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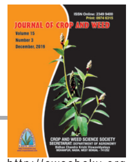

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Simultaneous consideration of AMMI analysis and yield of wheat genotypes for stability assessment evaluated under Central Zone of India

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ABSTRACT

Highly significant effects of environment (E), GxE interaction and genotypes (G) was observed by AMMI analysis during 2018-19 and 2019-20 study years. WAASB measure assessed the stable behaviour of genotypes as least deviated from the average yield across environments. Genotypes DDW47 and MP3288 would be more suitable as compared to UAS466 by WAASB measure for the first year. Superiority index obtained as weighted average of stability and yield of genotypes identified DDW47 and HI8627 in comparison to DBW110, though the yield ranked DBW110 and MP3288 of higher order. Adaptability measures PRVG and MHPRVG settled for DBW110 and MP3288 wheat genotypes. Negative correlations values were exhibited by SI with most of the considered measures. More over WAASB measure expressed all most direct relationships with other measures. Value of WAASB for the second year of study found suitability of UAS466, DDW47 and HI8627 wheat genotypes. Superiority index pointed towards HI8823, MP3288 and UAS472 as of stable performance. Strong direct relations were expressed by SI values. WAASB had also expressed direct relations. Simultaneous use of AMMI analysis and yield in stability measures would be more meaningfull and useful as compared to measures based on either the AMMI or yield only.

Keywords: AMMI analysis, ASV, SIPC, Za, EV, SI, SSI, Biplot graphs

AMMI analysis retains most of the genotype x environment interaction pattern in the earlier interaction principal component axis (IPCA) resulting from the singular value decomposition (SVD) of the non-additive effects matrix, while most of the random error has been retained as noise in the last IPCAs (Zhang *et al.,* 1998; Gauch 2013; Bocianowski *et al.,* 2019; Veenstra *et al.,* 2019). At the same time biased interpretation regarding the stability of the genotypes observed for cases of low proportion of the variance explained by first interaction principal component IPCA1 (Zali *et al.,* 2012; Ajay *et al.,* 2019). Stability measure WAASB was proposed to overcome the problem of biased interpretation by incorporated all significant interaction principal components as the weighted average of the IPCA scores based on the sum of absolute values of the IPCA scores. The lower WAASB value recognised stable performing genotypes. The simultaneous consideration of yield and stability in a single measure had been advocated by researchers (Kang, 1993; Farshadfar, 2008). Simultaneous Selection Indices had been advocated by adding the ranks of stability measure and yields (Farshadfar *et al.,* 2011). The superiority index WAASBY allowed variable weighting between yield and stability (WAASB) put forward by Olivoto (2019). The present study was planned to validate the relationships between SI and other stability measures defined as by AMMI model, of wheat genotypes evaluated under multi environmental trials in the Central Zone of the country under restricted irrigated timely sown trials in recent past.

MATERIALS AND METHODS

This zone of our country is well known for premium quality of wheat, comprises Madhya Pradesh, Chhattisgarh, Gujarat, Rajasthan (Kota and Udaipur divisions) and Jhansi division of Uttar Pradesh. Six advanced promising wheat genotypes at eleven locations and eight genotypes at twelve locations were evaluated under field trials during 2018-19 and 2019-20 cropping seasons, respectively. Field trials were conducted at research centers in randomized complete block designs with three replications. Recommended agronomic practices were followed to harvest good yield. Details of genotype parentage along with environmental conditions were reflected in Table 1 and 2 for ready reference. Stability measure Weighted Average of Absolute Scores has been calculated as

$$WAASB = \sum_{k=1}^{p} |IPCA_{ik} \times EP_k| / \sum_{k=1}^{p} EP_k$$

where WAASBi is the weighted average of absolute scores of the ith genotype (or environment); IPCAik is the score of the ith genotype (or environment) in the kth IPCA, and EPk is the amount of the variance explained by the kth IPCA. The genotype with the lowest WAASB value is considered the most stable, that is, the one that deviates least from the average performance across environments. Superiority index has been put

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forward that allows weighting between yield and stability measure WAASB index to select genotypes that combine high performance and stability as SI = $\frac{(rG_i \times \theta_Y)+(rW_i \times \theta_S)}{(\theta_Y+\theta_S)}$; where rGi and rWi are the rescaled values for yield and WAASB, respectively, for the ith genotype; Gi and Wi are the yield and the WAASB values for ith genotype. SI superiority index for the ith genotype that weights between yield and stability, and θY and θS are the weights for yield and stability assumed to be of order 65 and 35 respectively in this study.

