Journal of Crop and Weed, 15(2): 09-17 (2019)
ISSN- O : 2349 9400 ; P : 0974 6315
http://cwssbckv.org
www.cropandweed.com

Parameters of AMMI model to analyse GxE of feed barley trials

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Received : 15.04.2019 ; Revised : 21.05.2019 ; Accepted : 23.05.2019

ABSTRACT

Highly significant GxE interaction for feed yield was partitioned into signal 93.03 and noise 6.97per cent. AMMI model recommended usage of seven significant IPCAs accordingly Finally type 1 of AMMI measures (EV1, ASTAB1, SIPC1, D1), considered G19, G21, G13, G29 as desirable genotypes and G10 as of unstable performance; based on the type 2 (EV2, ASTAB2, SIPC2, D2 and ASV) G16, G21 were genotypes of choice and G10 as unsuitable; as per type 3 (EV3, ASTAB3, SIPC3 and D3), G16, G7, G5, G13 were stable genotypes and G26 of unstable type; according to the type 5 (EV5, ASTAB5, SIPC5 and D5), genotypes G23, G3, G5, G25 were of choice and G10 & G21 were not recommended; lastly based on the type 7 (EV7, ASTAB7, SIPC7 and D7), genotypes G4, G15, G2, G6 and G12 and G27 were detected as the unstable genotypes. AMMI based measures showed genotypes G25 and G13 had the good yield performance while the yield performance of G17 and G4 were of low yield. Clustering of measures with yield expressed three groups. Largest group I contains yield with SIPC1, SIPC2, SIPC3, SIPC5, SIPC7 as well as ASTAB2, ASTAB3 ASTAB5, ASTAB7 along with IPAC1 measures.

Keywords: AMMI, ASTAB, ASV, D, multi-environment trials and SIPC

Primarily barley is used for malt / beer production, and secondarily used as animal feed. Barley unable to meet malt quality standards often are utilized as feed for livestock, although some barley is produced solely as feed for animals, either as a grain or hay forage (Mortazavian *et al.,* 2014). In recent years, research dedicated to the development of feed varieties. Observed yield from on an individual is known as the phenotypic value and division of this phenotypic value into components attributable to the influence of genotype and environment is necessary to judge the real potential of genotype (Crossa *et al.,* 1990; Dehghani *et al.,* 2010). Multi location trials play an important role in the testing of GxE interaction and for specific/general adaptability of varieties (Akbarpour *et al.,* 2014). Numbers of statistical methods are available in literature with aim to subdivide the complex GxE interaction into simpler and more meaningful components to represent the pattern and random variation *i.e.* the noise (Tekdal & Kendal, 2018; Sabaghnia *et al.,* 2012). Methods vary from univariate models, such as regression slope (Yau 1995) and environmental variance (Flores *et al.,* 1998), to multivariate models such as additive main effect and multiplicative interaction (AMMI) analysis. AMMI analysis separates the additive variance from the multiplicative variance and then applies principal component analysis (PCA) to the interaction portion to explain interaction pattern in more details (Karimizadeh *et al.,* 2016; Kendal and Tekdal, 2016). Averages of the squared eigen vector (EV) values introduced as the AMMI stability parameter (Zobel, 1994). AMGE and SIPC stability parameters of AMMI model to describe the contribution of environments to GxE interaction suggested by Sneller *et al.* (1997). AMMI stability value (ASV) benefits from the first two IPCA of AMMI analysis (Purchase, 1997). The Euclidean distance from the origin of significant interaction IPCA axes as D parameter was suggested by Annicchiarico (1997). Any of these measures may also be of interest for breeding programs as an alternative to the conventional stability methods such as joint linear regression model (Kilic 2014). The prime objective of this study was to evaluate the effect of GxE interaction on the feed yield of barley genotypes by AMMI based measures.

