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Biplot Analysis to Evaluate Wheat Performance and Adaptability in Multi-location Trials of Peninsular Zone

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ABSTRACT

Highly significant effects of environments (55.2%), genotype x environments interactions (19.3%) and genotypes (7.3%) were observed by AMMI analysis of twenty wheat genotypes evaluated at ten major locations of the peninsular zone during last cropping season. AMMI Stability Value had exploited the 62.8% of the interaction components had identified UAS3021, UAS3020, NIAW4183 whereas MASV and Superiority Index had settled for UAS3021, HD3469B, MACS3949 wheat genotypes. BLUP based measures analytic measures had settled for MACS6811, HI8826, UAS3020,NWS2222.Composite non parametric measure $NP_i^{(1)}$ and $NP_i^{(2)}$ had identified MACS6222, UAS3021, MACS3949,PWU15 for stable performance. Biplot analysis had observed PWU15, HI8841, HI8826, HD3469B, UAS3201 genotypes were placed at far places from the origin. Ninety degree association had observed of HMGV, HMGV* Meanb with $NP_i^{(4)}$ and SD values. AMMI based measures had also showed the ninety degree angles with rays corresponding to BLUP based analytic measures. Straight line angle of CV had observed with IPC3 and of IPC2 with rASV, IPC7 with HMGV, IPC6 with GAI measure.

Keywords: AMMI analysis, Biplot plots, BLUP and Non parametric measures

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INTRODUCTION

The crops improvement programs identify or release the high yielding genotypes every year across the zone of the country to sustain the production requirement of gowning population (Azam *et al*., 2023). Off course the main emphasis laid on the grain yield, and the performance need to be evaluated by statistical methods to identify promising wheat genotypes (Khalid *et al*., 2023). The agro climatic zones of the country were defined to represent homogeneous environmental conditions for crop cultivations with similar altitude, temperature, and soil types. It has been advocated to conduct the evaluation process and recommendation of genotypes in sub regions, because a more homogeneous region reduces the GxE interaction effects and provides more reliable and meaningful results (Mohammadi *et al*.,2023). In addition, evaluating the genotypes in specific environments allows the selection and recommendation of genotypes that exploit their maximum yield potential before release; promising genotypes would be tested under multi location testing procedure (Saeidnia *et al*., 2023). This GxE interaction effects is responsible for differences in genotype performance in different growing environments and also pose a challenge for plant breeders foridentifying and recommending genotypes (Hossain *et al*., 2023). Several univariate and multivariate AMMI analysis based measures are available that determine GxE interactions to recommend better performing and higher yielding genotypes across different environments (Pour-Aboughadareh *et al*., 2019; Saremirad and Taleghani 2022). The main types of analyses process for interpreting GxE interaction effects viz. Parametric, non-parametric methods and BLUP based analytic measures had reported in recent literature (Taleghani *et al*., 2023). Biplotanalysis have been established as good tools for selecting superior genotypes and to increase efficiency in selection. To be considered ideal, genotypes must present both high grain yield (GY) performance and stability among different environments. The study was planned to ascertain the degree of relationships among the different measures available for selecting suitable wheat genotypes for the peninsular zone after evaluation in multi environment trials.

MATERIALS AND METHODS

Twenty four wheat genotypes at ten locations of the peninsular plains zone were evaluated under field trials during the cropping season 2022-23 as details were reflected in Table 1. The balanced random block designs with four replications were used as the genotypes were evaluated at third and final stage before their recommendation for large area cultivation in the zone. The plot size at each location was 6 x 2.40 m^2 and the inner 12 rows of each genotype were considered for data recording to overcome the effect of border rows. The recommended fertilizer dose (kg/ha) 120:60:40 (N:P:K) was thoroughly mixed with soil and sowing was completed during November 05-15 with 100 kg per acre seed rate. The details of AMMI analysis, BLUP and Non

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parametric based measures mentioned in the literature were reflected below for ready reference as: (Zali et al. 2012; Vineeth, 2022):

