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Durum Wheat Genotypes Stratification by AMMI Analysis for Irrigated Conditions of Central Zone

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Abstract: *Genotypes, environment and genotype x environment interaction showed highly significant effects as per AMMI analysis of 7 durum genotypes evaluated at 17 locations. First four highly significant interaction principal components (IPC1, IPC2, IPC3 and IPC 4) accounted 88% of GxE interaction sum of squares. The environment mean yield varied from 22.2 q/ha at Bardoli to 70.7 q/ha at Powerkheda. The average yields of the genotypes ranged from 47.7 q/ha for MPO 1215 to 54.3 q/ha for HD 4728. Genotypes HI 8737 and HI 8498 showing low AMMI stability value (ASV) & considered most stable. The highest ASV of genotypes was observed for MPO 1215 and HI 8750 hence would be unstable. Mean yield and Geometric adaptability index (GAI) pointed out genotypes HD 4728 and HD 4730 with higher values respectively. Genotypes HI8498 and HI 8737 had observed as desirable ones based on dynamic stability judged by Wricke's ecovalence. Genotypes HD4728 ranked first by mean yield, GAI and cultivars superiority whereas HD4730 identified by AMMI distance (D). Genotypes HD4730, HI8737 and HI8498 were the most stable genotypes whereas HI8758 was the unstable genotype based on SIPC4 parameter. MASV indicated that genotypes HI8498, HD4728 and HD4750 were most stable with relatively higher yield.*

***Key words**: GxE effects, AMMI, AMMI stability value, AMMI distance, MAS,SIPC4*

INTRODUCTION

Durum wheat (*Triticum turgidum* L.) cultivated for the production of high quality pasta and other derived products. Utility of additive main effect and multiplicative interaction (AMMI) approach for evaluation of genotypes x environment interaction had been exploited worldwide. The principal components analysis and analysis of variance have been merged into this approach and very well used for the multi-location experiments analysis [26]. AMMI analysis has been applied to interpret genotype × environment interaction in wheat [16], [17], [9], [15] and [11].

Number of parameters to study GxE interaction had defined based on AMMI analysis. One of the quite popular ASV (AMMI stability value) has been calculated from the first two IPCs scores [20]. Moreover, it's modified version i.e. MASV have several advantages over other AMMI based parameters [10]. Sabaghnia et al. [21] reported ASV as good dynamic criteria for detecting stable genotypes. Karimizadeh *et al.* [8] revealed that ASV and MASV were repeatable parameters and had high significant correlation with grain yield. Another reason for the popularity of two AMMI parameters is for explaining the dynamic concept of stability and would be useful for simultaneous selection of yield and stability. ASV and MASV parameters offer reliable statistic to describe GxE interaction [2].This study tried to evaluate the significance and magnitude of GxE interaction effect of durum genotypes by AMMI to point out the promising genotypes as per environmental conditions.

MATERIALS AND METHODS

The seven durum wheat genotypes were evaluated at 17 environmental conditions, viz Anand, Amreli,

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Bardoli, Junagarh, SK Nagar, Vijapur, Gwalior, Indore, Jabalpur, Powarkheda, Bhopal, Rewa, Sagar, Banswara, Udaipur, Bilaspur and Raipur during 2013-14 under all India coordinated wheat and barley improvement programme. The particular characteristics of studied sites have been listed in Table 2 for ready reference. The Randomized Complete Block Design experimental design employed, with three replications. All the recommended cultural practices have carried out to harvest good yield. Software Genstat 17.1 had utilized for AMMI analysis.

The AMMI distance statistic coefficient (D) [25] was calculated based on the distances of the interaction principal component (IPC) point from the origin in space. The genotype with the lowest value of D statistic considered as the most stable.

AMMI Distance (D_i) = $\sqrt{\Sigma_{i=1}^{n} \gamma_{is}^{2}}$ (i= 1, 2, 3,.. n)

Purchase *et al.* [18] developed the AMMI stability value (ASV) based on the AMMI model's IPC1 and IPC2 scores for each genotype.

AMMI Stability Value (ASV) =

$$\sqrt{\left[\frac{SSIPCA1}{SSIPCA2} * IPCA1\ score\right]^2 + IPCA2\,score^2}$$

where SSIPCA1 and SSIPCA2 are sum of squares by the IPCA1, IPCA2 respectively

The genotypes with the lowest ASV value would be more stable. Geometric adaptability index (GAI) [12] was used to evaluate the adaptability of genotypes. The genotypes with the higher GAI value would be desirable.

