through each other. The grain yield per plant was found positively and significantly associated with biological yield per plant followed by number of pods per plant, harvest index, and number of seeds per pod in F_1's while in F_2's; biological yield per plant followed by number of pods per plant and harvest index. Hence, during the selection of elite genotypes in faba been the above significant traits should be emphasized to upgrade the economic status of poor formers of salt-affected soil.

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