Zobel *et al.* (1988)	Averages of the squared eigen vector values	$EV = \sum_{n=1}^{N} \lambda_{in}^2 / n$
Sneller *et al.* (1997)	Sums of the absolute value of the IPC scores	$SIPC = \sum_{n=1}^{N} \lambda_n^{0.5} \gamma_{in}$
Purchase *et al.* (2000)	AMMI stability value	ASV = $[(\frac{SSIPC\,1}{SSIPC\,2} PC1)^2 + (PC2)^2]^{1/2}$
Rao and Prabhakaran (2005)	AMMI based stability parameter	$ASTAB = \sum_{n=1}^{n} \lambda_n \gamma_{ni}^2$
Zali *et al.* (2012)	ASV1	ASV1 = $[\frac{SSIPC\,1}{SSIPC\,2}(PC1)^2 + (PC2)^2]^{1/2}$
Zali *et al.* (2012)	Modified AMMI stability value	$MASV = \sqrt{\sum_{n=1}^{N-1} \frac{SSIPC_n}{SSIPC_{n+1}} (PC_n)^2 + (PC_{n+1})^2}$
Zali *et al.* (2012)	Absolute value of the relative contribution of IPCs to the interaction	Za = $\sum_{n=1}^{N} \lvert \lambda_n \gamma_{in} \rvert$
Ajay *et al.* (2014)	MASV1	$MASV1 = \sqrt{\sum_{n=1}^{N-1} (\frac{SSIPC_n}{SSIPC_{n+1}} PC_n)^2 + (PC_{n+1})^2}$
Resende and Durate (2007)	Relative performance of genotypic values across environments	PRVGij = VGij / VGi
Resende and Durate (2007)	Harmonic mean of relative performance of genotypic values	MHPRVGi. = Number of environments/ $\sum_{j=1}^{k} \frac{1}{PRVG_{ij}}$
Olivoto *et al.* (2019)	Superiority Index	SI = $\frac{(rG_i \times \theta_Y)+(rW_i \times \theta_S)}{(\theta_Y+\theta_S)}$

AMMI analysis was performed using AMMISOFT version 1.0, available at https://scs.cals.cornell.edu/people/ hugh-gauch/ and SAS software version 9.3. Stability measures had been compared with recent analytic measures of adaptability calculated as the relative performance of genetic values (PRVG) and harmonic mean based measure of the relative performance of the genotypic values (MHPRVG) for the simultaneous analysis of stability, adaptability and yield (Resende and Durate, 2007).

RESULTS AND DISCUSSION

First year of study (2018-19)

AMMI analysis

Highly significant effects of environment (E), GxE interaction and genotypes (G) was observed by AMMI analysis. Environment explained 77.1% , GxE interaction accounted for 12.2% and genotypes contributed only 2.3% for the total sum of squares due to treatments (Table 3). More over up to 80%

Table 1: Parentage details of genotypes and environmental conditions (2018-19)

Code	Genotype	Parentage	Environments	Latitude	Longitude	Altitude
G 1	HI 8627	(HD4672/PDW233)	Vijapur	23°33' N	72°45' E	129.4
G 2	DBW 110	(KIRITATI/4/2*SERI1B*2/3/ KAUZ*2/BOW//KAUZ)	Dhandhuka	22° 22' N	71° 59' E	24
G 3	UAS 466	(AMRUTH//BIJAGA YELLOW/ AKDW299-16)	Sanosara	21° 72' N	71° 76' E	89
G 4	MP 3288	(DOVE/BUC/DL788-2)	Anand	22° 33' N	72° 56' E	39
G 5	DBW 277	(NI 5439/ MACS 2496)	Indore	22° 43' N	75° 51' E	550
G 6	DDW 47	(PBW34/RAJ1555//PDW314)	Jabalpur	23° 10' N	79° 55' E	403
			Bhopal	23° 15' N	77° 24' E	496
			Powarkheda	22° 70' N	77° 73' E	308
			Gwalior	26° 13' N	78° 10' E	213
			Pratapgarh	24° 03' N	74° 77' E	491
			Udaipur	24° 34' N	73° 41' E	585

Table 2: Parentage details of genotypes and environmental conditions (2019-20)

