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PERFORMANCE AND STABILITY OF FABA BEAN (*VICIA FABA*) ADVANCED LINE FOR SEED YIELD AND QUALITY TRAITS IN DIFFERENT ENVIRONMENTS ACROSS INDIA

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ABSTRACT

The creation of high-yielding and stable cultivars of diverse legume crops in various conditions is crucial for their acceptance by farmers. Moreover, climate change presents novel problems to primary crop species, particularly grain legumes like faba bean (*Vicia faba* L.), regarding their adaptability to adverse settings. In order to stabilize productivity throughout seasons and geographical areas, this study was carried out in 2019–22 on 10 genotypes of faba beans (*Vicia faba*) in 5 locations. The seed production of each genotype varied considerably depending on the climate. According to stability analysis, the Location (linear) and Advance line × Location (linear interaction) were also significant. Because of its greater seed output (18.10 q/ha), protein content (26.75% respectively), and improved stability (b_i = 1.25, Sdi^2 = 0.58), the genotype HB-15-51 can be grown successfully in plains. However, "HB-15-21," which produced more seeds (18.10 q/ha) and was more stable (b_i = 1.10, Sdi^2 = 0.78), could be utilised in future breeding initiatives to improve faba beans.

***Key words*:** Faba bean, variety, stability, stability parameters

Introduction

After dry beans, dry peas, and chickpeas, faba beans are the most significant pulse crop in the world. Faba bean serves as a valuable source of protein (20-30%) for both human and animal consumption (Qahtan *et al*., 2021). The major faba bean growing countries are China, Egypt, United Kingdom and Syria. About 70% of total global production is contributed by China alone. It is also an important crop in North Europe, the Meditetrranean Basin and Latin America. In India, its cultivation is confined as a underutilized pulses in Himalayan hills, Bihar, Eastern Uttar Pradesh and around cities and towns where faba bean pods fetch a good premium (Singh *et al*., 2013). Faba bean thrives well under irrigated conditions and can withstand high water table and soil salinity which have posed severe threat to successful cultivation of chickpea (Lockerman *et al*., 1983) Faba bean is a temperate crop and requires cool climate and a long season. Even in United States the summers are often too hot and the winters too cold for its cultivation. It can be grown towards the edge of tropics as a winter crop, as is done in the Northern Sudan and Myanmar (Burma) or at high altitude as in Latin America. In India, it is cultivated throughout the Gangetic plains in the winter season. Its nitrogen fixation ability is also very high as it can fix up to 500 kg N/ha, as reported from the International Centre for Agricultural Research in the Dry Areas (ICARDA), Syria. Through biological nitrogen fixation, it can

contribute to the long-term sustainability or augmentation of total soil nitrogen fertility (Lindemann *et al*., 2003). In Europe, faba bean is extensively cultivated for both immature and full grown pods as human food. It is cultivated mostly for cattle feeding in the United States of America. In Canada, it is used with corn to make silage called "Robertson Mixture". It is considered an important food crop in Latin America. However, its cultivation has not so far gained popularity as a pulse crop. Pods are primarily utilized as vegetables, whether they are fresh or canned, green or dry. You eat roasted seeds like peanuts. Another way to use beans is in soup. Similar to soybeans, the seeds can be processed to create a variety of high-protein goods. The major limiting factor in faba bean production is the unreliability of seed yields on account of its pollination system and effect of biotic and abiotic stresses. Faba bean is severely affected by leaf blight, charcoal rot and several other diseases (Dua *et al*., 2009). Therefore, there is a need to develop stable varieties resistant to diseases / pests and abiotic factors. At maturity, the pod shattering causes a great loss in seed yields. Therefore, there is need to develop varieties with uniform maturity and resistant to shattering. The seeds contain a number of anti-nutritional factors like tannins, saponins, glucosides, vicine, convicine and trypsin inhibitors which render them unacceptable for safe consumption. Therefore, there is a need to evaluate the germplasm to develop superior varieties with low level of antinutritional factors or means and ways to detoxify these factors before consumption should be established.

