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Adaptation Analyses of Wheat Genotypes in Different Agra-ecological Zones of Pakistan Through the Use of Various Biometrical Techniques

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Abstract: The current zoning system appears unduly complicated and of little relevance to wheat breeding, as there is no evidence of distinct target areas. A broad but sparser sampling than the present system is recommended. Overall adaptation should be routinely assessed, by ranking and AMMI analyses, from the resultant smaller data sets each year. There is strong evidence of a flow of germplasm far superior than Pak-81, with respect to both yield and adaptation. It is suggested that same genotypes should be tested at least for two years on the same locations to get better results.

Key words: *Triticum aestivum*, genotype x environment interaction, cluster analysis, agro-ecological zones, AMMI analysis

Introduction

The National Uniform Wheat Yield Trials (NUWYT) is a core activity of the Coordinated Research Programme on Wheat, Barley and Triticale. After the leaf rust *(Puccinia recondite* Rob. ex Desm f.sp, *tritici*) epidemic of 1978 and a decrease in national wheat production, the responsibility to organize an effective variety evaluation programme was given to the Pakistan Agricultural Research Council (PARC).

Previously, data were analysed each year for each location individually and then overall and zonal summaries (Result Reports PARC, 1985-1991) were produced by pooling the locations by province and for the country as a whole. Varieties are released on the basis of two years data for yield, diseases, agronomic traits and quality characteristics.

Often, zones for subdividing country's breeding efforts are formed from a mixture of climatic and edaphic information, political considerations and institution. In agro-ecological zoning, integration of factors over 12 months may produce patterns which do not reflect conditions during the months of a cropping cycle. Furthermore, environmental factors that influence yield levels may not discriminate among advanced genotypes. Crossa *et al*. (1991) provided an example in which location groupings, based on discrimination of germplasm, were unrelated to levels of production. This implies that zonation for agronomic practices may not necessarily be pertinent to genotypic selection. Zonation on the basis of minimizing genotype x environment interaction (GE) would be more efficient for breeding and the NUWYT system database now facilitates such a process, The major objective of this study was to examine the zoning for wheat breeding in Pakistan and suggest modifications, refinements or rationalization to the structure which had been established without the aid of wheat performance data.

Multivariate methods can facilitate interpretation of multilocation genotype trials. Cluster analysis has been used to group locations that discriminate among genotypes in a similar manner or to summarize patterns of genotypic performance across environments (Abou-El-Fittouh *et al*., 1969), The combination of ordination and cluster analysis is termed Pattern Analysis (Byth *et al*., 1976; Shorter *et al*., 1977).

Implicit in analyses of Peterson and Pfeiffer (1989), Braun *et al*. (1992) and DeLacy *et al*. (1993) is the premise that the phenotypic correlation for the yields of trial entries between locations is a measure of similarity of these locations for breeding purposes. Assuming the correlations not to be unduly biased by the entries chosen in a given year, Peterson and Pfeiffer (1989) pooled such correlations over the years and applied Factor Analysis to simplify the resultant long-term matrix, while DeLacy *et al*. (1993) used Pattern Analysis.

Materials and Methods

This study is based on replicated and non-replicated data from normal duration NUWYTs grown from 1982 to 1992. Numbers of locations and varieties differ with years (Table 1). Some varieties were tested for 2 or 3 years consecutively and some locations were sown regularly. Pak-81 was used as a common check for 8 years.