MATERIALS AND METHODS

Research field trials of thirty promising feed barley genotypes were conducted at twelve major barley producing locations of the country during cropping season 2017-2018. Randomized complete block design with four replications were laid out to estimate GxE interaction. All recommend agronomic practices were followed to harvest the good crop. More over feed yield was analysed further by AMMI model. The description of widely used measures based on AMMI analysis was mentioned in this article for completeness.

AMMI model computations were performed by software MATMODEL version 3.0 (Gauch, 2007) and SAS software version 9.3.

RESULTS AND DISCUSSION

Highly significant effects of genotypes, environments and their interactions (GxE) were observed (Table 2). Significance of GxE interactions justified complicated GE interaction (both crossover and non-crossover types) in genotypes. Larger magnitude of GxE interaction for feed yield is similar to other yield analysis of crops (Mohebodini *et al.,* 2006; Sabaghnia *et al.*, 2008a). Further, total GxE (63587.14) was partitioned into GxE noise (4435.05) that is 6.97% and GxE signal (59152.08)

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Measures based on AMMI analysis				
Zobel	1994	EV1	EVF	$\mathrm{EV} = \sum_{n=1}^{N} \lambda_{in}^{2} / n$
Sneller *et al*	1997	SIPC1	SIPCF	$\mathrm{SIPC} = \sum_{n=1}^{N} \lambda_{n}^{0.5} \gamma_{in}$
Purchase	1997	ASV		$\mathrm{ASV} = \left[\frac{SSIPC1}{SSIPC2} (PCI)^2 + (PC2)^2 \right]^{1/2}$
Annicchiarico	1997	D		$\mathrm{D} = \sqrt{\sum_{n=1}^{N} (\lambda_n \gamma_{in})^2}$
Rao and Prabhakaran	2005	ASTB		$\mathrm{ASTAB} = \sum_{n=1}^{N} \lambda_n \gamma_{in}^{2}$
Rao and Prabhakaran	2005	I_i stability indexes		$I_i = \frac{Y_i}{\mu} + \alpha \frac{1/ASTAB_i}{\left(\sum_{n=1}^{n} ASTAB\right) / N}$

of 93.03%. More over significant early IPCs capture signal and later IPCs mostly noise. Accordingly first seven IPCA's considered for various AMMI based measures. Note that the SS for GxE signal is 2.11 times that for genotypes main effects. Hence, narrow adaptations are important for this dataset. Even just IPC1 alone is 0.57 times the genotype main effects. Also note that GxE noise is 0.16 times the genotype main effects. Discarding noise improves accuracy, increases repeatability, simplifies conclusions, and accelerates progress. AMMI model revealed more complex GxE interaction which need as many as seven IPCAs for explanation of variation in the GxE interaction. Further it would not facilitate graphical visualization of the genotypes in low dimensions. Therefore, it demands to use an alternative procedure to interpret GxE interaction using further AMMI based measures.

AMMI based measures as per significant PCA's were calculated as EV1, ASTAB1, SIPC1, D1 (used first IPCA), while ASV, EV2, ASTAB2, SIPC2, D2 exploited IPCA1 and IPCA2 both while, EV3, ASTAB3, SIPC3 and D3 (considered three IPCAs), EV5, ASTAB5, SIPC5 and D5 (assumed five IPCAs), and EV7, SIPC7, ASTAB7 and D7 (used seven IPCAs).

Out of total GxE interaction, type 1 measures utilized 24.99%, type 2 accounted 45.56%, 58.84% used by type 3 measures whereas type 5 derived 78.03%, and lastly type 7 accounted of 89.96% (Table 2). AMMI derived measures based on more numbers of significant IPCAs would be considered most usage of GxE interaction variations.

Minimum and maximum values of EV1 observed for (G19, G21, G27, G28)and(G10, G13) while corresponding to D1 were(G19, G21, G27, G28) and (G10, G13) absolute values of ASTAB1 for (G13, G29, G17, G24) and (G10, G20) and for SIPC1 were (G13, G29, G17, G24) & (G10, G20), genotypes G12, G11, G28, G10 and G23 were of high yielder performance (Tables 3 and 4).

