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SUPERIORITY INDICES AS PER AMMI ANALYSIS TO ASSESS STABILITY OF FABA BEAN (*VICIA FABA* L.) GENOTYPES

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Abstract

AMMI stability values along with adaptability measures MASV and MASV1 identified HB14-15, HB14-40, HB14-16 genotypes. Relative Performance of Genotypic Values (RPGV) measure had settled for HB14.32, HB14-18, HB14-14 genotypes. Superiority indexes allowed variable weights to yield and stability measures considered HB14.32, HB14-18, HB14-20 as of genotypes with high yield and stable performance. Highly significant variations due to environments (64.2%), GxE(11.4%) and genotypes (9.1%) were observed in AMMI analysis of Faba bean genotypes in Hisar under field trials from *rabi* 2013-14 to *rabi* 2018-19. Biplot analysis had observed a cluster of RPGV, MHRPGV, along with the superiority measures as per arithmetic, geometric and harmonic means of yield values. Association analysis observed the stability measures W_1, W_2 and WAAS maintained direct relationship with AMMI based measures. Superiority indexes exhibited positive strong correlation with Sdev, PRVG and MHPRVG measures.

Introduction

Faba bean (*Vicia faba* L.) is a multi-purpose crop in warmer areas and very well accommodated in dominant cropping cycles owing to short growing season as observed in south eastern Ethiopia (Tadesse *et al*. 2021) . Genotype × Environment interaction is one of the most important aspects of the crop breeding as the response of the cultivars generally varies under different environments due to the genotypic differential responses in multi-dimensional environment (Papastylianou *et al*. 2021). Recently AMMI analysis based measures had been advocated in the breeding experiments for the stability assessment of genotypes (Agahi *et al*. 2020). Numbers of AMMI analytic measures have been compared in recent literature to interpret the stable performance of genotypes or lines irrespective of crops. Now days the variable weights to yield and stability of genotypes as per the objectives of the breeding improvement program has been facilitated by superiority indexes (Olivoto *et al*. 2019). The present study was carried out to analyze stability of genotypes by AMMI and Superiority indexes, to differentiate genotypes performance possessing high yield along with general and specific adaptations of genotypes and to find out the association among the stability measures.

Materials and Methods

Twenty promising Faba bean genotypes were evaluated over the period of five years at MAP Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during the period of 2015-16 to 2019-20. 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 yield. Data were recorded on plant height, branches/plant, pod length (cm), pods/plant and yield (q/ha). AMMI analysis was performed using AMMISOFT and SAS software's.

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Results and Discussion

Highly significant effects of plant height, branches/plant, pod length (cm), pods/plant and yield (q/ha) traits had been expressed by genotypes over the years as well as in combined analysis. Major portion of total sum of squares in the ANOVA table was accounted by genotypes effects as compared to error components (Table 1). AMMI analysis revealed highly significant variation due to environments, GxE interaction, and genotypes (Table 2). This analysis also revealed that about 64.2% of the total sum square of variation for yield was due to the environments, whereas 11.4% was due to genotype by environment interaction, and only 9.1% was because of the genotypes. The first two highly significant AMMI components accounted for 94.6% of the total variation.

Table 1. Analysis of variance for morphological traits.

Traits	Factor (MSS)	2015-16	2016-17	2017-18	2018-19	2019-20	Pooled	Year (MSS)	Interaction (MSS)
	Genotype	70.95	70.95	19.23	3.02	8.18	76.79	2014.40	23.88
Yield	Error	11.69	9.33	10.70	9.39	11.79	11.19		
	CD at 5%	5.70	5.09	5.46	5.11	5.73	2.41	1.35	
	Genotype	486.28	494.83	137.58	360.13	68.93	718.21	31505.84	207.39
Plant height	Error	5.75	0.79	21.42	0.66	0.47	11.41		
	CD at 5%	4.00	1.48	7.72	1.35	1.15	2.44	1.36	
	Genotype	4.47	0.37	0.39	1.85	0.19	1.61	99.40	1.42
Number of branches	Error	0.08	0.06	0.34	0.04	0.05	0.13		
	CD at 5%	0.46	0.40	0.97	0.35	0.39	0.26	0.15	
	Genotype	1.22	0.32	0.40	0.24	0.35	0.40	2.48	0.53
Pods length	Error	0.02	0.03	0.13	0.02	0.04	0.05		
	CD at 5%	0.23	0.29	0.59	0.26	0.32	0.16	0.09	
	Genotype	625.65	665.71	66.29	405.12	21.77	616.36	32968.01	292.05
Number of pods	Error	156.80	42.60	60.19	39.19	7.16	64.96		
	CD at 5%	20.88	10.88	12.94	10.44	4.46	5.81	3.25	

Table 2. AMMI analysis of Faba bean genotypes.