Table 1: Numbers of Locations and Varieties Tested by Year

Years	varieties	locations		
		Replicated	Non-Replicated	Total
1982-83	20	50	-	50
1983-84	19	29	22	51
1984-85	24	30	26	56
1985-86	20	31	28	59
1986-87	20	31	21	52
1987-88	20	34	16	50
1988-89	16	30	20	50
1989-90	18	33	11	44
1990-91	18	32	10	42
1991-92	16	37	-	37

Table 2: Ammi Analysis of Variance of Nuwyt 1991- 92

Source of variation	df	SS	MS	F Value
Model	591	2549.72	4.31	17.06 **
Locations (1-)	36	2177.91	60.50	239.25 **
Genotypes (G)	15	48.40	3.23	12.76 **
Interaction PCA 1	540	323.41	0.60	2.37 **
Error	1776	449.09	0.25	

** Significant at 0.01 probability level

Seed of entries was provided by breeders, It was recommended that, in replicated trials, each plot consists of 6 rows, 5 m long and 30 cm apart and each line be grown in four replicates. A harvested plot of 4 rows, 5 m long was recommended and a Randomized Complete Block Design was used. For non replicated trials, the plot was 6 rows, 15 m long and 30 cm apart. For yield analysis, three cuts of 2 m^2 (a form of replication) were suggested. Duplicate field books were provided for returning data to PARC. A unique number was assigned to each location reporting data during the 10-year period.

Statistical analysis within years for genotypes and locations

a) Clustering: The GEBEI package from the University of Queensland was used and within each year, clustering of genotypes and of locations was conducted using location standardized data and the incremental sum of squares fusion strategy with the HACLUS2 program.

The unstandardized squared Euclidean distance between two locations j and j' is defined as:

$$d^2_{jj'(raw)} = \sum_{i=1}^{s}\left(Y_i - Y_{ij}\right)^2$$

where Y_{ij} is the performance of the ith line in the jth location and s is the number of genotypes. The dissimilarity, when based on location standardized data, is directly related to the phenotypic correlation, $r_{jj'}$ (Fox and Rosielle, 1982) as follows:

$$d^2_{jj'(stan)} = 2\left(s-1\right)\left(1-r_{jj'}\right)$$

b) AMMI analysis: One year's data (1991-92) was analysed using the following AMMI model:

$$Y_{ij} = \mu + g_i + l_j + \sum_{k=1}^{n}\lambda_k\,\alpha_{ik}\,y_{ik} + E_{ij}$$

where Y_{ij}, is the yield of the ith genotype in the jth location; µ is the grand mean; g_i and l_j, are the genotype and location deviations from the grand mean respectively; λ_k is the eigenvalue of the principal component analysis axis k; α_{ik} and y_{ik}, are the genotype and location principal component scores for axis k; n is the number of principal components retained in the model and E_{ij} is the error term. An analysis considering the first PCA axis (n = 1) was conducted with a SAS program written by 1. Romagosa (UdL-IRTA, Spain).

Ranking analysis: The stratified ranking technique of Fox *et al*. (1990) was applied to the 1991-92 data. The procedure consisted of scoring the number of locations in which each genotype ranked in the top, the middle and the bottom third of trial entries.

Statistical analysis of locations across years: The mean yields of genotypes over replicates for the 201 locations reporting data for 5 or more years were considered. For each of the 10 NUWYTs, a 201×201 dissimilarity matrix of squared Euclidean distances between each pair of locations was calculated as, for the within-year analysis.

The long-term squared Euclidean distance matrix was constructed by averaging, over individual cells which were not empty, the standardized within-year matrices produced by the HACLUS2 program. However, missing cells remained in the long-term matrix after averaging and, as classification algorithms cannot manage empty cells in the dissimilarity matrix, locations contributing to the largest number of empty cells were eliminated, one at a time, until a long-term matrix without empty cells was defined for 30 locations. The average over 10 years NUWYTs equally weights each year which contributes to a cell in the matrix (DeLacy *et al*., 1993).

The final long-term squared Euclidean distance matrix, without empty cells, was input to HACLUS2 to classify 30 locations by the incremental sums of squares fusion strategy in an hierarchical agglomerative clustering procedure (DeLacy and Cooper, 1990).