AMMI Stability Value	$ASV = [(\frac{SSIPC\,1}{SSIPC\,2} PCI)^2 + (PC2)^2]^{1/2}$
Modified AMMI stability Value	$MASV = \sqrt{\sum_{n=1}^{N-1} \frac{SSIPC_n}{SSIPC_{n+1}} (PC_n)^2 + (PC_{n+1})^2}$
Harmonic Mean Genotypic Value	HMGV = Number of environments / $\sum_{j=1}^{k} \frac{1}{GV_{ij}}$ GV_{ij} genetic value of ith genotype in jth environments
Relative performance of genotypic values across environments	$RPGV_{ij} = \sum GV_{ij} / \sum GV_j$
Harmonic mean of Relative performance of genotypic values	$HMRPGV_{i.}$ = Number of environments / $\sum_{j=1}^{k} \frac{1}{RPGV_{ij}}$
Geometric Adaptability Index	$GAI = \sqrt[n]{\prod_{k=1}^{n} \bar{X}_k}$
Simultaneous selection index	SSI = R (AMMI stability indices) + RY
Weighted Average of Absolute Scores	$WAASB = \sum_{k=1}^{p} \lvert IPCA_{ik} \times EP_k \rvert / \sum_{k=1}^{p} EP_k$
Superiority index	$SI = \frac{(rG_i \times \theta_Y) + (rW_i \times \theta_S)}{(\theta_Y + \theta_S)}$;
Non parametric measures based on the ranks	
$S_i^{(1)} = \frac{2\sum_{j}^{n-1}\sum_{j'=j+1}^{n} \lvert r_{ij} - r_{ij'} \rvert}{[n(n-1)]}$	$S_i^{(2)} = \frac{\sum_{j=1}^{n} (r_{ij} - \bar{r}_{i.})^2}{(n-1)}$
$S_i^{(3)} = \frac{\sum_{j=1}^{n} (r_{ij} - \bar{r}_i)^2}{\bar{r}_{i.}}$	$S_i^{(4)} = \sqrt{\frac{\sum_{j=1}^{n} (r_{ij} - \bar{r}_i)^2}{n}}$
$S_i^{(5)} = \frac{\sum_{j=1}^{n} \lvert r_{ij} - \bar{r}_i \rvert}{n}$	$S_i^{(6)} = \frac{\sum_{j=1}^{n} \lvert r_{ij} - \bar{r}_i \rvert}{\bar{r}_{i.}}$
	$S_i^{(7)} = \frac{\sum_{j=1}^{n} (r_{ij} - \bar{r}_i)^2}{\sum_{j=1}^{n} \lvert r_{ij} - \bar{r}_i \rvert}$
Measures based ranks of corrected means of genotypes with average of ranks and median	
$NP_i^{(1)} = \frac{1}{n} \sum_{j=1}^{n} \lvert r_{ij}^* - M_{di}^* \rvert$	$NP_i^{(2)} = \frac{1}{n} \left(\frac{\sum_{j=1}^{n} \lvert r_{ij}^* - M_{di}^* \rvert}{M_{di}} \right)$
$NP_i^{(3)} = \frac{\sqrt{\sum (r_{ij}^* - \bar{r}_{i.}^*)^2 / n}}{\bar{r}_{i.}}$	$NP_i^{(4)} = \frac{2}{n(n-1)} \left[\sum_{j=1}^{n-1} \sum_{j'=j+1}^{m} \frac{\lvert r_{ij}^* - r_{ij'}^* \rvert}{\bar{r}_{i.}} \right]$

The recent and well known software's viz. Meta-R, AMMIsoft and SAS were used to analyse the research data generated under multi location evaluation of wheat genotypes.

Table 1: Locations and parentage details of wheat genotypes evaluated under timely sown conditions of zone

