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SHORT RESEARCH ARTICLE

Long-term evaluation of new elite genotypes of Faba bean (*Vicia faba* L.) by Superiority Index and AMMI analysis

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Abstract

Highly significant effects of genotypes yield had been observed during field evaluation. A total variation of 51% accounted by the environments, 32.9% by genotype x environment interaction, and only 10.7% due to the genotypes in AMMI analysis. Adaptability measure harmonic means of relative performance of genotypes ranked HB13-48, HB13-10 and HB13-11 as per their performance. The relative performances of genetic values were settled for HB13-48, HB13-10, HB13-26 genotypes. ASV1 and ASV measures pointed HB13-26, HB13-15 and HB13-40 as of stable performance. Biplot analysis observed the strong bondage of arithmetic, geometric and harmonic means along with relative performance of genetic values and measure of the relative performance of the genotypic values. The information accrued from the study may be useful in cultivating stable genotype(s).

Keywords: ASV, GAI, HMPRVG, MASV, PRVG, SI

Faba bean (*Vicia faba* L.) is considered as one of the potential legume crop for *rabi* season in India. This multipurpose crop is being grown for forage, vegetable, pulse, green manure and as a cover crop along with seeds as an excellent source of lysine, protein, vitamins, minerals and carbohydrates (Raiger et al. 2021). The substitution of soybean meal in cow diets by a mixture of 1/3 of rapeseed and 2/3 of faba bean (with 3.7 kg/cow/day) do not alter the milk production or the milk composition (Kumar et al. 2019). Like other legumes, the beneficial effect of pelleting being explained by a better starch and protein digestibility (Arya et al. 2020). The genotype responses are multivariate, as AMMI techniques are preferable to explaining G × E interactions than linear regression models (Ajay et al. 2019). The present study was carried out to point out stable faba bean genotypes possessing high yield.

Twenty promising faba bean genotypes were evaluated over the period of six years at Research Farm of MAP Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar under field conditions from *rabi* 2013-14 to *rabi* 2018-19. Field trials were conducted in randomized complete block designs with three replications. Row to row spacing was kept 30 cm and plant to plant spacing was 10 cm. Recommended agronomic practices were followed to harvest good yield. The data were recorded on plant height (cm), number of branches/plant, number of pods/plant, days to maturity and seed yield (kg/ha). Number of well-established measures as per AMMI analysis, relative performance of genetic values (PRVG), harmonic mean based measure of the relative performance of the genotypic values (MHPRVG) were compared with superiority indexes (Verma et al. 2021). The measure superiority index allowed variable weights to yield and stability measure as per breeding objectives (Olivoto et al. 2019). Relative weights of 65 and 35 have been considered in the present study. AMMISOFT and SAS software had utilized for analysis.

AMMI stability analysis

Highly significant effects of yield and contributing traits had been expressed by genotypes over the years as well as in combined analysis (Table 1). AMMI analysis revealed

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highly significant variation due to environments (51%), GxE interactions (32.9%), and genotypes (10.7%) (Table 2).

Mean yield of genotypes selected HB13-48, HB13 -10, HB13-46 (Table 3). Values of standard deviation and CV identified HB13-2, HB13-16, HB13-18. Geometric mean observed higher values of HB13-48, HB13-10 and HB13-11 genotypes as also reported by Mohammadi and Amri (2008) in durum wheat. The harmonic mean of genetic values (HMGV) depicted as maximum values by HB13-48, HB13 -10, HB13-11 genotypes. Harmonic Mean of Relative Performance of Genotypic Values (HMRPGV) ranked HB13-48, HB13 -10, HB13-11 genotypes. Relative Performance of Genotypic Values (RPGV) had settled for HB13-48, HB13 -10, HB13-26 genotypes. Variable weights to yield value and stability in the Superiority index (SI) pointed out same set of genotypes even for considering three types of yield averages i.e. HB13-48, HB13-38, HB13-26 as also mentioned by Verma et al. (2021). Values of IPCA's in the AMMI analysis indicate stability or adaptability of genotypes. Absolute IPCA-1 scores pointed for HB13 -10, HB13-49, HB13-48 (Table 3). While for IPCA-2, the genotypes, HB13-46, HB13 -10 and HB13-2 would be a choice. Values of IPCA-3 favoured HB13-40, HB13-20 and Vikrant genotypes. As per IPCA-4, HB13-20, HB13-45, HB13-11 genotypes would be of stable performance. Environment plays a very significant role in determining the stability of the genotypes. Lal et al. (2021) carried out AMMI and GGE biplot analysis and identified significant environmental effect followed by genotype, and GE interactions for all nodule related traits, except for fresh nodule weight in peanut at 60 and 80 days after sowing. They reported