Results and Discussion

a)Cluster analysis: In the dendrogram for genotypes in 1991-92 (Fig. 1) at the two-group level, the genotypes in group 26 are more stable than group 30. It is confirmed by the AMMI analysis and stratified ranking procedure. At the nine-group level subgroup 21 comprises genotypes V-8829, WS-56, V-89099 and V-7222, which are high-yielding and broadly-adapted, properties confirmed by ranking and AMMI analyses.

The presence or absence of the 1 BL/1 RS translocation in NUWYT 1988-89 (Jahan *et al.,* 1990) and also for NUWYT 1989-90 (Ter-Kuile *et al*., 1991) was used in interpretation of the genotypic dendrogram. For 1988-89, all genotypes having the translocation *are* in the same cluster (Fig. 2), except V-8512 which is in subgroup 21. The genotypes included in NUWYT 1989-90 (Fig. 3) were also tested for 1BL/1RS, The same pattern was observed at the two-group level, with V-6300 the only exception.

Table 3: Stratified ranking of NUWYT (Normal duration) entries for the year 1991-92

Entry	Top	Middle	Bottom
V-88042	10	12	15
WS-56	10	19	8
NR-30	4	10	23
V-7210	9	13	15
V-87094	19	8	10
V-5300	10	7	20
PR-38	13	15	9
PAK-81	7	10	20
V-8829	19	13	5
NR-29	8	12	17
M-283	17	10	10
V-5200	6	9	22
V-89099	16	16	5
V-7222	16	12	9
V-4072	7	13	17
L.CHECK	12	12	13

Top: No. of locations in top third of line
Middle: No. of locations in middle third of lines
Bottom: No. of locations in bottom third of lines

The final long-term analysis was conducted for 30 locations (Table 4), which represent all the agro-ecological zones of the country, except Zone 2. The established agro-ecological zones of the country are mentioned in Table 5 and Fig. 7. Figure 8 is the dendrogram of long-term relationship among locations. The two to five group levels were selected arbitrarily and are indicated on Fig. 8 but more detail is given in Table 4 upto nine group levels. These major groups are mapped in Fig. 9 (a-d).

At the two-group level, Location Group One, comprises subgroups 49 and 51. Zones 1, 3, 4, 8, 9 and 10 are represented. Within subgroup 49, group 43 consists of two locations Quetta and Gilgit with high altitude and a long maturity period and two other locations from NWFP in group 46, In this subgroup 49, all the four locations are from different zones. Subgroup 51 consists of Dokri and Dadu from Zone 4 and one of three locations from Zone 3. At Umar Kot, all the non-replicated trials were planted (Table 5).

Location Group Two represents Zones 3 to 10, comprising subgroups 48, 32, 42, 34, 37, 47 and 50. Locations in subgroups 32 and 42 belong to Zone 6 except ARF Sargodha which is included in subgroup 50 and one location, PSC Farm Khanewal, of Zone 5 is in subgroup 42. All these locations have the same disease pattern i.e. Leaf Rust and Loose Smut, temperate weather and moderate rainfall. Replicated trials were planted at all the locations in these sub groups 32 and 42 except at 249/G.B Faisalabad where four times non-replicated trials were planted out of 9 times. However, at the six-group level, subgroups 32 and 42 having maximum locations of Zone 6 are in the same cluster. It means that NUWYT locations are over-represented in this zone. A location from Sind, AEARC Tandojam, occurred in Sub-group 47, which is different in vegetative growth period and climatic conditions. Rainfed locations occurred in subgroups 47 and 50.