The faba bean is regarded as a crop species suited to diverse climatic conditions and soil types. Nevertheless, its output is inconsistent, as it is significantly influenced by environmental variations. Consequently, it is essential to utilize stable genotypes that are well-suited to diverse environmental conditions. In conjunction with effective management practices, this will enhance productivity and expand acreage. This necessitates the assessment of genetic adaptation and stability across several contexts, which entails multi-environment trials (METs). The examination of cultivars and genotypes in METs enables breeders and agronomists to identify and comprehend genotype x environment interaction (GEI) for optimal genotypes and their ranking across various environments (Temesgen *et al.,* 2015 & Sharifi *et al.,* 2017). Moreover, climate change can influence the reaction of genotypes across various contexts (Gurmu *et al.*, 2012). Consequently, it is essential to perform experiments in METs to facilitate the understanding and analysis of GEI, so enabling the identification and recommendation of stable, extensively adapted genotypes for production in the target settings.

Recently, certain farmers in Chhattisgarh, Bihar, Jharkhand, Odisha, Punjab, Haryana, Delhi and UP have expressed interest in cultivating this crop due to its nutrient composition and climate adaptability. Due to the minimal research conducted on this crop in our nation. At the global level, information on genetic improvement, adaptability and genotype-environment interactions of Vicia faba is restricted to few publications (Raiger *et al*., 2023). The objective of this study was to understand the magnitude of genetic variation, genotype-environment interaction and its adaptability in Faba bean to identify the best genotype to utilize for future genetic improvement work.

To boost and stabilise output and productivity, it is essential to choose suitable cultivars with high yield potential. Understanding how different varieties respond to changing environmental conditions is made easier with the use of stability analysis. In order to stabilise productivity throughout seasons and geographical areas, it is crucial to employ highly adaptable cultivars.

Materials and Methods

The research was carried out at five distinct sites between 2019 and 2022: IGKV in Ambikapur; ANDAUT in Ayodhya; CCS HAU in Hisar; PAU in Ludhiana; and BAU in Ranchi. Four replications were used in a complete randomized bock design. Five competing plants were observed in terms of seed output (q/ha), 100 seed weight (g), days to 80% maturity, pod length (cm), plant height (cm), and days to 50% flowering. According to the model put forth by Eberhart and Russell (1966), the data were examined for stability characteristics, specifically mean ($\bar{X}$), regression coefficient (b_i), and deviation from regression (S^2d_i).

During rabi 2018-19, 50 accessions of Faba bean of diverse origin were grown in Augmented Block Design with ten blocks. Each block contained five entries and three checks. The experiment was repeated at 3 locations, namely, Hisar, Ludhiana and Ayodhya. The seed yield was recorded on plot basis. The best performing accessions, based on average seed yield over locations 10 genotypes (7 breeding line and 3 release varieties) (Table 1) were grown during Rabi 2019-22. The experiment was laid out in a Randomized Block Design with four replications at 5 test locations (Table 2) of AICRN on Potential Crops, namely, IGKV, Ambikapur; ANDAUT, Ayodhya; CCS HAU, Hisar; PAU, Ludhiana; BAU, Ranchi. The experimental layout consisted of three four-meter rows. In every setting, the intervals between rows and plants were maintained at 30 cm and 10 cm,

Table 1: Analysis of variance for stability of seed yield during 2019-22.

Source of Variation	DF	Days to 50% Flowering	Pod length (cm)	100 seed weight (g)	Days to 80% maturity	Seed yield (q/ha)	Plant Height (cm)	Protein (%)	Vicine convicine (%)	Phenol (%)
Variety	9.00	5.188	0.18	2.50	2.08	2.969	43.843	2.15*	0.01439**	0.00168**
Environment	4.00	379.66**	3.848**	37.77**	652.439**	306.454**	1646.734**	2.32*	0.05346**	0.00247**
Var. × Env.	36.00	7.553**	0.22	1.96**	2.177*	4.035*	32.147**	0.78**	0.00243**	0.00034**
Env. + Var. × Env.	40.00	44.763	0.59	5.54	67.20	34.277	193.606	0.93	0.00753	0.00055
Env (Linear)	1.00	1518.642**	15.393**	151.078**	2609.757**	1225.814**	6586.934**	9.30**	0.21382**	0.00989**
Env. × Var. (Lin)	9.00	13.092*	0.15	3.10	0.46	8.708**	62.37*	0.51	0.00749**	0.00079
Pooled Deviation	30.00	5.135**	0.224**	1.424**	2.474**	2.23**	19.866**	0.78	0.00066	0.00017
Pooled Error	135.00	7.11	0.28	0.58	1.34	2.391	31.446	0.42	0.00125	0.00008
Avg. Error		1.78	7.09	0.14	0.33	0.59	7.86	2.15	**0.00031**	**0.00002**
** P < 0.01 and * P < 0.05										