Genotypes EV2 pointed towards (G16, G28, G7, G2) as desirable at the same time undesirable genotypes (G21, G10), for values of D2 genotypes were (G29, G17, G26, G16) & (G2, G6), whereas as per criterion of SIPC2 were (G4, G21, G5, G25) &(G10, G11) and of ASTAB2 were (G4, G15, G21, G17) & (G10, G11) (Tables 4 and 5). In recent studies, agronomic concept of stability would be more preferred instead of static concept of stability (Becker and Leon 1988). In agronomic or dynamic concept of stability it is not required that the genotypic response to environmental conditions should be equal for all genotypes. It seems that using first two IPCAs in stability analysis could benefits dynamic concept of stability in identification of the most stable genotypes and high mean yield.

ASV recommended (G16, G28, G7, G23) as of stable performance and unsuitable were G21, G10 (Table 3). Considering first two IPCAs in ASV parameter, 45.56% of GxE interaction is used in GE interaction exploration. The two IPCAs have different values and meanings and the ASV parameter using the Pythagoras theorem and to get estimated values between IPCA1 and IPCA2 scores to produce a balanced measure between the two IPCA scores (Purchase, 1997). Also, ASV parameter of this

Table 1: Parentage details of feed barley genotypes along with environmental conditions

Code	Genotypes	Parentage	Code	Environments	Latitude	Longitude	Altitude (m)
G 1	JB360	JB 14/JB 211	E 1	Durgapura	26 f 51 ′N	75 f 47 ′E	390
G 2	PL891	IBON 343/12th HSBN-176	E 2	Hisar	29 f 10 ′N	75 f 46 ′E	215.2
G 3	UPB1073	EIBGN Plot 58 (2015-16)	E 3	Ludhiana	30° 54 ′N	75° 52 ′E	247
G 4	DWRB188	PENCO/CHEVRON-BAR/3/LEGACY// PENCO/CHEVRON-BAR (Hull less)	E 4	Pantnagar	29° 02 ′N	79 f 48 ′E	237
G 5	DWRB187	RD2035/ RD2552	E 5	Tabiji	26 f 35 ′N	74 f 61 ′E	456.1
G 6	KARAN 16	AZAM (DWARF)1/EB7576	E 6	Varanasi	25 f 20 ′N	83 f 03 ′E	75.5
G 7	PL903	DWRUB64/RD2668	E 7	Faizabad	26 f 47 ′N	82 f 12 ′E	113
G 8	BH1021	NBGSN-30(2010-11)/BQCN-25(2010-11)	E 8	Kanpur	26 f 29 ′N	80 f 18 ′E	125.9
G 9	RD2552	RD2035/DL472	E 9	Ranchi	23 f 34 ′N	85 f 30 ′E	640
G 10	BH1020	NBGSN-4 (2011-12)/BH393	E 10	Sabour	25 f 24 ′N	87 f 04 ′E	41
G 11	BH946	BHMS22A/BH549//RD2552	E 11	Udaipur	24 f 34 ′N	70 f 42 ′E	582
G 12	DWRB137	DWR28/DWRUB64	E 12	Gwalior	26 f 21 ′N	78 f 18 ′E	238
G 13	KB1605	BON46/Jyoti					
G 14	UPB1074	UPB 1006/Jyoti					
G 15	NDB943	K 1178/Karan 748					
G 16	RD2899	RD2592/RD2035//RD2715					
G 17	HUB261	33RD IBON-43-1/BH 902					
G 18	PL902	VJM560/K898					
G 19	RD2970	RD-2552/RD-2503//RD 2715					
G 20	NDB1698	NDB226/Azad					
G 21	JB357	30th IBYT – 911					
G 22	RD2786	RD2634/NDB1020//K425					
G 23	HUB260	BH 550/IBON-39-1					
G 24	HUB262	25THIBYT-45-1/K-727					
G 25	KB1606	Manjula/DWRUB52					
G 26	RD2972	RD-2715/RD-2552					
G 27	RD2971	RD-2552/RD-2747					
G 28	RD2969	RD-2552/RD-2503//RD 2715					
G 29	PL900	PL751/BH902					
G 30	UPB1075	RD2552/RD2670					