Table 1. ANOVA and combined analysis of traits

Traits	Factor (MSS)	Year 1	Year II	Year III	Year IV	Year V	Year VI	Combined	Year	Interaction
	Genotype	291.69	77.51	24.64	79.21	24.60	82.98	143.06	2627.64	87.52
Yield	Err	6.87	2.38	4.94	4.31	4.49	0.93	4.00		
	CD 5%	4.33	2.55	3.67	3.43	3.50	1.59	1.31		
	Genotype	348.22	372.65	442.85	661.79	21.27	14.59	754.63	6190.17	221.35
Maturity	Err	0.48	0.44	0.45	0.86	0.90	0.43	0.59		
	CD 5%	1.14	1.09	1.11	1.53	1.57	1.09	0.50		
	Genotype	660.00	1352.13	1735.60	1721.50	114.80	198.91	2284.85	3662.22	699.62
Plant height	Err	78.77	21.82	64.02	25.29	40.41	14.63	41.54		
	CD 5%	14.67	7.72	13.23	8.31	10.51	6.32	4.23		
	Genotype	2.33	2.50	4.79	4.89	0.67	1.39	6.12	67.00	2.09
Pods	Err	0.26	0.40	0.25	0.25	0.11	0.22	0.25		
	CD 5%	0.84	1.04	0.82	0.83	0.55	0.77	0.33		
	Genotype	614.78	418.84	1027.62	2390.00	120.65	353.92	1826.11	7644.78	619.94
Branches	Err	67.98	11.60	18.06	8.11	8.15	4.12	21.98		
	CD 5%	13.63	5.63	7.02	4.71	4.72	3.36	3.08		

Table 2. AMMI analysis of Faba bean genotypes

Source	Degree of freedom	Mean Sum of Squares	Level of significance	% of Total SS	% of GxE SS	Cumulative % SS by PCA's
Treatments	119	203.1121	***	95.83		
Genotypes	19	143.0581	***	10.78		
Environments	5	2627.643	***	52.09		
GxE interactions	95	87.51604	***	32.96		
IPC1	23	197.663	***		54.68	54.68
IPC2	21	101.8919	***		25.74	80.42
IPC3	19	39.8254	***		9.10	89.52
IPC4	17	41.84993	***		8.56	98.08
Residual	15	10.66081				
Error	240	4.37969				
Blocks/Env	12	11.88222				
Pure Error	228	3.98482				
Total	359	70.25479				