Code	Genotype	Parentage	Location	Latitude	Longitude	Altitude
PZTS101	PBW891#	NADI/COPIO//NADI	Niphad	20° 4' N	74° 6' E	551
PZTS102	NIAW4153	HUW-620/KINGBIRD	Pune	18° 31' N	73° 51' E	562
PZTS103	GW322	PBW173/GW196	Dhule			
PZTS104	HD3469B	HD2733/HD3043	Parbhani	19° 15' N	76° 46' E	413
PZTS105	AKAW5100	SelfromNATP2002-03DL-9-74-3	Nashik	19° 59 ' N	73° 47' E	583
PZTS106	DBW444B	MUNAL#1*2/4/HUW234+LR34/PRINIA//PBW343*2/KUKUNA/3/ROLF07*2/5/WBLL1*2/B RAMBLING*2//BAVIS	Karad	17° 17 ' N	74° 10' E	577
PZTS107	UAS3020	C306/UAS315/(92.001E7.32.5/SLVS/5/NS-732/HER/3/PRL/SARA//TSI/VEE#5/4/FRET2/6/SOKOLL/3/PASTOR//HXL7573/2*BAU)	Dharwad	15° 27' N	75° 0' E	724
PZTS108	HI8841	HI8713/HI8663	Ugar-Khurd	16° 39 ' N	74° 49' E	548
PZTS109	WH1306	CROC-1/AE.SQUARROSA(205)//BORL95/3/PRL/SARA//TSI/VEE#5/4/ FRET2/5/ CIRO16	Kalloli	16° 26 ' N	74° 86' E	625
PZTS110	MACS6809	MACS6222*2/HI1571	Nippani	16° 23 ' N	74° 22' E	606
PZTS111	MACS4100	5/KJOVE_1/7/AJAIA_12/F3LOCAL(SEL.ETHIO.135.85)//PLATA_13/8/SOOTY_9/RASCON _37//WODUCK/CHAM_3				
PZTS112	MP1378	18HRWYT218/DBW17				
PZTS113	MACS3949	STOT//ALTAR84/A LD/3/THB/CEP7780//2*MUSK_4				
PZTS114	AKAW5314	AKAW4656/UAS304				
PZTS115	NIAW4183	UP-2691/KINGBIRD				
PZTS116	DBW187	NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU				
PZTS117	PWU15	HW4059/HI2932				
PZTS118	MACS6222	HD2189*2/MACS2496				
PZTS119	UAS3021	SIALIA/4/PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI/5/SAUAL/3/C80.1/3*BATA VIA//2*WBLL1/4/SAUAL#1				
PZTS120	MP1386	UAS-2021/HI-8627				

RESULTS AND DISCUSSION

Highly significant effects of, environments, genotype x environments interactions and genotypes were observed by AMMI analysis of 24 wheat genotypes evaluated at ten major locations of the peninsular zone during 2022-23 cropping season (Table 1). Major share of variation accounted by environments effects 55.2% followed by GxE interactions 19.3% then 7.3% by genotypes (Table 2) as reflected by Jędzura *et al*. 2023. Interaction effects had been further partitioned into in to significant five IPC1, IPC2, IPC3, IPC4, IPC5 with their share as 45.9%, 16.9%, 14.9%, 7.9%, 5.8%, 2.6% respectively. A total of nearly 62.8% of interaction effects had been augmented by first two significant interaction components whereas the total of significant interaction components was of 91.4% in the current study as observed by Bocianowski and Prazak, 2022.

Table 2: Additive and multiplicative effects analysis of variance of AMMI model

Source	Degree of freedom	Sum of squares	Mean Sum of squares	Level of significance	Share of factors (%)	IPC's share (%)	Cumulative share of IPC's (%)
Treatments	239	106753.02	446.67	***	81.77		
Genotype (G)	23	9513.18	413.62	***	7.29		
Environment (E)	9	72000.41	8000.05	***	55.15		
GxE interaction	207	25239.43	121.93	***	19.33		
IPC1	31	11586.00	373.74	***		45.90	45.90
IPC2	29	4258.83	146.86	***		16.87	62.78
IPC3	27	3757.99	139.18	***		14.89	77.67
IPC4	25	1999.95	80.00	***		7.92	85.59
IPC5	23	1467.57	63.81	**		5.81	91.41
IPC6	21	876.11	41.72				
IPC7	19	561.34	29.54				
Residual	32	731.65	22.86				
Error	720	23802.46	33.06				
Blocks/Env	30	6130.20	204.34				
Pure Error	690	17672.26	25.61				
Total	**959**	**130555.48**	**136.14**				

Performance of genotypes as per AMMI analysis based measures

MACS6811, HI8826, UAS3020 genotypes had been ranked as higher yielders as compared to others evaluated wheat genotypes (Table 3). Lower values of IPC1 measure had pointed towards UAS3021, MACS3949, UAS3020 for stable performance among the locations of the zone while IPC2 measure had settled for GW322, DBW444B, UAS3021 and by values of IPC3 measure, genotypes PWU15, HD3469B, MACS6811 would be desirable ones. Minimum values of IPC4 had selected the MACS6809, MACS3949, MACS6811 wheat genotypes whereas values of IPC5 had settled for UAS3020, NIAW4153, AKAW5314 wheat genotypes. ASV measure had exploited the 62.8% of the interaction components based on fist two components of the study and identified the UAS3021, UAS3020, NIAW4183 genotypes whereas values of measure MASV while considering all the significant interaction components had settled for UAS3021, HD3469B, MACS3949 wheat genotypes as these measures highlighted by Karimizadeh *et al*., 2023. Superiority Index measure had selected the UAS3021, MACS3949, HD3469B wheat genotypes whereas as per values of W2 identified UAS3021, DBW444B, UAS3020 & UAS3021, MACS3949, NIAW4183 by W3 whereas as per values of W4 the genotypes UAS3021, MACS3949, HD3469B and UAS3021, MACS3949, HD3469B by W5 respectively.