respectively. For every genotype at every test site, the seed yield was calculated on a plot basis and translated to q/ha. At harvest, the amount of seed produced by each genotype at each site was measured. Five environments' worth of yield data were taken into consideration for the stability analysis.

Results and Discussion

For all four of the traits under study, environment-wise analysis showed that there are notable differences in the genotypes under each environment (Table 1). Significant variations between the habitats were indicated by the significant mean square attributable to environment (season, year, and location). The regression of the environments on performance for different characteristics explained the majority of the overall variance for all traits, as evidenced by the high magnitude of mean square owing to environment (linear) compared with the genotype-environment interaction (linear) (Rai *et al.*, 1989). Significant mean square resulting from pooled deviation indicated that the variation from linear regression also played a significant role in the variations in genotype stability. Considerable environment interaction in faba beans was found in Senegal and Cape Verde, and the considerable G×E interaction showed that genotypes in different environments reacted differently for the expression of the features under study (Heller, 1996). It implies that different varieties may react differently to a given environment or that a given variety may not have the same phenotypic performance under various conditions.

Stability parameters

According to Eberhart and Russell (1966), a genotype is considered stable if its mean performance is high, its regression coefficient is near unity (bi=1), and its deviation from the regression slope is as small as feasible. For different features, the stability parameters showed the following trend (Table 2 & 3).

Seed yield: Seed yield is an important attribute in Faba bean which is a deciding factor for obtaining the high economic returns. The genotypes 'HB-15-51' (bi=1.88, S^2di=1.59) with highly significant regression coefficient and deviation from regression were not stable for seed yield. The higher yielding genotypes such as 'HB-15-04' (bi=1.21, S^2di=0.12); 'HB-15-14; (bi=1.23, S^2di=0.56); 'HB-15-55' (bi=1.25, S^2di=-0.58) had higher regression coefficients and less deviation from regression were stable for favourable environments. However, genotypes such as 'HB-15-21' (bi=1.10, S^2di= 0.78) and 'HB-15-41' (bi=1.10, S^2di= 0.34) had better seed yield (1.70 tonnes/ha) and had non-significant regression with non-significant deviation from regression. Thus, the genotypes were categorized as stable genotypes.

Plant height: Data on plant height revealed that genotypes were observed to be stable. The genotype 'HB-15-34' (bi=1.45, S^2di=28.041) and 'HB-15-55' (bi=1.45, S^2di=23.83) had the highest significant deviation from regression. The genotype, 'HB-15-14' (bi=1.80, S^2di=0.27) had higher regression coefficient and less deviation from regression were stable for favourable environments. The genotypes, 'HFB-1' (bi=0.82, S^2di=-

Table 2: Mean performance and stability parameters for different agronomy traits in *Vicia faba* during 2019-22.