Table 3. AMMI stability measures as per significant IPCA's

	ASV	ASV1	ASTAB	W1	W2	W3	WAAS	MASV	MASV1	Mean	Sdev	CV	SImean	Har Mean	SI HM	Geo Mean	SIGM	PRVG	HMPRVG
HB13-2	1.64	1.66	7.79	0.1645	0.6306	0.6205	0.6415	3.38	5.01	34.50	3.57	10.36	54.80	34.35	61.03	34.20	68.36	0.9934	0.9811
HB13-6	1.25	1.79	2.40	0.8310	0.6639	0.6770	0.6488	1.80	2.33	34.76	7.85	22.59	56.21	33.90	58.25	32.91	60.49	0.9781	0.9700
HB13-9	0.95	1.30	1.90	0.5711	0.5366	0.5582	0.5442	1.68	2.18	33.62	5.98	17.78	51.25	33.15	55.59	32.67	60.79	0.9550	0.9505
HB13 -10	4.99	7.03	30.85	3.1968	2.7483	2.4828	2.2960	5.85	8.68	39.33	9.21	23.42	55.72	38.43	57.63	37.51	60.76	1.1321	1.0823
HB13-11	1.86	2.65	4.34	1.2197	1.0071	0.9591	1.0005	2.64	3.49	37.37	6.87	18.37	65.76	36.73	69.17	35.96	72.99	1.0627	1.0488
HB13-15	0.44	0.45	0.69	0.0492	0.1736	0.1935	0.1940	1.03	1.44	35.86	5.64	15.72	70.25	35.48	75.18	35.10	81.22	1.0203	1.0188
HB13-16	1.59	1.63	8.71	0.2567	0.6678	0.7342	0.6833	3.59	5.04	35.00	4.28	12.24	57.04	34.78	62.90	34.57	69.88	1.0054	0.9932
HB13-18	2.28	2.97	9.34	1.2300	1.2863	1.2278	1.2102	3.59	5.17	35.62	5.23	14.68	51.95	35.28	57.11	34.93	63.31	1.0262	1.0036
HB13-20	2.34	2.97	14.48	1.1835	1.3124	1.3856	1.4242	4.95	6.41	31.98	6.94	21.70	26.95	31.36	30.32	30.76	34.63	0.9181	0.8824
HB13-26	0.19	0.19	0.67	0.0205	0.0738	0.1411	0.2373	1.67	1.74	36.54	6.53	17.87	73.58	36.05	77.83	35.55	83.22	1.0385	1.0332
HB13-28	2.19	2.89	7.95	1.2149	1.2401	1.1420	1.0960	3.17	4.72	35.33	9.94	28.13	52.12	34.11	52.06	32.89	52.92	0.9885	0.9711
HB13-38	1.11	1.13	3.43	0.1272	0.4368	0.4014	0.4433	2.33	3.41	37.28	9.10	24.41	74.46	36.22	75.45	35.06	76.82	1.0443	1.0374
HB13-40	0.65	0.91	5.39	0.4129	0.3619	0.5422	0.5531	3.23	3.39	32.52	8.62	26.49	44.62	31.46	45.40	30.29	46.32	0.9119	0.8958
HB13-41	2.46	3.21	10.41	1.3367	1.3890	1.2976	1.2199	3.62	5.38	37.06	10.62	28.65	60.28	35.52	58.34	33.70	55.73	1.0329	1.0074
HB13-43	2.54	3.68	6.62	1.7257	1.2764	1.1502	1.0764	2.61	3.80	35.85	8.56	23.88	55.51	34.89	57.03	33.85	59.00	1.0147	0.9894
HB13-45	2.77	4.03	7.73	1.8973	1.3069	1.2015	1.2232	3.15	4.30	32.75	8.56	26.14	34.84	31.68	35.54	30.47	36.21	0.9287	0.8904
HB13-46	3.45	4.40	21.69	1.7667	1.9341	1.7851	1.6663	5.23	7.87	38.00	12.67	33.34	58.39	35.69	51.95	32.83	43.09	1.0513	0.9960
HB13-48	2.98	4.26	10.13	1.9660	1.5968	1.4564	1.3622	3.31	4.86	40.91	10.02	24.49	80.55	39.67	80.55	38.22	80.55	1.1521	1.1285
HB13-49	3.71	5.23	16.96	2.3804	2.0408	1.8337	1.7243	4.36	6.45	32.67	11.49	35.17	26.03	30.50	20.22	27.84	12.09	0.9113	0.8294
Vikrant	1.14	1.59	3.62	0.7177	0.6328	0.7060	0.7541	2.69	3.11	29.87	8.60	28.80	25.67	28.69	25.67	27.42	25.67	0.8344	0.8142

that the environmental factors affected the nodulation characters reflecting stability and adaptability of the peanut genotypes.