Behaviour of genotypes as per BLUP and Non parametric measures

Average of BLUP's of genotypes evaluated over ten locations of peninsular zone had observed more values for MACS6811, HI8826, UAS3020 and the consistent performance had expressed by AKAW5314, DBW444B, NWS2222 and MACS4100, HI8841 DBW443 genotypes as evident from least values of standard deviation measure and coefficient of variation values (Table 4). HMRPGV method provides information on adaptability, stability, and yield in the same measured unit and on the same scale as the assessed trait. The lower the standard deviation of the genotypic behaviour at the locations, the greater will be the harmonic mean of their genotypic values across locations. Thus, selection for the highest values of HMGV allows a simultaneous selection for yield and stability as mention by Mohammadi *et al*. 2020a. GAI measure found the large values for MACS6811, HI8826, UAS3020 whereas as per HMGV measures the genotypes MACS6811, HI8826, UAS3020 had achieved more values as compared to other wheat genotypes. More values of RPGV and RPGV* Mean measures had been maintained by MACS6811, HI8826, UAS3020as observed by Mohammadi *et al*. 2020b and last two analytic measures HMRPGV & HMRPGV*Mean had settled for MACS6811, HI8826, NWS2222.

Rank based non parametric measure S_i^1 had favoured the PBW891, UAS3021, NWS2222 whereas S_i^2 found suitability of

Table 3: Locations and parentage details of wheat genotypes evaluated under timely sown conditions of zone

Genotype	Mean	IPC1	IPC2	IPC3	IPC4	IPC5	IPC6	IPC7	ASV	rASV	MASV	rMASV	W2	W3	W4	W5	W6	WAASB	rWAASB
PBW891	51.73	0.686	-0.074	-0.801	1.713	-0.657	0.054	-0.226	1.134	5	3.360	9	0.513	0.574	0.697	0.694	0.663	0.648	7
NIAW4153	50.04	-1.987	-1.230	0.794	-1.144	0.106	0.581	-1.641	3.501	19	4.740	17	1.774	1.567	1.521	1.409	1.368	1.377	18
GW322	51.14	-0.978	-0.012	-1.270	0.283	1.516	0.102	0.718	1.614	7	3.758	12	0.706	0.825	0.766	0.826	0.790	0.788	11
HD3469B	52.34	-0.599	0.181	0.053	0.624	-0.271	-1.238	-0.509	1.005	4	2.521	2	0.481	0.391	0.416	0.405	0.446	0.448	3
AKAW5100	50.37	-0.975	0.875	-1.153	1.552	-0.464	-0.850	0.748	1.831	12	4.089	13	0.947	0.990	1.051	1.004	0.997	0.988	13