Table 2: AMMI analysis of feed barley genotypes

Source	df	MS	Level of significance	TSS (%)	GxE SS (%)	Cumulative of PCA (%)
Treatments	359	503.62728	***	92.33		
Genotypes	29	968.02177	***	14.34		
Environments	11	8103.85625	***	45.52		
GxE interaction	319	199.33274	***	32.47		
IPC1	39	407.43286	***		24.99	24.99
IPC2	37	353.44242	***		20.57	45.56
IPC3	35	241.38402	***		13.29	58.84
IPC4	33	209.65506	***		10.88	69.72
IPC5	31	170.33342	***		8.30	78.03
IPC6	29	140.89553	***		6.43	84.45
IPC7	27	129.7979	***		5.51	89.96
Residual	88	72.52256	***			
Error	1080	13.90301				
Total	1439	136.07884				

investigation used advantages of cross validation due to computation from first two IPCAs. The results of ASV parameter have many similarities with the other AMMI stability parameters which calculated from the first two IPCAs scores.

Minimum values EV3 preferred G16, G7, G2, G3 as well of unstable performance of G21, G26 while SIPC3 pointed towards G25, G5, G13, G4 and G6, G10 whereas D3 for G16, G7, G23, G3 & G21 G26 ASTAB3 measure considered G5, G25, G13, G4 & G26, G10

G2, G23, G7, G3 preferred by least values EV5 and maximum values for G21, G25, measure SIPC5 identified G5, G25, G4, G13 and G10, G12 whereas D5 considered G23, G7, G2, G3 as suitable & G21, G26 as unsuitable ones; ASTAB5 selected G5, G25, G4, G13 as suitable & G10, G12 as unsuitable genotypes.

According to D7 minimum values, G7, G2, G3 and G6 were genotypes of stable yield while G21 and G4 as undesirable; SIPC7 observed G4, G25, G5, G17 & G10, G27 as of stable and unstable yield behaviour (Tables 6 and 7). EV7 pointed towards G7, G2, G6, G3 & G4, G12. Measure ASTAB7 identified G4, G25, G5, G13 as desirable and G10, G27 for unstable behavior over the studied environments. Composite measure I_1 selected G4, G15, G2, G6 as of stable performance and G12, G28 not recommended for cultivation due to unstable yield behavior.

Finally type 1 of AMMI measures (EV1, ASTAB1, SIPC1, D1), considered G19, G21, G13, G29 as desirable genotypes and G10 as of unstable performance; based on the type 2 (EV2, ASTAB2, SIPC2, D2 and ASV) G16, G21 were genotypes of choice and G10 as unsuitable; as per type 3 (EV3, ASTAB3, SIPC3 and D3), G16, G7, G5, G13 were stable genotypes and G26 of unstable type; according to the type 5 of AMMI parameters (EV5, ASTAB5, SIPC5 and D5), genotypes G23, G3, G5, G25 and G10 & G21; lastly based on the type 7 (EV7, ASTAB7, SIPC7 and D7), genotypes G4, G15, G2, G6 and G12 & G27 were detected as the unstable genotypes. Considering all of the AMMI based measures, only genotypes G25 and G13 had the good yield performance while the yield performance of G17 and G4 were of low yield.

To better understand the relationship among the AMMI based estimates along with yield, principal component analysis (PCA) was performed. The relationship among these estimates is graphically displayed in a plot of PC1 versus PC2. Clustering of measures showed that the studied the AMMI based parameters and mean yield could be divided into three major groups (Fig. 1). Largest group I contains yield with SIPC1, SIPC2, SIPC3, SIPC5, SIPC7 as well as ASTAB2, ASTAB3 ASTAB5, ASTAB7 along with IPAC1 measures. Group II contains IPCA4, IPCA5, IPCA6, IPCA7, whereas IPCA2 was lying far way. Group III contains ASV with EV1, EV2, EV3, EV5 and D1, D3, D5, D7 and D2 and EV7 were outliers.