Code	Genotype	Parentage	Environments	Latitude	Longitude	Altitude
G 1	MPO1357	(PDW02/TERTER//GW1133)	Vijapur	23°33' N	72°45' E	129.4
G 2	HI8627	(HD4672/PDW233)	Dhandhuka	22° 22' N	71° 59' E	24
G 3	UAS466	(AMRUTH//BIJAGA YELLOW/ AKDW299-16)	Amreli	21° 36' N	71° 13' E	126
G 4	UAS472	(BIJAGAYELLOW/(YAZI_1/ AKAKI_4//SOMAT_3/3/AUK/ GUIL//GREEN/5)	Sanosara	21° 72' N	71° 76' E	89
G 5	DBW110	(KIRITATI/4/2*SERI1B*2/3/ KAUZ*2/BOW//KAUZ)	Indore	22° 43' N	75° 51' E	550
G 6	MP3288	(DOVE/BUC/DL788-2)	Jabalpur	23° 10' N	79° 55' E	403
G 7	HI8823	(HI8709/HD4676)	Bhopal	23° 15' N	77° 24' E	496
G 8	DDW47	(PBW34/RAJ1555//PDW314)	Powarkheda	22° 70' N	77° 73' E	308
			Gwalior	26° 13' N	78° 10' E	213
			Pratapgarh	24° 03' N	74° 77' E	491
			Udaipur	24° 34' N	73° 41' E	585
			Bilaspur	22° 4' N	82° 9' E	264
			Ambikapur	23° 6' N	83° 11' E	623

Table 3: AMMI analysis of wheat genotypes evaluated under MET (2018-19)

Source	Degree of freedom	Mean Sum of Squares	Level of significance	Proportional contribution of factors	GxE interaction Sum of Squares (%)	Cumulative Sum Squares (%) of by IPCA's
Treatments	83	426.13	***	91.62		
Genotype (G)	5	178.26	***	2.31		
Environment (E)	13	2288.70	***	77.08		
GxE interaction	65	72.68	***	12.24		
IPC1	17	162.35	***		58.42	58.42
IPC2	15	50.25	***		15.95	74.38
IPC3	13	45.34	***		12.48	86.85
IPC4	11	33.75	***		7.86	94.71
Residual	9	27.75	*			
Error	252	12.83				
Total	335	115.23				

Table 4: AMMI analysis of wheat genotypes evaluated under MET (2019-20)

Source	Degree of freedom	Mean Sum of Squares	Level of significance	Proportional contribution of factors	GxE interaction Sum of Squares (%)	Cumulative Sum of Squares (%) by IPCA's
Treatments	103	298.41	***	86.16		
Genotype (G)	7	69.83	***	1.37		
Environment (E)	12	2,098.36	***	70.58		
GxE interaction	84	60.33	***	14.20		
IPC1	18	154.95	***		55.04	55.04
IPC2	16	59.42	***		18.76	73.80
IPC3	14	37.48	**		10.36	84.16
IPC4	12	38.27	0.06		9.06	93.22
IPC5	10	15.35	0.59		3.03	96.25
IPC6	8	17.20	0.60		2.72	98.97
Residual	6	8.73	0.76			
Error	312	15.83				
Total	415	85.96				

contribution of environmental effects was reported in various crops (Adjebeng *et al*., 2017). Larger GxE interaction effects over genotype were reported in several studies (Bornhofen *et al*., 2017), thus making selection of stable genotype was difficult. Further GxE interaction revealed that the first four multiplicative terms (IPCA1, IPCA2, IPCA3 and IPCA4) explained 58.4%, 15.9% , 12.5% and 7.9 % of interaction sum of squares, respectively. Total of significant components were 94.7 % and remaining 5.3% was the residual / noise, not interpretable thus discarded (Oyekunle *et al*., 2017; Ajay *et al*., 2019).

Stability measures

Least value of absolute IPCA1 was expressed by G6, G4 and G2 possessed the higher value. Low values of EV was associated with stable genotype G2 followed by G5 (Table 5). SIPC measure identified G6 followed by G2 as the stable genotypes. Za measure revealed G6 and G4 genotypes as most stable in descending order of stability, whereas G3 genotype with the least stability. ASTAB measure observed lower value of measure possessed by G6 and G2 genotypes as most stable (Rao and Prabhakaran, 2005). ASV measure showed that genotypes G6, G5 possessed lower values would express stable performance. Values of ASV1 selected G6, G4 for their stable behaviour. Measures MASV and MASV1considered all significant IPCAs and their lower values were showed by the stable G6 and G5 genotypes (Ajay *et al*., 2019).