Geno-types	Days to 50 % Flowering			Pod length (cm)			100 seed weight (g)			Days to 80 % maturity			Seed yield (q/ha)			Plant Height (cm)		
	Mean	bi	sd_i^2	Mean	bi	sd_i^2	Mean	b_i	sd_i^2	Mean	b_i	sd_i^2	Mean	b_i	sd_i^2	Mean	b_i	sd_i^2
HB-15-04	69.15	0.91	2.13	4.68	1.35	0.37	28.33	0.63	0.407**	135.07	1.05	2.029**	18.06	1.21	0.12	84.073	0.84	10.459
HB-15-14	69.43	1.31	4.61**	4.90	1.25	0.66	28.37	1.31	1.391**	135.43	1.04	0.39	17.68	1.23	0.56	87.258	1.18	0.217
HB-15-21	67.92	1.24	0.13	4.66	0.62	-0.01	27.61	1.71	1.135**	134.77	1.01	3.612**	17.28	1.10	0.78	78.775	0.75	22.928*
HB-15-34	71.07	0.72	1.32	4.91	1.13	-0.06	26.73	1.30	0.09	136.55	1.00	5.661**	17.93	1.05	2.817**	84.206	1.45	28.041**
HB-15-41	68.80	1.28	-0.03	4.70	0.76	0.21	27.90	0.62	1.152**	135.80	1.05	1.786**	18.10	1.10	0.34	86.297	0.68	-0.405
HB-15-51	70.25	1.21	0.14	4.59	0.80	0.40	28.05	0.45	0.595**	134.82	1.01	1.199**	17.00	1.18	1.59*	85.831	1.29	-3.447
HB-15-55	69.98	1.07	2.94	5.25	1.42	-0.02	28.15	1.32	0.624**	134.73	0.94	2.89**	18.10	1.25	0.58	87.583	1.45	23.838**
HFB-1	68.13	1.10	6.346**	4.87	0.57	-0.02	27.38	0.70	0.769**	134.82	0.98	0.831**	17.47	0.62	1.326*	84.746	0.82	-5.042
HFB-2	70.38	0.42	13.305**	4.82	0.89	0.02	29.23	1.40	3.354**	134.35	1.00	1.471**	16.74	0.69	1.646*	90.113	0.80	50.14**
Vikrant	70.07	0.76	2.69	4.75	1.23	-0.02	27.16	0.54	3.271**	135.47	0.93	1.538**	15.68	0.57	6.563**	85.508	0.73	-6.685

** P < 0.01 and * P < 0.05

5.0442); 'HB-15-04' (bi=0.84, S^2di=10.459) had had non-significant regression with non-significant deviation from regression. For plant height, these genotypes were therefore classified as stable.

Pod length: For pod length all the genotypes, Vikrant (bi=1.23, S^2di=-0.02); HB-15-14 (bi=1.25, S^2di=0.66); HB-15-04 (bi=1.35, S^2di=0.37) and HB-15-55 (bi=1.42, S^2di=-0.02) had higher regression coefficient and less deviation from regression were stable for favourable environments. While HB-15-51 (bi=0.80, S^2di=0.40); HFB-2 (bi=0.89, S^2di=0.02) and HB-15-34 (bi=1.13, S^2di=-0.06) had non-significant regression with non-significant deviation from regression to stable genotype for pod length.

100-seed weight: Genotypes for 100 seed weight such as 'HB-15-34' (bi=1.30, S^2di= 0.09) had higher regression coefficient and less deviation from regression were stable for favourable environments.

Flowering: The genotype for early flowering and stable, HB-15-14 (bi=1.31, S^2di= 4.61); HFB-1 (bi=1.10, S^2di= 6.346) and HFB-2 (bi=0.42, S^2di= 34.305) had highly significant regression coefficient and deviation from regression. The genotypes, HB-15-51 (bi=1.21, S^2di= 0.14); HB-15-21 (bi=1.24, S^2di= 0.13) and HB-15-41 (bi=1.28, S^2di= 0.03) had higher regression coefficient and less deviation from regression were stable for favourable environments. The stable genotypes, HB-15-04 (bi=0.91, S^2di= 2.13) and HB-15-55 (bi=1.07, S^2di= 2.94) had non-significant regression with non-significant deviation from regression.

Maturity: The genotype for early maturity and stable, HB-15-14 (bi=1.04, S^2di= 0.39) had a non-significant regression with non-significant deviation from regression with maturity days 135 days.