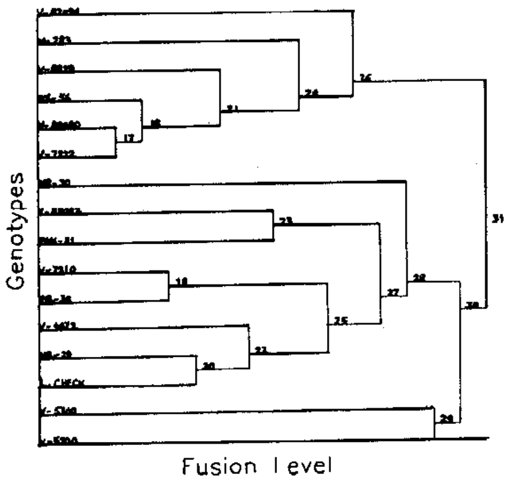

Fig. 1: Dendrogram of genotypes for NUWYT 1991-92

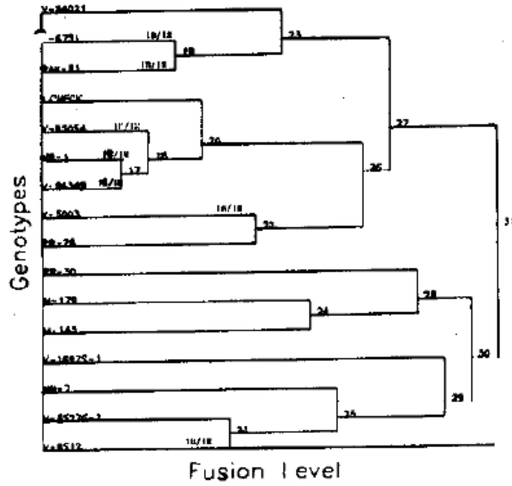

Fig. 2: Dendrogram of genotypes for NUWYT 1988-89

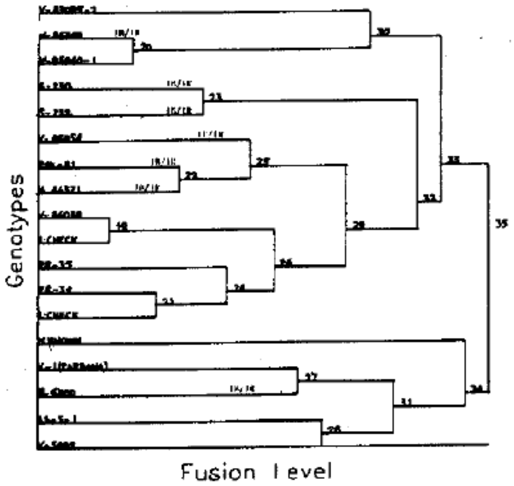

Fig. 3: Dendrogram of genotypes for NUWYT 1989-90

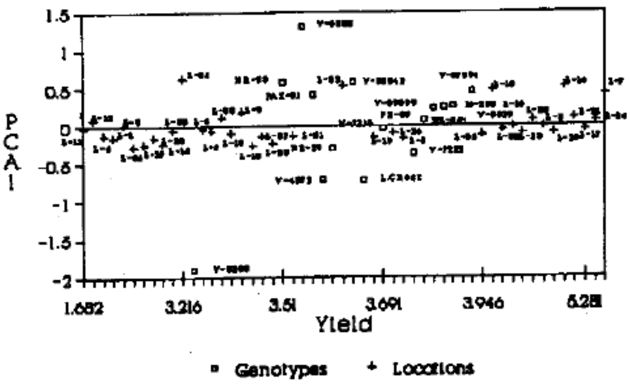

Fig. 4: B1-plot of the means lt/ha) and the first PCA axis for interaction of 10 genotypes and 37 locations

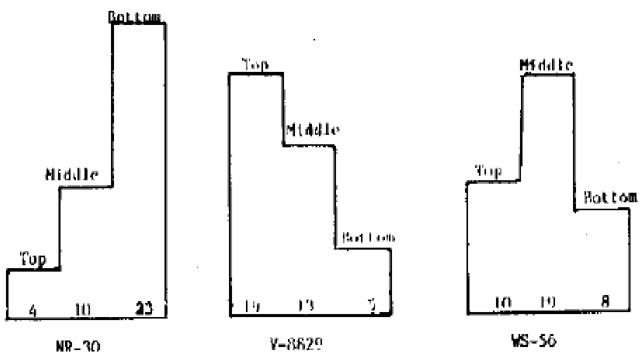

Fig. 5: Stratified ranking analysis for three selected genotypes AMMI estimates over all locations, giving number of locations for which a genotype occurred in the top,middle ad bottom third of entries