The lower values of WAASB associated with stable nature of genotypes as G6, G4 for considered locations of the zone (Olivoto 2018). Lower value of Superiority index had observed for G2 and G5 (Olivoto *et al*., 2019). Genotypes G6 and G3 were identified for their more stable yield performance by MHPRVG and PRVG measures (Resende and Durate, 2007).

Ranking of genotypes as per AMMI measures and yield

As per the least values of ranks for IPCA1 measure MP3288 and DBW277 were considered as stable with high yield (Table 7). Composite measures MASV and MASV1 selected DBW110, DBW277. Least values of ASV measure were expressed by DBW277 and MP3288 wheat genotypes and ASV1 pointed towards MP3288 , DBW110. Lower value of Za measure was possessed by MP3288, DBW110. Genotypes MP3288 and DBW110 identified as stable by all measures in restricted irrigated timely sown conditions. EV measure identified DBW110 and DBW277 by whereas SPIC favoured DBW110 and MP3288 genotypes. Suitability of DDW47 and MP3288 by values of WAASB measure. Superiority index while weighting 0.65 and 0.35 for yield and stability found DDW47 and HI8627 as of stable performance with high yield in comparison to genotype DBW110. PRVG and MHPRVG measures settled for DBW110 and MP3288 wheat genotypes.

Biplot graphical analysis

Loadings of stability measures as per first two significant principal component analysis (PCA) for evaluating wheat genotypes were reflected in table 9. The first two PCAs explained 88.7 % of variation of the original variables (Balestre *et al*., 2009). Measure Za was clustered with ASV, ASV1, IPCA1 (Fig. 1). Separate group was comprised of yield with EV, PRVG and MHPRVG measures. Apart from SI and WAASB remaining measures formed a group *i.e*. SIPC, MASV1, ASTAB, MASV.

Table 5: Measures of stability as per AMMI analysis of wheat genotypes (2018-19)

Genotype	IPCA1	MASV1	MASV	ASV1	ASV	Za	EV	SIPC	ASTAB	WAASB	SI	MH PRVG	PRVG	Yield
G 1	1.65	4.76	4.16	3.29	2.88	26.21	0.085	6.08	54.34	1.587	59.10	0.972	0.983	37.64
G 2	2.47	4.46	3.64	4.08	3.31	25.22	0.045	4.47	52.68	1.689	14.58	1.055	1.069	40.71
G 3	3.36	5.72	4.67	5.38	4.30	34.13	0.090	6.21	95.85	2.268	51.36	0.936	0.955	36.95
G 4	0.83	5.39	4.77	3.09	2.99	21.05	0.102	5.58	55.87	1.195	42.22	1.027	1.037	39.60
G 5	2.28	4.12	3.48	3.62	2.88	23.94	0.074	4.63	54.41	1.560	34.81	1.021	1.033	39.47
G 6	0.57	3.30	3.36	0.93	0.75	15.81	0.104	4.24	51.28	0.878	100.00	0.915	0.922	35.96

Table 6: Measures of stability as per AMMI analysis of wheat genotypes (2019-20)

Genotype	IPCA1	MASV1	MASV	ASV1	ASV	Za	EV	SIPC	ASTAB	WAASB	SI	MHPRVG	PRVG	Yield
G 1	1.07	7.53	5.49	2.59	2.24	21.47	0.067	6.66	53.43	1.228	21.84	0.954	0.962	39.36
G 2	1.15	5.13	3.72	2.37	1.91	16.91	0.034	4.91	28.40	1.007	47.88	0.980	0.985	40.42
G 3	0.45	4.40	3.86	0.86	0.66	14.03	0.072	5.58	32.53	0.703	45.11	0.964	0.968	39.88
G 4	2.29	6.11	4.30	4.18	3.11	21.23	0.053	5.54	49.19	1.360	60.19	1.003	1.013	41.52
G 5	3.78	7.23	5.49	6.88	5.11	31.28	0.071	6.60	113.86	2.098	44.39	0.997	1.018	41.66
G 6	1.87	5.88	4.62	3.39	2.52	21.77	0.071	6.41	52.31	1.305	65.62	1.019	1.027	41.73
G 7	0.82	8.89	5.82	2.95	2.77	19.54	0.062	6.24	50.39	1.107	89.88	1.037	1.044	42.73
G 8	0.14	8.42	5.62	2.13	2.13	14.78	0.069	5.84	43.70	0.749	47.79	0.978	0.983	40.08