Protein (%): Protein is an important trait in Faba bean which is a deciding factor for quality pulse. The genotypes HB-15-55 (bi=2.01, S^2di=0.08), HB-15-34 (bi=1.69, S^2di=1.64**) with highly significant regression coefficient and deviation from regression were not stable for protein content. The higher yielding genotypes such as HB-15-21 (bi=1.27, S^2di=0.04) had higher regression coefficient and less deviation from regression were stable for favourable environments. However, genotypes such as 'HFB-1' (bi=1.23, S^2di= 0.05) had better protein content (26.33%) and had non-significant regression with non-significant deviation from regression. Thus, the genotypes were categorized as stable for protein content.

Vicine-convicine (%): Low Vicine-convicine content is more desirable trait for stable genotype. The genotype HB-15-34 (bi=1.23, S2di= 0.00146**) had highly

Table 3: Mean performance and stability parameters for different quality traits in *Vicia faba* during 2019-22.

Geno-types	Protein (%)			Vicine-convicine			Phenol			ALBS	RRDI
	Mean	bi	sd_i^2	Mean	bi	sd_i^2	Mean	b_i	sd_i^2		
HB-15-04	26.29	1.01	0.73**	0.84	0.28	0.00015	0.15	0.62	0.00005*	5.33	21.40
HB-15-14	25.50	0.60	1.31**	0.80	1.45	0.00063	0.13	1.12	0.00001	4.33	23.90
HB-15-21	25.67	1.27	0.04	0.86	0.39	0.00055	0.13	0.93	0.00002	6.00	23.40
HB-15-34	25.07	1.69	**1.64****	0.87	1.23	**0.00146****	0.14	2.07	**0.00001**	4.67	24.80
HB-15-41	25.05	0.45	1.61**	0.98	1.91	0.00072	0.14	2.28	0.00012	4.67	25.00
HB-15-51	26.74	0.82	0.57**	0.92	1.57	0.00005	0.12	1.41	0.00002	6.00	21.60
HB-15-55	25.64	2.01	0.08	0.87	0.10	0.00003	0.12	1.69	0.00002	4.33	24.00
HFB-1	26.33	1.23	0.05	0.83	1.16	0.00085*	0.15	0.21	0.00009**	4.67	15.00
HFB-2	24.86	-0.59	1.76**	0.84	1.01	0.00010	0.18	-0.54	0.00097**	6.33	13.30
Vikrant	**26.41**	1.51	**0.03**	**0.92**	0.90	**0.00209****	**0.16**	0.21	**0.00034****	5.67	23.00
ALBS: Alternaria Leaf Blight Score (1-9); RRDI: Root rot disease incidence (%)											

significant regression coefficient and deviation from regression were not stable for Vicine-convicine content. The less vicine content such as HB-15-14 (bi=1.45, S2di= 0.0006); HB-15-51 (bi=1.57, S2di= 0.00005) and HB-15-41 (bi=1.91, S2di= 0.00072) had higher regression coefficient and less deviation from regression were stable for favourable environments. However, genotypes such as HFB-2 (bi=1.01, S2di= 0.0001) had had non-significant regression with non-significant deviation from regression.

Phenol (%): Low phenol content is more desirable trait for stable genotype. The genotypes HFB-2 (bi=-0.54, S2di= 0.00097**); HFB-1 (bi=0.21, S2di= 0.00009**); Vikrant (bi=0.21, S2di= 0.00034**) and HB-15-04 (bi=0.62, S2di= 0.00005*) had highly significant regression coefficient and deviation from regression were not stable for phenol content. The less phenol content such as HB-15-51 (bi=1.41, S2di= 0.00002); HB-15-55 (bi=1.69, S2di= 0.00002); HB-15-34 (bi=2.07, S2di= 0.00001); and HB-15-41 (bi=2.28, S2di= 0.00012); had higher regression coefficient and less deviation from regression were stable for favourable environments. However, genotypes such as HB-15-21(bi=0.93, S2di= 0.00002) and HB-15-14 (bi=1.12, S2di= 0.00001) had non-significant regression with non-significant deviation from regression.