Source	Degree of freedom	Mean sum of squares	Level of significance	% of total sum of squares	% of GxE sum of squares	Cumulative % SS by PCA's
Treatments	79	134.715	***	84.83		
Genotypes	15	76.78794	***	9.18		
Environments	4	2014.404	***	64.23		
GxE interactions	60	23.88417	***	11.42		
IPC1	18	60.9985	***		76.62	76.62
IPC2	16	16.10679			17.98	94.60
IPC3	14	5.52632			5.40	100.00
Error	160	11.89186				
Total	239	52.49031				

AMMI derived measures based on the use of significant IPC's were calculated as EV1, ASTAB1, SIPC1, D1 measures (only first significant IPC; benefited 76% GxE interaction), while ASV, EV2, ASV1, ASTAB2, SIPC2, D2 based on first two significant utilized 94%, finally EV3, ASTAB3, SIPC3 and D3 considered three IPC's used up to 99% of variation. Values of IPCA's in the AMMI analysis indicate stability or adaptability of genotypes. Absolute IPCA-1 scores pointed for HB14-40, HB13-10, HB14-07, HB14-36 (Table 3). While for IPCA-2, HB14-15, HB14-16,

HB14-40 would be genotypes of choice. Values of IPCA-3 favoured HB 14-20, HB 14-42, HB14-43, genotypes. Minimum and maximum values of EV1 observed for (HB14-40, HB14-07, HB14-36) and (Vikrant, HB14-14) while corresponding to D1 were (HB14-40, HB14-07, HB14-36) and (Vikrant, HB14-14), values of SIPC1 marked for (Vikrant, HB14-31, HB14-22) and (HB14-14, HB14.32) and for ASTAB1 were (HB14-40, HB14-07, HB14-36) and (Vikrant, HB14-14). EV2 pointed towards (HB14-15, HB14-16, HB14-40) as desirable at the same time undesirable genotypes (Vikrant, HB14-25), for values of D2 genotypes were (HB14-15, HB14-40, HB14-36) and (Vikrant , HB14-14). Whereas as per SIPC2 were (Vikrant , HB14-31, HB14-22), (HB14-14, HB14.32) and of ASTAB2 were (HB14-15, HB14-40, HB 14-16) & (Vikrant , HB 14-14). EV3 pointed for HB14-15 HB14-40, HB 14-18 while D3 favoured HB14-15, HB14-40, HB14-16 and ASTAB3 settled for HB14-15, HB14-40, HB14-16 Faba bean genotypes. Using first two IPCAs in stability analysis could benefits dynamic concept of stability in identification of the stable high yielder genotypes. ASV1 measures recommended (HB14-40, HB14-15, HB14-36) and ASV pointed towards (HB14-40, HB14-15, HB14-36) as of stable performance and jointly marked Vikrant, HB14-14 as unsuitable ones.

Adaptability measures MASV and MASV1considered all three significant IPCAs of the AMMI analysis and identified HB14-15, HB14-40, HB14-16 genotypes would express stable yield whereas genotypes Vikrant, HB14-25, HB14-14 be of unstable yield performance by MASV1 and MASV measures, respectively.