Geometric Adaptability Index (GAI) =

$$\sqrt[n]{\Pi_{k=1}^{n} \overline{X}_k}$$

in which $\overline{X}_1, \overline{X}_2, \overline{X}_3, ...\overline{X}_m$ are the mean yields of the first, second and mth genotype across environments and n is number of environments.

For effective interpretation of GxE interactions via AMMI model a new parameter as modified AMMI's stability value (MASV) introduced by Adugna and Labuschange [1] as follows:

$$\text{MASV} = \sqrt{\Sigma_{n=1}^{N-1}\left(\frac{SSIPC_n}{SSIPC_{n+1}}\right)(IPC_n^2) + (IPC_{n+1}^2)}$$

where $SSIPC_n$ and $SSIPC_{n+1}$ are sum of squares by the IPC_n, IPC_{n+1} respectively. In this modified AMMI stability parameter, all significant IPCs were used.

Sum of IPC scores (SIPC) proposed by Sneller *et al.* [22] expressed as:

$$\text{SIPC} = \Sigma_{n=1}^{N} \gamma_{in} \lambda_n^{0.5}$$

where γ_{in} is the genotype eign value for axis n and λn is the eigen value of the IPC analysis axis n. In this equation N=1 for SIPC1; for SIPC4, 4 was the number of IPC that were retained in the AMMI model.

AMMI derived parameters were compared with Wricke [24] dynamic stability criterion for quantifying G x E interaction effects.

RESULTS AND DISCUSSION

AMMI analysis

The additive main effects and multiplicative interaction analysis (Table 2) of yield showed that highly significant effects for genotypes, environment and genotype by environment interaction at $P<0.001$. The environmental effects attributed largely as 76.5% of total sum of squares of the model. The diversity of environments proved by large sum of squares and the large differences among environmental means causing most of the variation in durum yield [19] and [5]. The significance of interaction indicates that each of the genotype interacted differently at each location [3], [4]. IPCA scores of genotypes and environments showed both positive and negative values (Table 4 & 5). As genotype has large positive IPCA score with some environment also has negative interactions with remaining environments. These values presented a disproportionate genotype response across environments [14], which was the major source of variation for any crossover interaction. The interaction sum of squares had partitioned further into the IPCA1, IPCA2, IPCA3and IPCA4; which explained 29.8, 25.4 21.3 and 11.4% of the interaction sum of squares, respectively. The four interaction principal components explained 88% the interaction sum of squares. Similar case mentioned by Anandan *et al.* [3] that 74.3% of the interaction sum of squares was explained by IPCA1.

Average yield

The genotype and the environment means are presented in two way table 3. The environment yield means (averaged over genotypes) varied from 22.2 q/ha at Bardoli to 70.7 q/ha at Powerkheda as large yield variation explained by environments. The small portion of the total sum of squares i.e.6.8% was attributed by genotypic effects. The yields of the genotypes (mean over environments) varied from 47.7 q/ha for G7 (MPO 1215) to 54.3 q/ha for G5 (HD 4728).The yield of HD4728 had shown maximum yield value at 6 locations followed by HD 4730 at four locations. Other genotypes observed as high yielder at most two locations only.

ASV

The genotypes with least ASV values are the stable in comparison to genotypes with high ASV score [7], [6]. The genotypes HI 8737 and HI 8498 showing low ASV and considered most stable in the present study. The highest ASV of genotypes was observed for MPO 1215 and HI 8750 may be unstable. Stability in itself should, however, not be the only parameter for selection, as the most stable genotype would not necessarily give the best yield performance [13]. In this study, for example, HI 8737 which had the lowest ASV had yield (49.78q/ha) lower than the HD 4728 (54.32q/ha). The selection of genotype HI 8737 based on ASV *per se*, there would be chances of yield reduction.

AMMI distance

The estimate of the stability index ‘D’ incorporates the scores of significant IPCA towards the interaction SS [25] and the lower D values indicate stabile yield performance across the tested environments and vice versa. The ranking of genotypes in ascending order of ‘D’ values was those in HD4730 (2.06) < HI8498 (2.23) < HI8737(2.71). Genotype with lowest yield MPO 1215 exhibited largest D values 3.99.