DBW444B	43.55	-1.556	-0.027	0.346	1.237	0.236	1.125	0.248	2.567	14	3.742	10	1.125	0.961	0.991	0.931	0.940	0.917	12
UAS3020	53.54	-0.120	0.253	-2.181	-1.122	-0.090	-0.746	0.282	0.322	2	4.287	15	0.158	0.585	0.643	0.599	0.606	0.595	5
HI8841	52.19	2.444	-3.384	0.244	-0.128	-1.465	0.374	0.318	5.264	24	6.863	23	2.710	2.189	1.967	1.927	1.850	1.798	23
WH1306	51.18	0.949	0.496	0.512	0.295	-0.771	0.755	-0.013	1.642	10	2.643	5	0.821	0.756	0.706	0.711	0.713	0.690	9
MACS6809	47.46	0.865	1.406	2.035	-0.007	0.902	0.073	1.526	2.003	13	4.765	18	1.017	1.232	1.100	1.084	1.034	1.051	15
MACS4100	46.53	1.937	-0.177	-3.096	-1.412	0.561	0.694	-0.184	3.200	17	6.685	22	1.441	1.790	1.749	1.655	1.607	1.559	21
MP1378	51.55	1.664	1.842	1.600	-1.531	-0.824	0.617	0.233	3.305	18	5.525	20	1.714	1.690	1.673	1.605	1.557	1.512	20
MACS3949	50.09	0.031	-1.253	-0.422	0.018	-0.169	-1.019	0.107	1.254	6	2.571	3	0.376	0.385	0.345	0.331	0.365	0.357	2
AKAW5314	48.67	-2.816	0.245	0.428	-0.778	0.102	-0.825	-0.699	4.651	23	5.091	19	2.091	1.740	1.636	1.514	1.480	1.454	19
NIAW4183	50.09	-0.493	-0.540	0.639	0.805	-1.073	0.541	0.104	0.975	3	2.797	7	0.506	0.534	0.563	0.604	0.601	0.584	4
DBW187	44.70	-2.214	-1.174	0.617	-1.868	-0.861	-0.751	1.618	3.835	21	5.627	21	1.920	1.646	1.670	1.605	1.563	1.565	22
PWU15	42.18	-1.829	-0.714	0.016	0.446	0.477	1.866	-0.086	3.101	16	4.494	16	1.515	1.199	1.117	1.066	1.106	1.071	16
MACS6222	50.32	-1.029	0.143	-0.386	1.283	0.196	0.075	0.111	1.703	11	2.715	6	0.779	0.696	0.760	0.715	0.683	0.664	8
UAS3021	49.43	0.061	-0.036	0.715	-0.397	1.223	0.020	-0.571	0.107	1	2.487	1	0.054	0.194	0.216	0.296	0.282	0.292	1
MP1386	47.78	0.566	1.334	-0.534	-0.855	1.041	0.653	0.025	1.628	9	3.348	8	0.783	0.730	0.744	0.767	0.762	0.737	10
NWS2222	52.76	-0.532	1.356	0.391	-0.124	-0.614	-0.359	-0.641	1.615	8	2.631	4	0.764	0.685	0.625	0.624	0.611	0.612	6
MACS6811	55.34	1.279	1.715	0.058	0.122	-1.183	-0.699	-1.036	2.719	15	4.103	14	1.402	1.119	1.011	1.025	1.008	1.009	14
DBW443	51.05	2.186	0.390	-0.234	0.420	-0.140	0.238	-0.050	3.627	20	3.755	11	1.680	1.375	1.271	1.181	1.135	1.098	17
HI8826	53.64	2.460	-1.613	1.626	0.570	2.222	-1.277	-0.383	4.366	22	6.922	24	2.221	2.095	1.930	1.953	1.920	1.868	24