Each of the AMMI stability parameters relates to a different concept of yield stability and may be useful to plant breeders attempting to select genotypes with high, stable and predictable yield across environments (Mohammadi *et al.,* 2015). However, it seems that there is no need to consider all of these measures simultaneously, and a few of them should be used in as per maximum usage of GxE interaction sum of squares. GE interaction was analyzed according to the AMMI model with several distinct significant multiplicative terms. AMMI model has demonstrated useful for exploring complex GxE interaction, gaining accuracy,

Table 3: Principal components analysis of feed barley genotypes

Code	Genotypes	Yield	IPCA 1	IPCA 2	IPCA 3	IPCA 4	IPCA 5	IPCA 6	IPCA 7	ASV
G 1	JB360	43.67	0.3724	2.9461	-0.5092	-0.3726	-0.0574	-0.6073	-0.4483	2.97
G 2	PL891	32.10	-1.1474	-0.1592	-0.1942	0.2554	-0.3909	0.6693	0.6952	1.27
G 3	UPB1073	39.06	-0.9582	0.6596	0.1853	-0.3478	0.5040	-0.9838	0.4021	1.25
G 4	DWRB188	30.04	-1.8850	-1.8595	1.0705	-1.5117	-0.8732	-3.1536	0.2970	2.79
G 5	DWRB187	38.27	-1.7953	-1.1563	-0.5044	-1.6158	-1.3902	0.7440	1.6926	2.29
G 6	KARAN 16	32.63	-0.4743	-1.1942	-0.4403	0.2768	0.8989	0.0123	0.3756	1.30
G 7	PL903	42.15	-0.9708	-0.0053	-0.5633	0.5832	0.0006	-0.0583	0.1514	1.07
G 8	BH1021	41.83	1.4260	-2.1254	-0.3947	0.6298	-0.3843	-0.9626	-0.3566	2.64
G 9	RD2552	41.42	1.4070	-0.1753	-1.6621	-0.2381	0.8677	-0.5939	1.5612	1.56
G 10	BH1020	**45.15**	3.0422	0.6480	0.3125	0.3474	1.1806	-0.3660	0.8480	3.42
G 11	BH946	**45.96**	1.7137	1.6579	-0.5617	-0.6784	-1.9970	0.4079	0.0331	2.51
G 12	DWRB137	**47.48**	0.8170	1.5563	0.7075	-0.9027	2.6301	-0.7787	-0.1151	1.80
G 13	KB1605	43.08	-2.5627	0.7418	-1.5909	-0.5703	0.0170	0.1119	1.1221	2.92
G 14	UPB1074	40.58	0.1571	1.3693	0.5410	-0.5627	-1.7618	0.8450	-2.3216	1.38
G 15	NDB943	31.33	-1.1592	0.7644	0.8444	2.9270	-1.5828	-1.2736	-0.0389	1.49
G 16	RD2899	43.98	-0.4355	-0.4282	0.5711	-0.9359	1.7865	1.5691	-0.5036	0.64
G 17	HUB261	37.71	-1.9190	-0.2189	-0.5086	1.8668	-0.3547	-0.3389	-2.1824	2.13
G 18	PL902	39.33	0.9382	-1.4069	-0.3817	-0.8002	-0.9329	2.2269	0.5235	1.75
G 19	RD2970	36.65	0.0265	2.3055	-0.0763	-0.8861	-0.0909	-0.9985	-0.4729	2.31
G 20	NDB1698	42.08	2.3240	-0.9679	-2.2242	1.2208	-0.8673	0.3633	0.1312	2.74
G 21	JB357	39.79	-0.1192	-2.9848	3.3794	1.0856	0.7843	0.7867	-0.0467	2.99
G 22	RD2786	40.60	1.5337	-1.0580	-0.7653	-0.4227	-0.0254	-0.2724	-1.5730	1.99
G 23	HUB260	**45.06**	0.1588	1.1709	0.1857	0.0437	-0.4024	1.1932	0.5680	1.18
G 24	HUB262	34.96	-1.8984	1.5893	1.8332	-0.4184	-0.1012	0.6167	1.3340	2.63
G 25	KB1606	42.56	-0.4234	-1.8588	-1.3482	-2.7163	0.0816	-0.0798	-1.4768	1.92
G 26	RD2972	37.63	1.8018	0.2434	3.1411	-1.3636	-0.2311	0.1107	-0.7383	2.00
G 27	RD2971	39.90	0.1281	1.2857	0.2550	1.3401	1.2165	0.4565	0.2920	1.29
G 28	RD2969	**45.96**	-0.1341	-0.8405	-1.5466	0.8067	1.9168	-0.8106	-0.3643	0.85
G 29	PL900	40.98	-2.0182	0.1261	-0.6161	1.5724	0.9114	1.6811	-0.8004	2.23
G 30	UPB1075	41.38	2.0541	-0.6252	0.8607	1.3877	-1.3525	-0.5165	1.4119	2.35