The genotype with the smallest WAASB value had been ranked with the first-order. Preferences of genotypes varied from HB14-40, HB 14-07, HB14-36 based on W1 to HB14-40, HB14-15, HB14-36 as per W2 values while HB14-40, HB14-15, HB14-07 by values of WAAS (Table 4). The genotype's ranking was altered utilizing more number of IPCAs in the stability estimation which was also supported by the findings of Tadesse *et al*. (2021). Higher average yield selected HB14.32, HB14-18, HB14-14 genotypes, while the lowest yield was of Vikrant (Table 4). This measure is simple, but not fully exploiting all information contained in the dataset. Consistent performance of Vikrant, HB14-31, HB14-22 justified by standard deviation along with CV values. Geometric adaptability index values also recommended for HB14.32, HB14-18 and HB14-14. Harmonic mean measure found maximum values by HB14.32, HB14-18, HB14-14 genotypes. Harmonic Mean of Relative Performance of Genotypic Values (HMRPGV) ranked HB14.32, HB14-18, HB14-14 as the top performer genotypes. Relative Performance of Genotypic Values (RPGV) had settled for HB14.32, HB14-18, HB14-14 genotypes. Superiority indexes assigned 65 and 35 as relative weights to yield and stability pointed out genotypes HB14.32, HB14-18, HB14-20 would maintain high yield and stable performance. SI measure, considered GM and stability pointed for HB14.32, HB14-18, and HB14-20 genotypes. Values of SI, using HM and stability, favoured the HB14.32, HB14-18, and HB14-20. Similar findings were also mentioned by Verma *et al*. (2021).

The first two significant PCs has explained about 88.9% of the total variation with respective contributions of 61.6 and 27.8 by PC1 and PC2. Two major clusters were observed in biplot analysis and seen in two quadrants only. Group comprised of AMMI based measures based on one, two or more number of interaction principal components observed in second quadrant (Fig. 1). More over RPGV and MHRPGV along with Arithmetic, geometric and harmonic means as well as superiority measures as per these measures expressed bondage with each other (Fig. 2). Obtuse angles of Superiority measures as per mean, geometric and harmonic expressed with ASTAB1, ASTAB2, ASTAB3 measures.

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

	IPC1	IPC2	IPC3	EV1	EV2	EV3	D1	D2	D3	SIPC1	SIPC2	SIPC3	ASTAB1	ASTAB2	ASTAB3
HB 14-05	0.5729	-1.0784	-0.2984	0.0099	0.0412	0.0308	3.30	5.44	5.51	0.5729	-0.5055	-0.8039	1.89	6.55	6.81
HB 14-07	-0.1710	-0.8537	-0.6768	0.0009	0.0231	0.0328	0.98	3.56	4.09	-0.1710	-1.0247	-1.7015	0.17	3.09	4.45
HB 14-14	1.5147	0.7061	0.1604	0.0692	0.0501	0.0344	8.72	9.17	9.18	1.5147	2.2208	2.3812	13.21	15.20	15.28
HB 14-15	0.2339	-0.0299	-0.2309	0.0017	0.0009	0.0026	1.35	1.35	1.52	0.2339	0.2040	-0.0269	0.31	0.32	0.48
HB 14-16	-0.3908	-0.1275	-1.0553	0.0046	0.0028	0.0441	2.25	2.31	3.89	-0.3908	-0.5184	-1.5737	0.88	0.94	4.25
HB 14-18	1.1702	0.3390	0.3910	0.0413	0.0242	0.0220	6.74	6.87	6.97	1.1702	1.5092	1.9002	7.88	8.34	8.80
HB 14-20	0.5898	1.3577	0.0221	0.0105	0.0627	0.0418	3.40	6.41	6.41	0.5898	1.9475	1.9696	2.00	9.39	9.39
HB 14-22	-1.3650	-0.3730	0.1826	0.0562	0.0324	0.0229	7.86	8.00	8.02	-1.3650	-1.7380	-1.5554	10.73	11.28	11.38
HB 14-25	-1.0418	1.2889	-0.8946	0.0328	0.0681	0.0757	6.00	7.91	8.35	-1.0418	0.2471	-0.6475	6.25	12.90	15.28
HB 14-31	-1.4816	-0.4361	0.2169	0.0662	0.0390	0.0278	8.53	8.71	8.73	-1.4816	-1.9177	-1.7009	12.64	13.40	13.54
HB 14.32	1.2099	0.7911	0.5640	0.0442	0.0416	0.0398	6.96	7.65	7.83	1.2099	2.0009	2.5650	8.43	10.93	11.88
HB 14-36	0.2094	-0.6784	1.0545	0.0013	0.0150	0.0521	1.21	2.97	4.32	0.2094	-0.4689	0.5856	0.25	2.10	5.39
HB 14-40	-0.0245	0.3445	-0.2967	0.0000	0.0037	0.0058	0.14	1.39	1.64	-0.0245	0.3199	0.0232	0.00	0.48	0.74
HB 14-42	1.0436	-0.7592	-0.1511	0.0329	0.0344	0.0238	6.01	6.73	6.75	1.0436	0.2844	0.1334	6.27	8.58	8.65
HB 14-43	0.4935	-0.9563	0.1516	0.0073	0.0322	0.0223	2.84	4.77	4.79	0.4935	-0.4628	-0.3112	1.40	5.07	5.13
Vikrant	-2.5632	0.4654	0.8606	0.1983	0.1059	0.0987	14.75	14.87	15.09	-2.5632	-2.0978	-1.2372	37.82	38.69	40.88