Table 1
Details of durum genotype, parentage and environmental conditions

Code	*Genotype*	*Parentage*	*Code*	*Environments*	*Latitude*	*Longitude*
G1	HI 8737	HI8177/HI8158//HI8498	E1	Anand	22° 35' N	72° 55' E
G2	HD 4730	ALTAR84/STINT//SILVER45	E2	Amreli	21°35′ N	71°12′ E
G3	HI 8750	HG822/HI8498	E3	Bardoli	21° 07' N	73° 06' E
G4	HI 8736	HI8416/SARANGPUR LOCAL/HD4672	E4	Junagarh	21° 31′ N	70° 33′ E
G5	HD 4728	ALTAR84/STINT//SILVER_45/3/ SOMAT_3.1/4/GREEN_14//YAV_10/ AUK	E5	SK Nagar	24° 19' N	72° 19' E
G6	HI 8498	RAJ6070/RAJ911	E6	Vijapur	23°35′ N	72°55′ E
G7	MPO 1215	GW1113/GW1114/lHI8381	E7	Gwalior	26° 13′ N	78° 14′ E
			E8	Indore	22°37′N	75°50′ E
			E9	Jabalpur	23°90′ N	79°58 ′E
			E10	Powarkheda	22° 44′N	77° 42′ E
			E11	Bhopal	23°25′N	77°41′E
			E12	Rewa	24° 31' N	81° 15' E
			E13	Sagar	24° 27′ N	78° 21′ E
			E14	Banswara	23°33′N	74°27′E
			E15	Udaipur	24° 34′ N	70°42′E
			E16	Bilaspur	22° 9′ N	82° 12′ E
			E17	Raipur	21°16′ N	81°36′ E

Table 2
AMMI analysis of durum genotypes over locations

Source	*Degree of freedom*	*Sum of squares*	*Variance ratio*	*% TSS*	*% GxE*
Treatments	118	58354	26.26**	88.59	
Genotypes	6	1984	17.55**	3.01	
Environments	16	50424	91.66**	76.55	
Block	51	1753			
Interactions	96	5947	3.29**	9.03	
IPCA 1	21	1772	4.48**		29.80
IPCA 2	19	1512	4.22**		25.42
IPCA 3	17	1268	3.96**		21.32
IPCA 4	15	680	2.41**		11.43
Residuals	24	715			
Error	306	5763			
Total	475	65871			

** denotes significance at 1% level of significance

%TSS: percentage of total sum of squares, % GxE: percentage of GxE total sum of squares

Table 3
Average yield of durum wheat genotypes across 17 environments

Genotype	*HI 8737*	*HD 4730*	*HI 8750*	*HI 8736*	*HD 4728*	*HI 8498*	*MPO 1215*	*Average*
Anand	48.41	47.05	42.76	48.7	**50.7**	43.58	34.55	45.11
Amreli	51.55	56.15	49.35	**57.38**	54.08	51.5	50.5	52.93
Bardoli	16.96	22.92	**27.92**	22.0	26.58	20.08	18.96	22.2
Junagarh	59.66	54.22	54.01	61.88	**63.57**	56.63	52.58	57.51
SK Nagar	44.4	42.84	42.27	40.27	45.85	41.24	**47.99**	43.55
Vijapur	56.73	55.68	61.13	61.08	**63.0**	59.15	55.83	58.94
Gwalior	46.49	55.4	**57.04**	42.7	55.98	44.7	38.54	48.69
Indore	50.01	**57.05**	52.22	55.17	57.61	47.7	48.32	52.58
Jabalpur	53.83	**57.69**	53.75	57.33	55.26	57.18	54.37	55.63
Powarkheda	68.13	**77.25**	75.81	65.25	68.75	64.94	74.63	**70.68**
Bhopal	52.42	56.14	50.14	54.0	**57.48**	50.19	51.13	53.07
Rewa	56.2	53.5	54.8	56.1	54.8	54.2	**57.8**	55.34
Sagar	39.25	37.75	40.88	37.63	38.75	**45.38**	39.88	39.93
Banswara	52.5	67.5	57.5	67.5	**75.0**	60.0	61.75	63.11
Udaipur	58.78	**61.93**	49.55	51.1	57.55	57.68	46.15	54.68
Bilaspur	43.45	49.05	46.63	43.95	45.68	**49.1**	37.93	45.11
Raipur	47.5	48.88	49.0	48.88	**52.88**	43.0	39.5	47.09
Average	49.78	53.0	50.87	51.23	**54.32**	49.78	47.67	

SIPC4

The values of the SIPC4 parameter could be useful in identifying genotypes expressing stable performance [10] and so HD4730, HI8737 and HI8498 were the most stable genotypes whereas HI8758 was the unstable genotype. It is interesting that stable genotypes HI8736 and HD4728 according this parameter had higher mean yield.