Table 7: Simultaneous ranks of genotypes as per AMMI based measures and yield (2018-19)

Genotype	IPCA1	EV	Za	SIPC	ASV1	ASV	ASTAB	MASV1	MASV	WAASB	SI	MH PRVG	PRVG	Yield
HI 8627	7	7	9	9	7	7	7	8	8	4	2	4	4	4
DBW 110	6	2	5	3	6	6	3	4	4	5	6	1	1	1
UAS 466	11	9	11	11	11	11	11	11	10	6	3	5	5	5
MP 3288	4	7	4	6	4	6	7	7	8	2	4	2	2	2
DBW 277	7	5	6	6	7	5	7	5	5	3	5	3	3	3
DDW 47	7	12	7	7	7	7	7	7	7	1	1	6	6	6

Table 8: Simultaneous ranks of genotypes as per AMMI based measures and yield (2019-20)

Genotype	IPCA1	EV	Za	SIPC	ASV1	ASV	ASTAB	MASV1	MASV	WAASB	SI	MHPRVG	PRVG	Yield
MPO1357	12	12	14	16	12	12	15	14	14	5	8	8	8	8
HI8627	10	6	8	6	8	7	6	7	6	3	4	5	5	5
UAS466	9	15	8	10	8	8	9	8	9	1	6	7	7	7
UAS472	11	6	9	6	11	11	8	8	7	7	3	3	4	4
DBW110	11	10	11	10	11	11	11	8	8	8	7	4	3	3
MP3288	8	8	9	8	8	7	8	5	6	6	2	2	2	2
HI8823	4	4	5	6	6	7	6	9	9	4	1	1	1	1
DDW47	7	11	8	10	8	9	9	13	13	2	5	6	6	6

Table 9: Loadings of measures as per two PC's (2018-19)

Measure	PC	1PC2
IPCA	10.259	0.284
MASV1	0.296	0.090
MASV	0.269	0.007
ASV1	0.259	0.284
ASV	0.274	0.241
Za	0.289	0.201
EV	0.253	-0.351
SIPC	0.305	0.066
ASTAB	0.285	0.053
WAASB	0.060	0.570
SI	-0.243	0.345
MH PRVG	0.286	-0.229
PRVG	0.286	-0.229
Yield	0.286	-0.229
% variance	68.202	0.49

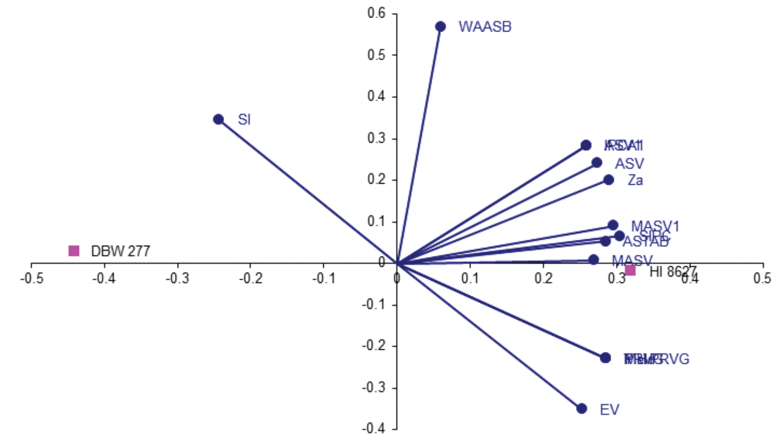

Fig. 1 : Biplot graphical analysis of stability measures for wheat genotypes evaluated under MET (2018-19)

Table 10: Loadings of measures as per two PC's (2019-20)

Measure	PC1	PC2
IPCA1	-0.233	0.305
MASV1	-0.238	-0.183
MASV	-0.242	-0.226
ASV1	-0.252	0.373
ASV	-0.259	0.296
Za	-0.288	0.266
EV	-0.255	-0.197
SIPC	-0.310	-0.033
ASTAB	-0.313	0.130
WAASB	0.012	0.564
SI	-0.316	0.013
MHPRVG	-0.301	-0.219
PRVG	-0.290	-0.226
Yield	-0.290	-0.226
% variance	61.70	21.57