Table 4. Weighted average of yield and stability measures.

	ASV	ASV1	MASV	MASV1	W1	W2	WAAS	PRVG	MHPRVG	MEAN	SI_{MEAN}	Sdev	CV	GAI	SI_{GM}	HM	SI_{HM}
HB 14-05	1.60	2.67	2.55	4.48	0.5729	0.6690	0.6490	0.9772	0.9736	34.83	57.88	7.69	22.09	34.18	56.31	33.56	54.58
HB 14-07	0.92	1.12	1.93	3.13	0.1710	0.3008	0.3211	0.9583	0.9564	33.97	57.05	6.07	17.86	33.55	56.78	33.15	56.46
HB 14-14	3.21	6.49	3.46	6.91	1.5147	1.3610	1.2961	1.0700	1.0648	38.40	73.49	9.93	25.87	37.40	71.89	36.47	70.16
HB 14-15	0.48	1.00	0.54	1.03	0.2339	0.1951	0.1971	0.9908	0.9906	35.25	68.93	6.97	19.79	34.72	68.72	34.21	68.51
HB 14-16	0.82	1.67	1.35	2.02	0.3908	0.3408	0.3794	0.9755	0.9740	34.52	60.22	5.68	16.45	34.15	60.83	33.80	61.51
HB 14-18	2.44	5.00	2.55	5.14	1.1702	1.0122	0.9786	1.0834	1.0810	38.75	81.72	9.11	23.50	37.92	81.79	37.14	81.97
HB 14-20	1.82	2.86	3.08	5.35	0.5898	0.7358	0.6973	1.0580	1.0543	37.73	78.96	8.26	21.90	37.01	79.10	36.30	79.07
HB 14-22	2.84	5.83	2.93	5.96	1.3650	1.1764	1.1228	0.9633	0.9586	33.81	41.84	3.47	10.26	33.67	43.78	33.54	46.03
HB 14-25	2.51	4.62	3.55	6.37	1.0418	1.0887	1.0783	0.9495	0.9431	33.48	40.14	5.10	15.22	33.16	40.26	32.82	40.15
HB 14-31	3.09	6.33	3.20	6.50	1.4816	1.2829	1.2253	0.9726	0.9666	34.09	42.18	3.21	9.43	33.97	44.51	33.86	47.22
HB 14.32	2.62	5.22	3.04	5.87	1.2099	1.1303	1.0997	1.0933	1.0899	39.12	82.42	9.34	23.88	38.25	82.42	37.42	82.42
HB 14-36	0.80	1.12	1.81	2.73	0.2094	0.2986	0.3394	1.0038	1.0016	35.67	69.66	7.01	19.66	35.13	69.72	34.62	69.76
HB 14-40	0.35	0.36	0.78	1.24	0.0245	0.0854	0.0968	0.9858	0.9854	35.01	68.88	6.52	18.62	34.54	68.98	34.08	69.06
HB 14-42	2.28	4.51	2.68	5.17	1.0436	0.9896	0.9443	1.0319	1.0284	36.88	68.20	8.69	23.57	36.10	67.17	35.37	66.14
HB 14-43	1.40	2.31	2.24	3.94	0.4935	0.5814	0.5582	1.0089	1.0065	35.92	67.67	7.52	20.92	35.31	67.37	34.74	67.07
Vikrant	5.31	10.93	5.45	11.07	2.5632	2.1644	2.0940	0.8777	0.8612	30.53	0.00	2.19	7.17	30.47	0.00	30.40	0.00

Table 5. Association analysis among stability measures of Faba bean genotypes.