MASV

The AMMI model in this study indicated that there was a more complex interaction of GE and it could not facilitate graphical visualization of the genotypes in low dimensions and so it is essential to use an alternative procedure to interpretation of GE interaction using AMMI parameters [21]. Simultaneous assessment of four IPCs scores of the AMMI method for durum wheat genotypes facilitates the interpretation of GE interaction and identification of superior genotypes[10]. The results of MASV indicated that genotypes HI8498, HD4728 and HD4750 were most stable which had relatively higher mean yield performance, whereas genotype MPO1215 was unstable genotype with lower yield (Table 4). MASV parameter introduced some of the high mean yielding genotypes (HD4728 and HD4730) as the most stable ones

In the last the mean yield and GAI estimates pointed out genotypes HD 4728 and HD 4730 with higher values respectively (Table 4). Wricke's ecovalence cretria based on dynamic stability observed HI 8498 and HI 8737 as desirable one.

Table 4
AMMI and derived estimates of durum genotypes across 17 environments

Genotype	*HI 8737*	*HD 4730*	*HI 8750*	*HI 8736*	*HD 4728*	*HI 8498*	*MPO 1215*
Gm	49.78	53.00	50.87	51.23	54.32	49.78	47.67
GAI	48.13	51.48	49.87	49.73	53.05	48.44	45.88
W	182.4	185.8	242.6	184.1	203.6	157.4	330.7
IPCA1	-0.082	1.009	-0.697	1.176	2.477	-0.444	-3.438
IPCA2	0.429	-1.777	-2.978	2.370	0.176	0.883	0.895
IPCA3	-2.675	0.264	0.166	0.835	1.605	-2.003	1.808
IPCA4	-0.119	-2.727	2.090	0.753	0.498	0.126	-0.621
ASV	0.44	2.13	3.09	2.74	2.90	1.02	4.12
D	2.71	2.06	3.06	2.77	2.96	2.23	3.99
SIPC4	-2.45	-3.23	-1.42	5.13	4.76	-1.44	-1.36
MASV	4.57	3.97	4.95	4.06	3.86	3.67	5.04

Gm - Mean Yield ,GAI- Geometric Adaptability Index , ASV- AMMI Stability Value , D- AMMI Distance , W- Wricke's Ecovalence, SIPC4 – Sum of 4 IPC; MASV-Modified AMMI stability value

Table 5
Average yield of environments with IPC values

Code	*Environment*	*Average yield*	*IPCA1*	*IPCA2*	*IPCA3*	*IPCA4*
E1	Anand	45.11	1.695	0.528	-1.038	0.238
E2	Amreli	52.93	0.010	0.939	0.126	-0.692
E3	Bardoli	22.2	-0.134	-0.947	0.825	1.246
E4	Junagarh	57.51	0.652	1.544	-0.375	0.959
E5	SK Nagar	43.55	-1.664	0.341	0.293	-0.258
E6	Vijapur	58.94	-0.197	0.418	0.110	1.624
E7	Gwalior	48.69	1.242	-2.914	-0.018	0.474
E8	Indore	52.58	0.694	-0.126	0.818	-0.330
E9	Jabalpur	55.63	-0.686	0.615	-0.294	-0.416
E10	Powarkheda	70.68	-1.978	-1.862	0.826	-1.018
E11	Bhopal	53.07	0.117	0.427	0.362	-0.677
E12	Rewa	55.34	-1.551	0.759	-0.118	0.327
E13	Sagar	39.93	-1.586	0.333	-1.075	0.632
E14	Banswara	63.11	1.291	1.003	2.775	-0.837
E15	Udaipur	54.67	0.890	-0.113	-1.989	-1.896
E16	Bilaspur	45.11	0.158	-0.575	-1.182	-0.090
E17	Raipur	47.09	1.049	-0.372	-0.044	0.716

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