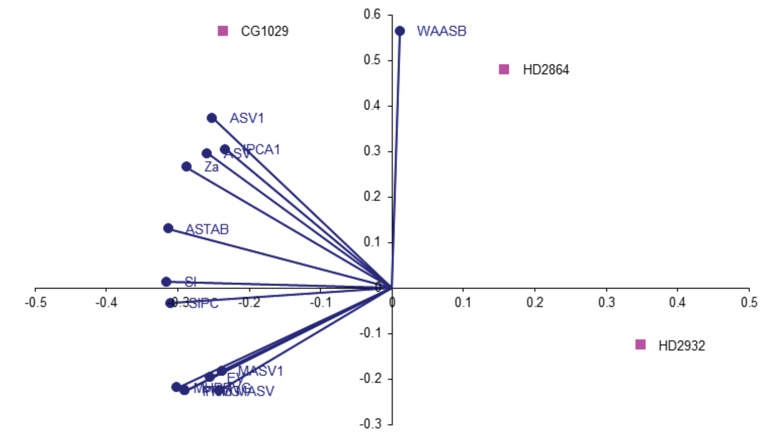

Fig. 2: Biplot graphical analysis of stability measures for wheat genotypes evaluated under MET (2019-20)

Association analysis

Mean yield showed highly significant positive correlations with MHPRVG and PRVG (Table 11). Negative correlation of with SI, EV, ASTAB along with moderate to weak positive relation with ASV1, ASV, IPCA1, MASV1,WAASB measures was found. MHPRVG and PRVG expressed highly significant direct relation with yield and other stability measures were related by indirect relationships. All negative values of correlations were exhibited by SI measure except positive with EV measure. WAASB measure exhibited direct relationships with other stability measures more over negative values were observed with SI and EV. All AMMI based measures Za, SIPC, ASV, ASV1, MASV1, MASV and ASTAB achieved only positive correlation values among themselves. Indirect relation of ASTAB had observed with SI, PRVG, MHPRVG and yield.

Table 11: Association analysis of SI with other stability measures (2018-19)

Measure	MASV1	MASV	ASV1	ASV	Za	EV	SIPC	ASTAB	WAASB	SI	MHPRVG	PRVG	Yield
IPCA1	0.481	0.175	0.910	0.820	0.908	-0.552	0.328	0.698	0.961	-0.556	0.116	0.185	0.183
MASV1		0.937	0.777	0.863	0.746	0.057	0.846	0.673	0.669	-0.444	0.163	0.212	0.193
MASV			0.513	0.632	0.521	0.367	0.865	0.586	0.409	-0.170	-0.011	0.021	0.001
ASV1				0.983	0.945	-0.452	0.562	0.700	0.955	-0.700	0.296	0.363	0.352
ASV					0.911	-0.387	0.640	0.658	0.901	-0.723	0.356	0.419	0.403
Za						-0.301	0.691	0.809	0.988	-0.454	0.001	0.070	0.052
EV							0.306	0.162	-0.410	0.769	-0.666	-0.689	-0.693
SIPC								0.625	0.571	-0.057	-0.207	-0.169	-0.208
ASTAB									0.783	-0.026	-0.411	-0.348	-0.345
WAASB										-0.510	0.053	0.123	0.111
SI											-0.884	-0.915	-0.911
MHPRVG												0.997	0.996
PRVG													0.998

Table 12: Association analysis of SI with other stability measures (2019-20)

Measure	MASV1	MASV	ASV1	ASV	Za	EV	SIPC	ASTAB	WAASB	SI	MHPRVG	PRVG	Yield
IPCA1	-0.060	0.058	0.945	0.870	0.930	0.042	0.346	0.832	0.963	-0.024	0.297	0.450	0.455
MASV1		0.953	0.254	0.422	0.227	0.275	0.551	0.342	0.162	0.242	0.324	0.343	0.296
MASV			0.340	0.486	0.375	0.504	0.756	0.515	0.292	0.112	0.248	0.298	0.244
ASV1				0.983	0.950	0.094	0.449	0.910	0.969	0.064	0.391	0.546	0.536
ASV					0.924	0.106	0.495	0.909	0.933	0.113	0.430	0.577	0.561
Za						0.208	0.625	0.930	0.993	-0.051	0.300	0.459	0.445
EV							0.746	0.414	0.125	-0.086	-0.016	0.029	-0.015
SIPC								0.663	0.531	-0.063	0.181	0.267	0.207
ASTAB									0.911	-0.092	0.216	0.381	0.368
WAASB										-0.038	0.308	0.467	0.460
SI											0.925	0.856	0.870
MHPRVG												0.984	0.974
PRVG													0.991