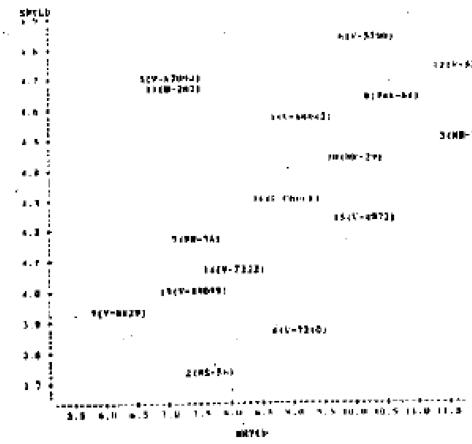

Fig. 6: Plot of sryld *MRYLD under SAS system for the year1991-92

Fig. 7: Wheat production Zones of Pakistan

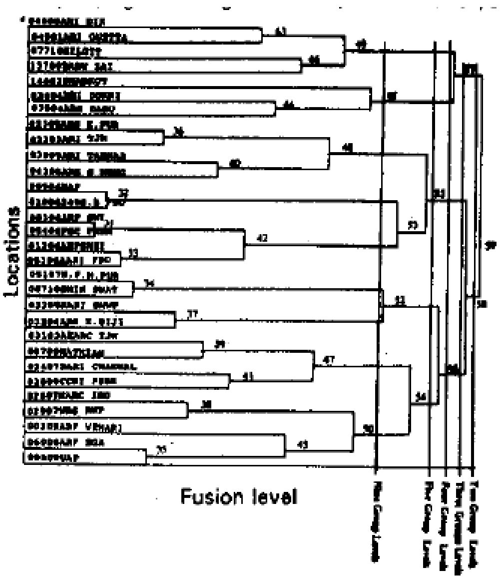

Fig. 8: Oendrogram of similarities among locations 10 years NUWYT for standardized data