	EV2	EV3	D1	D2	D3	SIPC1	SIPC2	SIPC3	ASTAB1	ASTAB2	ASTAB3	ASV	ASV1	MASV	MASV1	Sdev	CV	MEAN	GAI	HM	PRVG	MHPRVG	W_1	W_2	WAAS	SI_{MEAN}	SI_{GM}	SI_{HM}	IPC1	IPC2	IPC3
EV1	0.7724	0.6343	0.9384	0.9081	0.9173	-0.5497	-0.3030	-0.0928	1.0000	0.9708	0.9648	0.9328	0.9405	0.8423	0.8883	-0.4762	-0.5381	-0.4063	-0.4060	-0.4026	-0.3815	-0.4294	0.9384	0.9160	0.9208	-0.7311	-0.7356	-0.7377	-0.5497	0.2594	0.4783
EV2		0.7768	0.7765	0.8962	0.8896	-0.3902	-0.0717	0.0494	0.7724	0.9023	0.8918	0.8472	0.7961	0.9498	0.9210	-0.2809	-0.3213	-0.2842	-0.2945	-0.3068	-0.2697	-0.3183	0.7765	0.8411	0.8429	-0.5974	-0.6105	-0.6250	-0.3902	0.4351	0.2965
EV3			0.5561	0.6441	0.7182	-0.5181	-0.2181	-0.1280	0.6343	0.7241	0.7952	0.6085	0.5707	0.7451	0.6795	-0.4121	-0.4268	-0.4614	-0.4702	-0.4809	-0.4517	-0.4876	0.5561	0.5984	0.6223	-0.6472	-0.6570	-0.6686	-0.5181	0.3627	0.1871
D1				0.9672	0.9628	-0.4103	-0.1644	0.0228	0.9384	0.9305	0.9090	0.9903	0.9993	0.8972	0.9465	-0.3444	-0.4230	-0.2075	-0.2015	-0.1923	-0.1757	-0.2263	1.0000	0.9908	0.9906	-0.5985	-0.5993	-0.5975	-0.4103	0.3017	0.4472
D2					0.9914	-0.3963	-0.1376	0.0445	0.9081	0.9552	0.9328	0.9929	0.9758	0.9763	0.9970	-0.3166	-0.3876	-0.2125	-0.2111	-0.2081	-0.1843	-0.2369	0.9672	0.9902	0.9897	-0.6022	-0.6068	-0.6099	-0.3963	0.3284	0.4397
D3						-0.4359	-0.1714	0.0117	0.9173	0.9589	0.9524	0.9863	0.9707	0.9781	0.9910	-0.3540	-0.4232	-0.2533	-0.2514	-0.2478	-0.2247	-0.2770	0.9628	0.9825	0.9864	-0.6341	-0.6382	-0.6408	-0.4359	0.3262	0.4353
SIPC1							0.8208	0.7559	-0.5497	-0.5207	-0.5568	-0.4107	-0.4137	-0.3843	-0.3919	0.9895	0.9865	0.9134	0.8923	0.8643	0.8867	0.8970	-0.4103	-0.3808	-0.3942	0.9189	0.9016	0.8795	1.0000	0.0000	0.0000
SIPC2								0.9210	-0.3030	-0.2328	-0.2617	-0.1559	-0.1646	-0.1192	-0.1305	0.8735	0.8385	0.8739	0.8600	0.8384	0.8627	0.8569	-0.1644	-0.1258	-0.1358	0.7748	0.7618	0.7434	0.8208	0.5713	0.0000
SIPC3									-0.0928	-0.0443	-0.0767	0.0313	0.0233	0.0438	0.0463	0.8152	0.7560	0.8691	0.8595	0.8435	0.8681	0.8505	0.0228	0.0536	0.0436	0.6932	0.6826	0.6678	0.7559	0.5262	0.3895
ASTAB1										0.9708	0.9648	0.9328	0.9405	0.8423	0.8883	-0.4762	-0.5381	-0.4063	-0.4060	-0.4026	-0.3815	-0.4294	0.9384	0.9160	0.9208	-0.7311	-0.7356	-0.7377	-0.5497	0.2594	0.4783