IPCA, principal component of interaction, ASV = AMMI stability value

Table 4: AMMI based estimates of feed barley genotypes

Genotypes	EV1	EV2	EV3	EV5	EV7	D1	D2	D3	D5	D7	SIPC1	SIPC2
JB360	0.0011	0.0385	0.0266	0.0163	0.0130	4.1806	36.6688	32.1537	32.3365	32.8804	0.3724	3.3185
PL891	0.0104	0.0053	0.0037	0.0028	0.0042	12.8826	47.0566	13.1273	13.7423	15.6874	-1.1474	-1.3066
UPB1073	0.0073	0.0055	0.0038	0.0033	0.0049	10.7576	8.7361	12.9862	14.0414	16.3892	-0.9582	-0.2985
DWRB188	0.0282	0.0292	0.0236	0.0218	0.0380	21.1640	25.7853	30.8007	34.5569	42.8382	-1.8850	-3.7446
DWRB187	0.0256	0.0186	0.0133	0.0196	0.0222	20.1569	13.0773	24.1370	30.6627	33.8404	-1.7953	-2.9517
KARAN 16	0.0018	0.0071	0.0055	0.0057	0.0044	5.3256	59.6426	14.4662	16.5640	16.8145	-0.4743	-1.6686
PL903	0.0075	0.0037	0.0036	0.0030	0.0022	10.8998	19.3996	12.1644	13.2764	13.3355	-0.9708	-0.9761
BH1021	0.0161	0.0278	0.0191	0.0128	0.0115	16.0099	31.5466	28.0575	28.8261	29.9616	1.4260	-0.6995
RD2552	0.0157	0.0080	0.0153	0.0114	0.0148	15.7968	10.9233	22.5159	23.7991	27.0783	1.4070	1.2316
BH1020	0.0734	0.0385	0.0261	0.0198	0.0161	34.1562	6.9295	34.9806	36.5373	37.2304	3.0422	3.6902
BH946	0.0233	0.0237	0.0169	0.0222	0.0163	19.2407	17.7295	26.7122	32.2743	32.4396	1.7137	3.3717
DWRB137	0.0053	0.0132	0.0106	0.0274	0.0209	9.1727	16.6422	20.1771	31.2659	31.8920	0.8170	2.3732
KB1605	0.0521	0.0285	0.0281	0.0177	0.0157	28.7725	7.9324	33.5175	33.9190	35.0118	-2.5627	-1.8209
UPB1074	0.0002	0.0083	0.0066	0.0133	0.0241	1.7642	14.6431	15.6345	22.2784	29.3433	0.1571	1.5264
NDB943	0.0107	0.0079	0.0078	0.0322	0.0266	13.0151	8.1748	17.3710	34.5888	36.0579	-1.1592	-0.3948
RD2899	0.0015	0.0016	0.0022	0.0122	0.0148	4.8894	4.5786	8.6515	19.4843	23.4952	-0.4355	-0.8636
HUB261	0.0292	0.0148	0.0108	0.0152	0.0226	21.5449	2.3413	22.2136	28.1506	32.8901	-1.9190	-2.1379
PL902	0.0070	0.0121	0.0086	0.0091	0.0183	10.5331	15.0454	18.7270	21.6149	28.2919	0.9382	-0.4688
RD2970	0.0000	0.0232	0.0155	0.0112	0.0108	0.2978	24.6543	24.6669	25.9686	27.4105	0.0265	2.3320
NDB1698	0.0428	0.0255	0.0350	0.0266	0.0194	26.0929	10.3502	35.2515	37.7001	37.8253	2.3240	1.3562
JB357	0.0001	0.0390	0.0674	0.0450	0.0335	1.3381	31.9191	45.5010	47.0433	47.4633	-0.1192	-3.1040
RD2786	0.0187	0.0142	0.0116	0.0074	0.0114	17.2200	11.3135	21.8714	22.2096	25.3868	1.5337	0.4758
HUB260	0.0002	0.0061	0.0042	0.0030	0.0061	1.7834	12.5215	12.7725	13.2312	16.8871	0.1588	1.3298
HUB262	0.0286	0.0253	0.0291	0.0179	0.0179	21.3137	16.9955	32.4346	32.6697	34.5974	-1.8984	-0.3091
KB1606	0.0014	0.0158	0.0171	0.0280	0.0253	4.7535	19.8774	24.1819	34.6257	36.4480	-0.4234	-2.2822
RD2972	0.0258	0.0131	0.0445	0.0313	0.0237	20.2292	2.6034	36.3717	38.4897	38.9166	1.8018	2.0452
RD2971	0.0001	0.0073	0.0051	0.0114	0.0088	1.4384	13.7490	14.0385	21.3069	21.7337	0.1281	1.4138
RD2969	0.0001	0.0032	0.0108	0.0181	0.0147	1.5057	8.9876	17.4038	24.9800	25.9588	-0.1341	-0.9746
PL900	0.0323	0.0162	0.0122	0.0155	0.0190	22.6589	1.3488	23.4549	28.5681	32.1669	-2.0182	-1.8920
UPB1075	0.0335	0.0184	0.0150	0.0187	0.0187	23.0623	6.6852	25.3900	30.6228	32.7539	2.0541	1.4290