* First three digits represent location nos. and next two digits for zoning

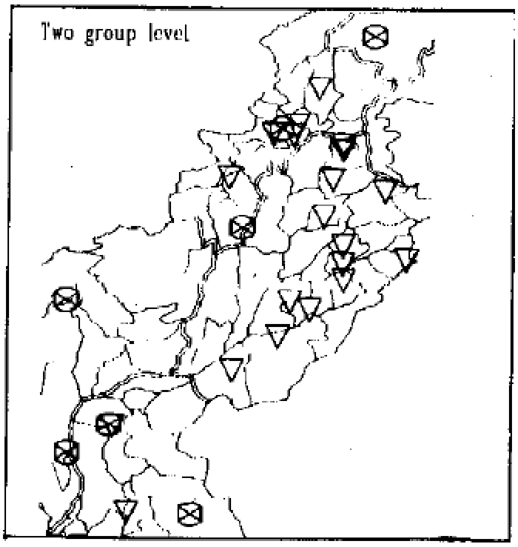

Fig 9a: Standarrhiled location cluster at two grot p levels

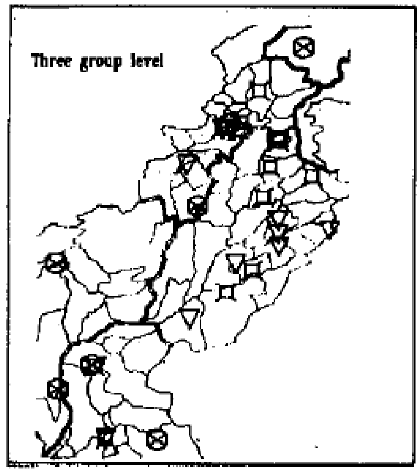

Fig. 9b: Stanciardaired location, it three group levels

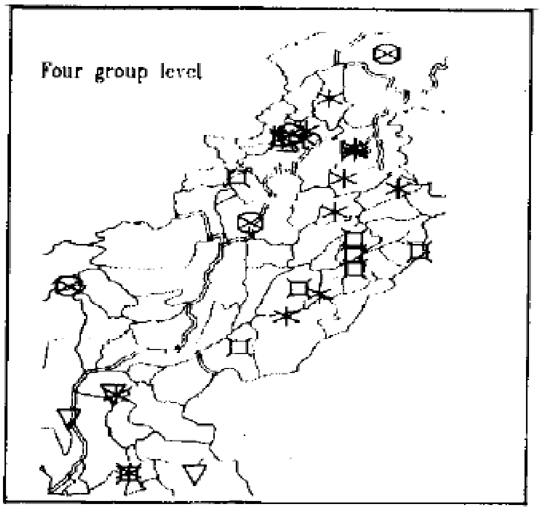

Fig. 9c: Standardaized location cluster at four group levels

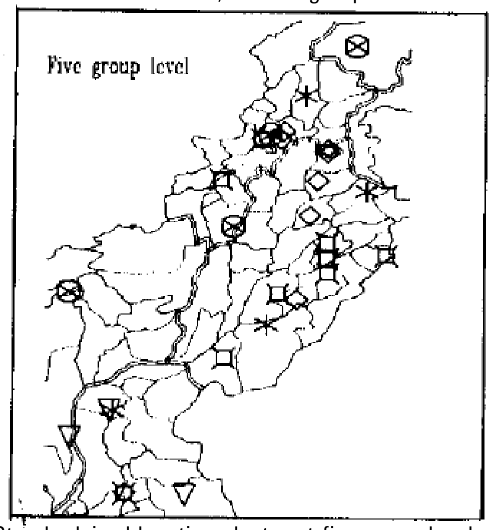

Fig. 9d: Standardaized location cluster at five group levels

Table 4: Summary Table of Locations Ordered to Correspond to Fig. 8

Group1	Location	Time[x]	Let. N	Long E	Elev. m	Zone regime	Moisture[3] regime	Temperature
49	ARI-D.I.Khan	(8+1) 9	32	71	290	8	Irrigated	Temperate Low rainfall
	ARI-Quetta	(9+0) 9	30	67	1600	1	irrigated	Cool Low rainfall
	Gilgit	(7+0) 7	36	73	1300	10	Irrigated	Cool Low rainfall
	Babu Zai	(0+6) 6	34	71	365	9	Irrigated	Temperate Low rainfall
51	Umar Kot	(0+5) 5	25	69	16	3	Irrigated	Hot[4] Low rainfall
	RRI-Dokri	(6+0) 6	27	68	37	4	Irrigated	Hot Low rainfall
	ARS-Dadu	(5+0) 5	26	67	35	4	Irrigated	Hot Low rainfall
48	ARS-Khanpur	(7+0) 7	28	70	91	5	Irrigated	Temperate Low rainfall
	ARI-Tandojam	(6+0) 6	25	68	28	3	Irrigated	Hot Low rainfall
	ARI-Tarnab	(5 +0) 5	34	71	359	9	Irrigated	Temperate Low rainfall
	ARS-S.Naurang	(10+0) 10	33	70	384	8	Irrigated	Temperate Low rainfall
32	UAF	(10+0) 10	31	73	184	6	Irrigated	Temperate Low rainfall
	249/G.B Fbd	(5 +4) 9	31	73	184	6	Irrigated	Temperate Low rainfall
42	ARF-Sahiwal	(6+0) 6	30	73	200	6	Irrigated	Temperate Low rainfall
	PSC-Khanewal	(9 + 0) 9	30	72	170	5	Irrigated	Temperate Low rainfall
	ARF-Sheikhupura	(7 +0) 7	31	74	260	6	Irrigated	Temperate Low rainfall
	AARI-Fbd.	(9+0) 9	31	73	184	6	Irrigated	Temperate Low rainfall
34	Mirpur	(6 + 0) 6	32	74	320	7	Irrigated	Temperate Low rainfall
	Shin Swat	(3+3) 6	35	72	960	10	Irrigated	Temperate Low rainfall
37	RARI-Bwp	(8 +0) 8	29	71	117	5	Irrigated	Temperate Low rainfall
	ARS-Kot diji	(5+0) 5	27	68	36	4	Irrigated	Hot Low rainfall
47	AEARC-Tandojam	(10+0) 10	25	68	28	3	Irrigated	Hot Low rainfall
	Nathan Mardan	(5+2) 7	34	72	355	9	Irrigated	Temperate Low rainfall
	BARI-Chakwal	(7+0) 7	33	73	490	7	Irrigated	Temperate Low rainfall
	CCRI-Pirsabak	(10 +0) 10	34	72	340	9	Irrigated	Temperate Low rainfall
50	NARC-Ibd.	(10+0) 10	33	73	683	7	Irrigated	Temperate High rainfall
	WRS-Rwp.	(10+0) 10	33	73	500	7	Irrigated	Temperate High rainfall
	ARF-Vehari	(4 + 2) 6	30	72	135	5	Irrigated	Temperate Low rainfall
	ARF-Sargodha	(8 + 1) 9	32	72	187	6	Irrigated	Temperate Low rainfall
	UA-Peshawar	(5+1) 6	34	71	359	9	Irrigated	Temperate Low rainfall