Performance

In the trial, seven advanced lines and three released varieties were assessed across five locations (Ambikapur, Faizabad, Hisar, Ludhiana, Ranchi) in five faba bean-producing states for seed yield and other agronomic characteristics (Fig. 1). The quality analysis of seed samples provided by Hisar and Ranchi was conducted at CCSHAU, Hisar. Screening for Alternaria blight disease was conducted at the Ludhiana and Hisar centres under natural field settings, and root rot incidence was assessed at CCSHAU, Hisar (Raiger *et al*., 2022).

Seed yield: Variations in seed output were noted both across different locations and among various years/ seasons at the same location. The average yield for a genotype was higher at Hisar (23.98 q/ha) and Faizabad (21.28 q/ha) in 2021-22, indicating that these regions were particularly conducive to Faba bean cultivation. According to averages across locations and years, the genotypes 'HB-15-41' and 'HB-15-55' (18.10 q/ha) were the highest yielders, followed closely by 'HB-15-04' (18.06 q/ha).

Table 4: Correlation between yield and quality traits.

Traits	Days to 50% Flowering	Pod length (cm)	Plant Height (cm)	Days to 80% maturity	100 seed weight (g)	Seed yield (q/ha)	Protein (%)	Vicine-convicine	Phenol
Days to 50% Flowering	1								
Pod length (cm)	-0.043	1							
Plant Height (cm)	0.207	0.062	1						
Days to 80% maturity	-0.076	-0.091	-0.215	1					
100 seed weight (g)	0.423**	-0.034	0.532**	-0.135	1				
Seed yield (q/ha)	0.109	0.015	0.588**	-0.025	0.463**	1			
Protein (%)	-0.189	-0.317	-0.274	-0.274	-0.219	-0.337	1		
Vicine-convicine	0.099	-0.331	-0.01	0.305	-0.269	-0.137	0.035	1	
Phenol	0.122	-0.169	0.331	-0.132	0.233	-0.471	-0.232	-0.129	1
** P < 0.01 and * P < 0.05									

Table 5: Range, Mean, Standard Error (SE), Critical Difference (CD), Coefficient of Variation (CV), Heritability in broad sense (H2) and Genetic Advance (GA) of 13 quantitative characters of grain amaranth.

S. No.	Genetic parameters	Days to 50% Flowering	Pod length (cm)	Plant Height (cm)	Days to 80% maturity	100 seed weight (g)	Seed yield (q/ha)
1	**Range**	57.00-71.50	3.50-4.45	61.85-91.95	146.00-148.50	26.29-31.47	11.91-16.08
2	**Mean**	62.05	3.90	75.14	146.93	27.63	13.55
3	**Standard Error (d)**	3.35	0.41	5.80	0.83	1.04	0.92
4	**Heritability (%)**	42.43	0.48	39.86	7.39	44.29	34.12
5	**Genotypic CV (%)**	6.55	1.04	8.88	0.23	4.76	6.90
6	**Phenotypic CV (%)**	10.05	15.03	14.07	0.83	7.15	11.82
7	**Genetic Advance**	5.45	0.01	8.68	0.19	1.80	1.13
8	**Genetic Advance (%) of means**	8.78	0.15	11.55	0.13	6.53	8.31

Plant height: The average plant height for a genotype was greatest at Hisar (105.68 cm), moderate at Faizabad and Ambikapur, and least at Ludhiana (73.63 cm). The genotype HFB-2 had the greatest plant height, measuring 90.11 cm, based on the average across location and season.

100-seed weight: It was the highest at Hiar (30.94 g) and very low at Ludhiana (28.13 g). Based on average over location/season, the genotype HFB-2 had the boldest seed (29.22 g).

Flowering: Flowering time ranged from 62.05 days at Ambikapur to 77.27 days at Hisar centre. Based on the average over the locations HB-15-21 (67.92 days) was the earliest flowering line.

Maturity*:* Maturity period varied among the locations with mean maturity period ranging from 125.97 days at Ludhiana to 146.97 days at Ambikapur centre. On the basis of overall mean, HFB-2 (134.35 days) had the earliest maturity.

Pod length (cm): Pod length was the longest at Faizabad (5.43 cm) followed by at Hisar (5.34 cm) centre. Based on the average over the locations the entry, HB-15-55 (5.25 cm) showed the highest pod length.