SD: Standard deviation; GAI: Geometric Adaptability Index; HMGV: Harmonic mean of Genotypic values; RPGV: Relative performance of genotypic values; HMRPGV: Harmonic mean of relative performance of genotypic values

Table 4: Non parametric and BLUP based analytic indexes

Genotype	S_i^1	S_i^2	S_i^3	S_i^4	S_i^5	S_i^6	S_i^7	$NP_i^{(1)}$	$NP_i^{(2)}$	$NP_i^{(3)}$	$NP_i^{(4)}$	Meanb	SD	CV	GAI	HMGV	RPGV	RPGV* Meanb	HMRP GV	HMRPGV *Meanb
PBW891	25.47	30.40	2.17	5.51	4.40	4.73	6.91	4.400	0.419	0.238	2.738	51.23	11.36	22.18	50.29	49.52	1.02	51.05	1.02	50.92
NIAW4153	82.67	45.56	3.30	6.75	6.00	5.00	7.59	6.000	0.462	0.215	6.889	50.22	8.74	17.40	49.55	48.90	1.01	50.54	1.00	49.96
GW322	58.40	37.85	2.80	6.15	5.10	4.81	7.42	5.100	0.425	0.225	5.509	50.63	9.10	17.98	49.95	49.32	1.02	50.79	1.01	50.50
HD3469B	34.40	24.25	1.80	4.92	4.10	4.94	5.91	3.900	0.520	0.257	4.145	51.81	8.60	16.59	51.24	50.72	1.04	52.01	1.04	51.87
AKAW5100	30.00	48.40	4.03	6.96	6.00	5.56	8.07	5.400	0.600	0.239	2.778	50.13	9.05	18.06	49.50	48.95	1.01	50.32	1.00	50.03
DBW444B	60.93	67.45	5.40	8.21	7.90	4.34	8.54	7.900	0.405	0.163	3.348	45.00	7.15	15.90	44.53	44.09	0.91	45.32	0.90	44.96
UAS3020	29.73	42.24	3.41	6.50	5.60	8.75	7.54	5.600	1.400	0.390	4.646	52.56	11.75	22.35	51.48	50.48	1.05	52.37	1.04	51.98
HI8841	42.27	98.56	7.14	9.93	9.64	9.94	10.22	8.600	1.323	0.337	4.357	52.46	16.45	31.36	50.38	48.52	1.04	51.60	1.01	50.53
WH1306	39.73	18.29	1.68	4.28	3.88	4.26	4.71	3.700	0.463	0.228	4.366	50.55	10.16	20.11	49.69	48.89	1.01	50.46	1.01	50.28
MACS6809	65.73	42.24	4.40	6.50	5.52	4.28	7.65	5.400	0.386	0.192	5.096	48.14	7.92	16.45	47.50	46.79	0.97	48.39	0.96	47.89
MACS4100	70.93	49.09	4.96	7.01	5.70	3.90	8.61	5.700	0.326	0.172	4.858	47.22	15.48	32.79	44.99	42.78	0.93	46.35	0.90	44.73
MP1378	91.87	64.84	6.23	8.05	7.48	8.80	8.67	6.800	1.511	0.339	10.808	50.55	10.50	20.77	49.46	48.25	1.01	50.54	1.00	49.69
MACS3949	29.07	23.04	1.72	4.80	3.88	3.34	5.94	3.800	0.362	0.179	2.506	50.44	10.71	21.23	49.53	48.72	1.01	50.26	1.01	50.15
AKAW5314	84.67	45.25	3.12	6.73	5.40	3.80	8.38	5.300	0.342	0.172	5.962	49.07	7.00	14.26	48.63	48.19	1.00	49.70	0.98	48.95
NIAW4183	36.67	32.01	2.41	5.66	4.96	4.24	6.45	4.700	0.427	0.201	3.134	50.27	9.26	18.42	49.59	49.00	1.01	50.36	1.01	50.19
DBW187	63.87	74.16	6.08	8.61	8.04	4.79	9.22	7.600	0.390	0.178	3.802	46.42	9.01	19.41	45.58	44.70	0.94	46.62	0.92	45.81
PWU15	74.53	63.05	4.67	7.94	7.10	3.62	8.88	7.100	0.309	0.143	3.803	43.88	8.21	18.72	43.21	42.57	0.88	44.04	0.87	43.57
MACS6222	48.53	24.64	1.84	4.96	3.84	3.17	6.42	3.600	0.267	0.171	4.011	49.97	8.37	16.75	49.41	48.91	1.01	50.18	1.00	50.00
UAS3021	25.60	23.56	1.93	4.85	3.96	3.19	5.95	3.800	0.271	0.169	2.065	49.53	8.17	16.49	48.96	48.43	1.00	49.67	1.00	49.59
MP1386	50.53	40.25	3.83	6.34	5.90	4.31	6.82	5.900	0.421	0.187	3.689	47.84	9.41	19.67	47.02	46.21	0.96	47.81	0.95	47.52
NWS2222	29.07	26.89	1.91	5.19	4.30	5.12	6.25	4.300	0.538	0.260	3.460	51.84	7.62	14.70	51.39	50.97	1.05	52.18	1.04	52.01
MACS6811	53.73	60.00	4.62	7.75	7.00	14.00	8.57	6.800	1.700	0.558	10.747	53.76	10.89	20.25	52.85	52.00	1.08	53.77	1.07	53.37
DBW443	86.40	35.44	3.11	5.95	5.08	5.64	6.98	5.000	0.667	0.264	9.600	50.56	12.58	24.87	49.18	47.80	1.01	50.17	0.99	49.49
HI8826	54.00	86.96	7.13	9.33	8.80	11.89	9.88	8.800	2.514	0.423	7.297	53.56	13.24	24.72	52.11	50.68	1.07	53.29	1.05	52.34

Meanb : Average of BLUP ; rASV, rMASV and rWAASB: Rank of genotypes for ASV, MASV and WAASB values

Table 5: Loadings of measures and genotypes based on significant principal components