ASTAB2											0.9920	0.9534	0.9393	0.9307	0.9511	-0.4294	-0.4867	-0.3832	-0.3869	-0.3893	-0.3609	-0.4118	0.9305	0.9397	0.9436	-0.7221	-0.7301	-0.7370	-0.5207	0.3405	0.4367
ASTAB3												0.9313	0.9176	0.9210	0.9322	-0.4623	-0.5155	-0.4263	-0.4302	-0.4328	-0.4046	-0.4546	0.9090	0.9168	0.9251	-0.7494	-0.7573	-0.7642	-0.5568	0.3419	0.4220
ASV													0.9948	0.9470	0.9815	-0.3370	-0.4121	-0.2168	-0.2131	-0.2071	-0.1866	-0.2386	0.9903	0.9979	0.9976	-0.6091	-0.6119	-0.6127	-0.4107	0.3170	0.4491
ASV1														0.9115	0.9573	-0.3457	-0.4235	-0.2131	-0.2077	-0.1992	-0.1817	-0.2327	0.9993	0.9941	0.9940	-0.6045	-0.6059	-0.6046	-0.4137	0.3062	0.4491
MASV															0.9900	-0.2944	-0.3548	-0.2237	-0.2259	-0.2279	-0.1995	-0.2513	0.8972	0.9439	0.9464	-0.5926	-0.5999	-0.6068	-0.3843	0.3434	0.3943
MASV1																-0.3083	-0.3759	-0.2157	-0.2156	-0.2144	-0.1888	-0.2414	0.9465	0.9786	0.9789	-0.6001	-0.6057	-0.6102	-0.3919	0.3346	0.4275
Sdev																	0.9929	0.9112	0.8870	0.8549	0.8842	0.8890	-0.3444	-0.3070	-0.3190	0.8846	0.8642	0.8383	0.9895	0.1074	0.0273
CV																		0.8644	0.8366	0.8004	0.8315	0.8408	-0.4230	-0.3828	-0.3940	0.8787	0.8559	0.8273	0.9865	0.0504	-0.0418
MEAN																			0.9983	0.9921	0.9980	0.9978	-0.2075	-0.1847	-0.1998	0.9058	0.9027	0.8971	0.9134	0.2174	0.1648
GAI																				0.9977	0.9996	0.9996	-0.2015	-0.1812	-0.1964	0.9029	0.9026	0.9002	0.8923	0.2234	0.1729
HM																					0.9972	0.9975	-0.1923	-0.1756	-0.1909	0.8955	0.8983	0.8996	0.8643	0.2258	0.1832
PRVG																						0.9985	-0.1757	-0.1548	-0.1699	0.8912	0.8907	0.8879	0.8867	0.2363	0.1886
MHPRVG																							-0.2263	-0.2068	-0.2219	0.9136	0.9135	0.9113	0.8970	0.2112	0.1574
W_1																								0.9908	0.9906	-0.5985	-0.5993	-0.5975	-0.4103	0.3017	0.4472
W_2																									0.9993	-0.5836	-0.5866	-0.5877	-0.3808	0.3269	0.4350
WAASB																										-0.5962	-0.5993	-0.6005	-0.3942	0.3287	0.4330
SI_{MEAN}																											0.9989	0.9948	0.9189	0.0359	-0.0522	
SI_{GM}																												0.9985	0.9016	0.0381	-0.0489	
SI_{HM}																													0.8795	0.0377	-0.0435
IPC1																														0.0000	0.0000
IPC2																															0.0000