Second year of study (2019-20)

AMMI analysis

Diversity of environments had been reflected by 70.6% whereas GxE interaction explained 14.2% and genotypes explained 1.4% of total sum of squares, of treatment variation in yield (Table 4). Further GxE interaction revealed that the first six multiplicative terms explained 55%, 18.8%, 10.4% , 9.1%, 3.0%, and 2.7% of interaction sum of squares, respectively. Approximately 98.9% of sum of squares was accounted by three PC's and 1.1 % were left for the residual.

Stability measures

Least value of absolute IPCA1 was expressed by G4, G2, G10 (Table 6). EV values anticipated stable performance of G2, G4, G7 genotypes. SIPC identified G2 followed by G4, G3 as the stable genotypes. Za revealed G3, G8 and G2 genotypes as of stable behaviour in descending order of stability. AMMI-based stability parameter (ASTAB) identified genotypes G2, G3 for stable performance in this study. ASV measure selected G3, G2, G8 genotypes. ASV1 settled for G3, G8, G2. MASV showed that G2, G3 and G4 were most genotypes and MASV1 considered G3, G2, G6 as genotypes of stable yield. WAASB measure had pointed towards by G3, G8 and G2 as desirable genotypes. Superiority index had observed lower values by genotypes G5, G9. Stable performance of genotypes G5, G1, G6 was assured by values of PRVG measure while MHPRVG measure selected G5, G1, G7 genotypes.

Ranking of genotypes as per AMMI measures and yield

IPCA1 measure considered HI8823, DDW47 and MP3288 genotypes (Table 8). EV measure identified HI8823, HI8627 and HI8627 for stable performance whereas as per SPIC values genotypes HI8627, UAS472 and HI8823 were favoured. Least values of ASV and ASV1 pointed towards HI8823, MP3288 and HI8627 wheat genotypes. Za measure settled for HI8823, DDW47 and UAS466 genotypes. More or less all measures identified HI8823, MP3288, and HI8627 genotypes for stable and high yield as per considered locations of this zone.

Modified AMMI stability value measure MASV along with MASV1 selected MP3288, HI8627, UAS472 genotypes of choice. WAASB measure observed suitability of UAS466, DDW47 and HI8627 wheat genotypes for the locations of this zone. Superiority index found HI8823, MP3288 and UAS472 as of stable performance. PRVG as well as MHPRVG measures observed suitability of HI8823, MP3288 & DBW110.

Biplot graphical analysis

Biplot graphical analysis considered the loadings of stability measures as per the first two significant principal component analysis (Table 10). The first two PCAs explained 83.3% of variation of the original variables. Three groups among the stability measures were seen (Fig. 2). SI was clubbed with ASTAB. Measures IPC1, Za, ASV, ASV1 formed a group. Yield was grouped with MASV, MASV1, PRVG, MASV1and MHPRVG measures. WAASB observed as outlier among stability measures.

Association analysis

Average yield of genotypes had positive values of higher magnitude with SI, MHPRVG and PRVG values along with moderate to weak with other stability measures (Table 12). All direct relations were maintained by MHPRVG and PRVG with other measures. Indirect relations of least values were expressed by SI measure whereas direct relations were of strong nature. Measure WAASB had exhibited direct relations with almost of the other measures. AMMI based measures, ASTAB, SIPC, EV, Za, ASV, ASV1, MASV, MASV1 expressed only positive correlation values within themselves and with others. Weak negative correlation of AMMI based measures with SI, MHPRVG, PRVG and yield were also observed.

CONCLUSIONS

AMMI analysis has been established as a role model under multi environmental trials tool to study GxE interaction effectively. Stability measures by simultaneous consideration of AMMI analysis and yield of wheat genotypes had expressed significant positive correlation among themselves. Measures SI, WAASB showed close proximity with measures i.e. MASI, MASV and SIPC which could be used to identify stable high-yielding genotypes.

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