Protein content (%): The 10 genotypes were analyzed for protein content on the basis of seed weight. The best genotype for protein content was HB-15-51 having 26.76% followed by HFB-1 (26.33%).

Vicine-convicine (%): The 10 genotypes were analyzed for vicine content on the basis of seed weight. The best genotype for vicine content was HB-15-14, having a low 0.80% followed by HFB-1 (0.83%).

Phenol (%): The 10 genotypes were analyzed for phenol content on the basis of seed weight. The best genotype for phenol content was HB-15-51 & HB-15-55 having low 0.12%.

Disease reaction: Two entries, HB-15-14 and HB-15-55 (4.33), were found to be moderately resistant to Alternaria blight at Ludhiana centre. Based on disease severity (< 15%), the check HFB-2 was found to be resistant to alternaria blight at Hisar centre, and two checks, HFB-1 and HFB-2, were found to be moderately resistant to alternaria blight and Root rot incidence at Hisar centre.

Character association

The seed yield (q/ha) was found to have a positive correlation relationship with days to flowering (0.109), pod length (0.015) and plant height (0.588**) and 100-seed weight (-0.025) (Table 4) and negative correlation with days to 80% maturity (-0.025) and with quality traits protein (-0.337), vicine convicine (-0.137) and phenol (-0.471). Similar type of relationships was reported by Salih *et al.*, (2020). Such relationship can be explored in selecting the genotypes to have an early indication about protein yield and yield performance. It is interesting to note that none of the traits showed positive correlation with each other. Thus, these characters may not be used to the advantage of the breeder for easily bringing simultaneous improvement of the trend. The inter correlation found among the 100-seed weight and quality trait is consistent with earlier studies (Ginwal *et al*., 2004).

Genetic parameters

The values of the investigated attributes' environmental, phenotypic, and genotypic variations as influenced by various environment (Table 5). It was clear that the phenotypic variation of the traits under study, rather than the environmental variation, was the cause of the greater genetic variation values. In addition to demonstrating the importance of genotype genetic makeup in expressing phenotypes, the aforementioned presentation gives plant breeders a chance to make informed selection decisions. Consequently, the genotypic variations for the most desirable traits may be used as a selection criterion (Kalia and Sood, 2004).

The findings showed that environmental factors had a significant impact on the traits of plant height (8.88%) and seed yield (6.90%), resulting in high levels of genetic variation. Days to maturity, pod length, and 100 seed weight characteristic had the lowest genetic variation values (0.23, 1.04, and 4.76, respectively). To improve the genotypes, it is crucial to consider the type of genetic variability and the proportion of inheritance of the desired features (Abbadi and Al-Kamar, 2010; Shakarji, 2010). Regarding phenotypic variation, the differences between genotype plants grown in various environments showed that both genotypic and phenotypic changes were more indicative of heritability (in the broadest sense). In contrast to days to 50% blooming, when heritability dramatically dropped, heritability was highest in 100 seed weight (44.29). The findings also showed that genetic variation played a greater effect than phenotypic variance.

The study that was presented additionally showed that different yield-contributing features had inheritance ratios with variable rates. These can strengthen genetic resources and aid in the genetic enhancement of quantitative traits. Additionally, with intensive selection, the inheritance ratios can help improve these features (Mather and Jinks, 1982). According to Robinson *et al*. (1966), the projected genetic progress values were lowest for days to maturity (0.13) and pod length (0.12) and highest for plant height (11.55).

Conclusion

This study revealed significant variability in seed production and quality traits among the five evaluation sites in India. The majority of attributes were predominantly influenced by environmental factors. Nonetheless, high-yielding and stable faba bean genotypes for yield and quality attributes were identified through multi-environmental trials conducted in the Gangetic plains throughout the winter season.

On the basis of above finding's it can be concluded that the genotype HB-15-41 and HB-15-51 can be successfully cultivated in plains on account of its higher seed yield, protein content and better stability for favorable environment. However, HB-15-21 which had higher seed yield with better stability across the environments for seed yield, could be used in further breeding programmes for improvement of Faba bean.

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