Table 5: Further AMMI based estimates of feed barley genotypes

Genotypes	SIPC3	SIPC5	SIPC7	ASTAB1	ASTAB2	ASTAB3	ASTAB5	ASTAB7	I_1
JB360	2.8093	2.3793	1.3237	46.94	383.84	337.04	301.88	236.52	1.08874
PL891	-1.5008	-1.6362	-0.2718	-144.64	-162.84	-180.69	-187.85	-103.91	0.80044
UPB1073	-0.1132	0.0430	-0.5387	-120.78	-45.35	-28.31	-20.62	-59.70	0.97402
DWRB188	-2.6740	-5.0590	-7.9156	-237.62	-450.27	-351.87	-541.06	-725.06	0.74898
DWRB187	-3.4561	-6.4621	-4.0255	-226.31	-358.55	-404.91	-640.33	-492.57	0.95415
KARAN 16	-2.1088	-0.9331	-0.5452	-59.79	-196.36	-236.83	-148.48	-125.46	0.81349
PL903	-1.5394	-0.9556	-0.8625	-122.38	-122.98	-174.76	-126.20	-120.97	1.05081
BH1021	-1.0941	-0.8487	-2.1679	179.75	-63.30	-99.58	-75.13	-157.77	1.04283
RD2552	-0.4304	0.1992	1.1666	177.36	157.31	4.54	47.79	102.25	1.03262
BH1020	4.0027	5.5308	6.0127	383.49	457.59	486.31	601.01	627.81	1.12554
BH946	2.8100	0.1345	0.5754	216.02	405.62	353.99	152.44	180.47	1.14581
DWRB137	3.0808	4.8082	3.9145	102.99	280.95	345.99	462.03	405.44	1.18374
KB1605	-3.4119	-3.9651	-2.7312	-323.04	-238.21	-384.45	-430.64	-357.07	1.07413
UPB1074	2.0675	-0.2570	-1.7336	19.81	176.40	226.13	51.30	-32.12	1.01236
NDB943	0.4496	1.7938	0.4812	-146.13	-58.71	18.90	147.35	63.63	0.77981
RD2899	-0.2925	0.5580	1.6235	-54.90	-103.86	-51.37	0.60	71.09	1.09711
HUB261	-2.6465	-1.1344	-3.6557	-241.89	-266.93	-313.68	-184.18	-335.04	0.94013