Measures	Contribution in PC1	Contribution in PC2	Measures	Contribution in PC1	Contribution in PC2	Genotype	Contribution in PC1	Contribution in PC2
Mean	-0.046	0.299	SD	0.114	0.125	PBW891	-0.178	0.078
IPC1	0.061	0.155	CV	-0.111	-0.080	NIAW4153	0.104	0.005
IPC2	-0.088	0.008	GAI	-0.060	0.295	GW322	-0.096	0.012
IPC3	0.044	0.029	HMGV	-0.087	0.277	HD3469B	-0.271	0.131
IPC4	-0.089	0.027	RPGV	-0.045	0.299	AKAW5100	-0.039	0.021
IPC5	0.005	-0.063	RPGV*Meanb	-0.045	0.299	DBW444B	0.071	-0.357
IPC6	0.032	-0.183	HMRPGV	-0.074	0.289	UAS3020	-0.118	0.229
IPC7	0.031	-0.102	HMRPGV*Meanb	-0.074	0.289	HI8841	0.413	0.213
ASV	0.217	0.002	S_i^1	0.153	-0.092	WH1306	-0.191	0.021
rASV	0.216	-0.012	S_i^2	0.220	0.004	MACS6809	0.026	-0.145
MASV	0.227	0.020	S_i^3	0.222	0.006	MACS4100	0.228	-0.243
rMASV	0.224	0.011	S_i^4	0.221	0.012	MP1378	0.244	0.117
W2	0.221	0.018	S_i^5	0.214	0.016	MACS3949	-0.254	0.000
W3	0.231	0.018	S_i^6	0.118	0.238	AKAW5314	0.122	-0.078
W4	0.231	0.008	S_i^7	0.219	0.022	NIAW4183	-0.191	-0.008
W5	0.232	0.018	$NP_i^{(1)}$	0.213	0.006	DBW187	0.267	-0.255
W6	0.233	0.015	$NP_i^{(2)}$	0.121	0.231	PWU15	0.138	-0.451
WAASB	0.233	0.015	$NP_i^{(3)}$	0.067	0.267	MACS6222	-0.189	-0.042
rWAASB	0.231	-0.011	$NP_i^{(4)}$	0.116	0.141	UAS3021	-0.301	-0.071
Meanb	-0.032	0.303	% share of factors (71.39%)	44.58%	26.81%	MP1386	-0.068	-0.167
						NWS2222	-0.222	0.128
						MACS6811	0.071	0.429
						DBW443	0.059	0.052
						HI8826	0.374	0.379

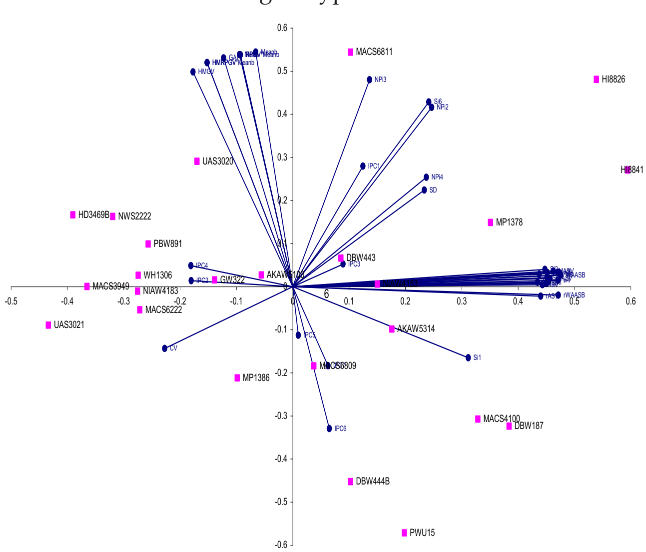
WH1306, MACS3949, UAS3021 genotypes while S_i^3 had identified WH1306, MACS3949, HD3469B genotypes as used by Saremirad and Taleghani, 2022. Minimum values of S_i^4 had been expressed by WH1306, MACS3949, UAS3021 genotypes. Measure S_i^5 had identified MACS6222, MACS3949, WH1306 and values of S_i^6 had pointed out for MACS6222, UAS3021, MACS3949 and last measure S_i^7 had settled for WH1306, MACS3949, UAS3021 genotypes. Value of first composite non parametric measure based on the ranks of genotypes as per yield and corresponding corrected yield values pointed for $NP_i^{(1)}$ had identifiedMACS6222, UAS3021, MACS3949 and as per values of $NP_i^{(2)}$ measure theMACS6222, UAS3021, PWU15 would be of stable performance. Genotypes PWU15, DBW444B, UAS3021 preferred by values of $NP_i^{(3)}$ while least values of $NP_i^{(4)}$ had expressed by UAS3021, MACS3949, PBW891 genotypes.

Biplot analysis of genotypes and measures of the study

Table 5 had explained that the first two principal components had accounted up to 71.4% of total variation among data values (Shojaei *et al*., 2021). First component had contributed to the tune of 44.6% whereas the second component had augmented up to 26.8%. More values of loadings for the first component had expressed by WAASB, W6, W5, W4, W3,rWAASB MASV while for the second components major share contributed by Meanb, Mean, RPGV, RPGV* Meanb, GAI, HMRPGV, HMRPGV* Meanb measures. In terms of genotypes contribution for the first components HI8841, HI8826, UAS3021 were large contributors and genotypes PWU15, MACS6811, HI8826 had expressed more shares in second component.