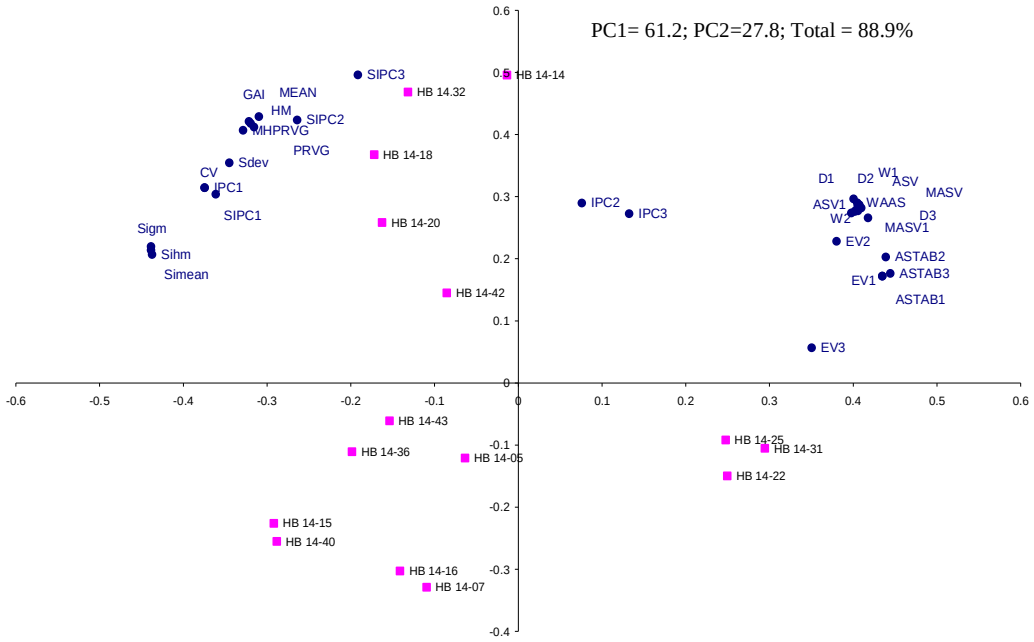

Fig. 1. Clustering pattern of various measures.

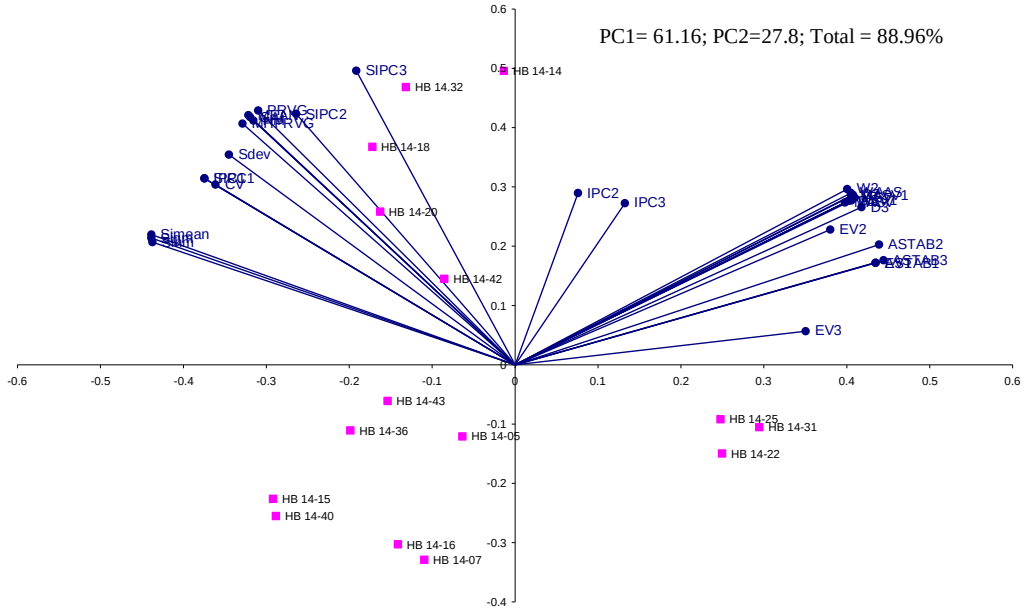

Fig. 2. Biplot analysis of stability measures vis a vis genotypes.

AMMI based measures expressed highly significant positive values of correlation themselves along with negative values for SIPC1, SIPC2, SIPC3 etc (Table 5). Even MASV and MASV1 also maintained negative relationship with Mean, Sdev, CV, geometric and harmonic means PRVG, MHPRVG showed direct relation with SIPC1, SIPC2, SIPC3 measures. Similar trends were observed for superiority indexes based on these means and IPC1, IPC2, IPC3 values. Stability measures W_1, W_2 and WAAS maintained direct relationship with AMMI based measures while exception of SIPC(s) measures. Superiority indexes as per various measures exhibited positive strong correlation with Sdev, PRVG and MHPRVG measures (Anuradha *et al.* 2022). PRVG and MHPRVG measures showed indirect relationships with AMMI based measures.

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