PL902	-0.8505	-2.5836	0.1669	118.26	-42.63	-77.72	-212.07	-38.73	0.98046
RD2970	2.2557	1.2787	-0.1927	3.34	266.99	259.98	179.67	87.85	0.91550
NDB1698	-0.8680	-0.5146	-0.0200	292.96	182.27	-22.16	16.35	47.35	1.04922
JB357	0.2754	2.1453	2.8853	-15.02	-356.36	-45.74	101.56	149.08	0.99405
RD2786	-0.2895	-0.7376	-2.5830	193.34	72.35	2.01	-34.99	-145.53	1.01261
HUB260	1.5154	1.1568	2.9180	20.02	153.92	170.99	145.39	255.29	1.12380
HUB262	1.5241	1.0045	2.9552	-239.30	-57.55	110.95	68.79	187.18	0.87125
KB1606	-3.6303	-6.2650	-7.8217	-53.37	-265.93	-389.85	-609.86	-702.39	1.06118
RD2972	5.1863	3.5916	2.9640	227.12	254.96	543.68	413.46	376.83	0.93805
RD2971	1.6688	4.2253	4.9739	16.15	163.18	186.61	386.48	432.94	0.99491
RD2969	-2.5211	0.2024	-0.9725	-16.91	-113.02	-255.17	-48.78	-122.17	1.14633
PL900	-2.5081	-0.0244	0.8563	-254.40	-239.98	-296.61	-99.59	-39.52	1.02168
UPB1075	2.2896	2.3249	3.2203	258.93	187.44	266.55	283.70	334.27	1.03154

EV = Eigenvector, SIPC = Sum of the value of the IPC Scores, D = Parameter of Annicchiarico (1997); SIPC1 = SIPC for first IPCA, SIPC 2 = SIPC for first two IPCAs, ... ASTAB1 = AMMI stability based on 1 IPCA; I_1 = Stability index

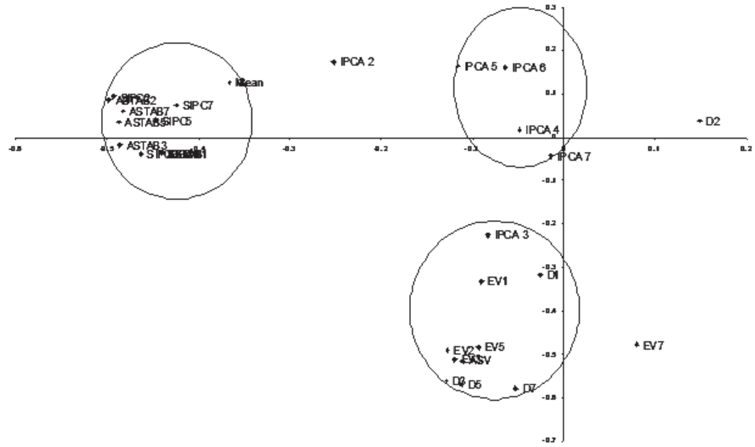

Fig. 1: Grouping of AMMI based measures by Ward's method

improving selections, and increasing experimental efficiency (Sabaghnia *et al.,* 2013).

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