Adaptability measures MASV and MASV1 identified HB13 -10, HB13-46, HB13-49 and HB13-20 genotypes for stable yield. Preferences of genotypes varied from HB13-26, HB13-15 and HB13-38, based on W1 to HB13-26, HB13-15 and HB13-40 as per W2 values while HB13-26, HB13-15, HB13-38 by values of W3. WAASB based on four significant IPCA's simultaneously and settled for HB13-15 HB13-26 and HB13-38 genotypes for stable high yield. First two IPCAs in ASV & ASV1 measures utilized 80.1% of G×E interaction sum of squares. ASV1 and ASV measures pointed towards HB13-26, HB13-15, HB13-40 as of stable performance. ASTAB2 settled for (HB13-26, HB13-15, and HB13-9) genotypes for cultivation also supported by Tadesse et al. 2021.

In the biplot vectors of traits expressed acute angles would be positively correlated whereas those achieved obtuse or straight-line angles would be negatively correlated and those showed right angles would be independent (Verma et al. 2021). Yield, number of pods and number of branches had correlated very tightly. Plant height showed positive relation with days to maturity. Yield along with number of pods expressed negative relation with days to maturity. Plant height maintained positive correlation with yield, number of pods and number of branches (Fig. 1).

The first two significant PC's have explained about 78.8% of the total variation with respective contributions of 49.5 and 29.3%. A similar trend was reported in durum wheat by Mohammadi et al. (2015). Two major clusters observed of studied measures in biplot analysis and IPC3 had maintained from other measures as outlier in another quadrant. A group comprised of measures based on two or more number of interaction principal components observed in quadrant 2 (Fig. 2). Arithmetic, geometric and harmonic means along with the

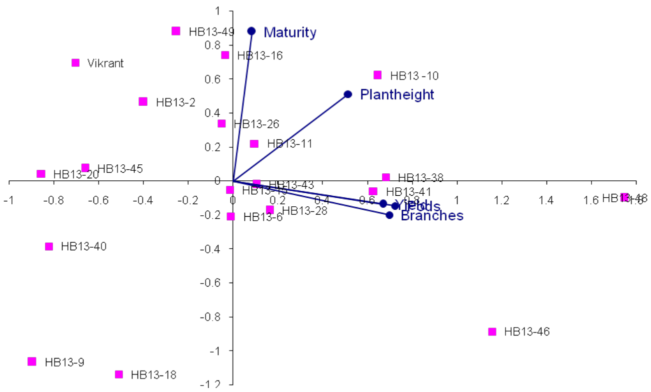

Fig. 1. Association analysis among traits of Faba bean genotypes

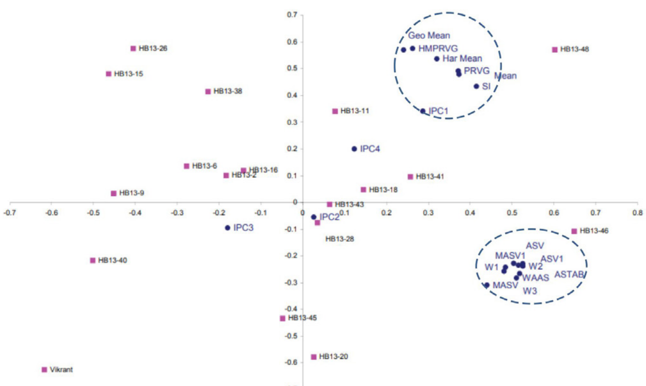

Fig. 2. Biplot analysis of genotypes and AMMI based measures

corresponding values of RPGV & MHRPGV expressed bondage with each other. The cluster is seen in different quadrants. Moreover, this group maintained the right angle with MASV, MASV1 & stability measures. Superiority indexes were based on the mean yield of wheat genotypes placed in the same quadrant (Verma et al. 2021). The performance difference of genotypes would be very less by Superiority and AMMI analysis-based measures.

Authors' contribution

Conceptualization of research (RKA, V); Designing of the experiments (RKA, AV); Contribution of experimental materials (RKA, V); Execution of field/lab experiments and data collection (RKA, V); Analysis of data and interpretation (AV); Preparation of the manuscript (RKA, AV, V)

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