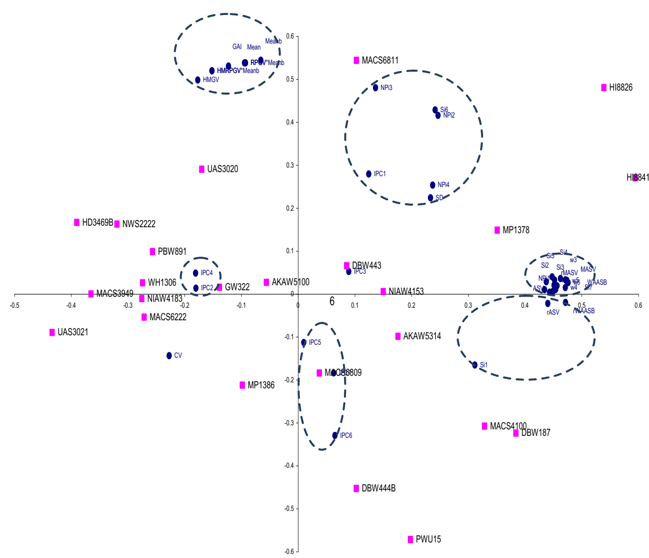
Genotypes PWU15, HI8841, HI8826, HD3469B, UAS3201 were placed at far places from the origin in the biplot analysis based on first two principal components (Fig.1) as found by Olivoto *et al.* 2019. Shorter rays of IPC3, IPC5, IPC7 had expressed their least share in interaction variations as compared to rays pertaining to BLUP based analytic measures. Highly tight association had observed for rASV and rWAASB values and direct relation with S_i^1 measure.

Fig. 1: Biplotanalysis for the genotypes and measures for evaluated wheat genotypes



AMMI analysis based measures W2, W3, W4, W5, WAASB, ASV, MASV had expressed very strong association among themselves whereas the measure S_i^6 had maintained direct relation with $NP_i^{(2)}$, $NP_i^{(4)}$, SD measures on one side and with IPC1, $NP_i^{(3)}$ on other side. Measure GAI had exhibited strong direct association with other BLUP based analytic measures of the current study. Ninety degree association had observed of HMGV, HMGV* Meanb with $NP_i^{(4)}$ and SD values. Similar type of nature had expressed by S_i^1 with $NP_i^{(3)}$ values and of IPC6 with SD as well as with CV values. AMMI based measures had also showed the ninety degree angles with rays corresponding to BLUP based analytic measures. Straight line angle of CV had observed with IPC3 ray and IPC2 with rASV, IPC7 with HMGV, IPC6 with GAI measure. First quadrant with negative values of first and second principal components found only CV measure alone and the next quadrantobserved the cluster of IPC5, IPC6, IPC7 and of rASV, rWAASB & S_i^1 measures (Fig.2). Large cluster ofS_i^2, S_i^3, S_i^4, S_i^5, S_i^7 W2, W3, W4, W5, WAASB, ASV, MASV, $NP_i^{(1)}$ measures found in third quadrant along with another cluster of S_i^6, $NP_i^{(2)}$$NP_i^{(3)}$, $NP_i^{(4)}$,IPC1, IPC3 values. Last cluster of BLUP based analytic measures GAI, HMGV, HMPRVG, HMGV*Meanb, HMPRVG*Meanb placed in fourth quadrant.

Fig. 2: Association analysis among the measures based on two principal components



CONCLUSION

Highly significant effects of environments, genotype x environments interactions and genotypes were observed by AMMI analysis of twenty wheat genotypes evaluated at ten major locations of the peninsular zone. AMMI Stability Value had identified the UAS3021, UAS3020, NIAW4183 whereas MASV along with Superiority Index measure had settled for UAS3021, HD3469B, MACS3949. BLUP based measures had settled for MACS6811, HI8826, UAS3020 NWS2222. Composite non parametric measure $NP_i^{(1)}$ and$NP_i^{(2)}$ had identifiedMACS6222, UAS3021, MACS3949 and PWU15. Biplot analysis had observed strong direct association of GAI with other BLUP based analytic measures. AMMI based measures had also showed the ninety degree angles with rays corresponding to BLUP based analytic measures. Straight line angle of CV had observed with IPC3 ray and IPC2 with rASV, IPC7 with HMGV, IPC6 with GAI measure.

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CONFLICT OF INTEREST

All the author both individually and collectively, affirms that they do not possess any conflicts of interest either directly or indirectly related to the research being reported in the publication.

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