1. Groups are numbered from two and nine group level (Fig.8)
2. Number of years location occurred in analyses. In brackets replicated & non-rep. trial are mentioned
3. Rainfall refers to just before and during the crop cycle, high = >500 mm, low = <500 mm
4. Mean temperature of the coolest month >17.5°C

Table 5: Wheat Production Zones of Pakistan

	Zone Area	Districts	Expected Diseases
1.	Uplands of Baluchistan	Ka!at, Quetta, Pisin, Loralai,Bandin, Khuzdar, Kohln and Barkhan	Yellow Rust and complete bunt
2.	PLAINS ANd foot-hills of Baluchistan	Nasirabad, Kachhi, Sibi, Lasbela, Makran and Harnar,	Leaf and stem rust
3.	Southern Region of Sind	Thatta, Badin, Tharparkar, Hyderabad, Souther, part of sanghar and Dadu.	Leaf and stem Rust
4.	Northern Region of Sind	Nawabshah, Khairpur, Larkana, Sukkur, Jaccobabadabad, Shikarpur Northern parts of sanghar and Dadu.	Leaf Rust
5.	Southern Punjab	R.Y.Khan, Bahawalpur, B,Nagar, D.g.Khan, Rajanpur, Layyah,Bhakkar, Muzaffargarh, Vehari and Multan,	Leaf Rust and Loose Smut
6.	Central Punjab	Sahiwal,Okara, Faisalabadrir., Kasur, Sheikhupura, Lahore, Mianwali and southern parts of khushab and Sargodha	Leaf Rust Partial Bunt and Loose Smut
7.	Northern Punjab	Gujranwala,Gujrat, Sialkot, Jahelum, Rawalpindi, Chakwal, Attack and Northern Parts of Khushab and Attock.	Yellow and leaf Rust Partial Bunt, Loose and Flag Smuts
8.	Southern Plains of NWFP	D.I,Khan , Bannu, Karak and Southern half part of NWFP	Leaf Rust and Loose smut
9.	Foothills of NWFP	Peshaqar, Mardan, Northern parts of kohat and Haripur	Leaf and Yellow Rusts, Loose smut and Partial Bunt
10.	Uplands of NWFP	Mansehra, Abbotabad, Dir,Swat, Chitral, Kurram Agency and Northern parts	Yellow and Leaf Rusts, Loose smut and powdry Mildew

AMMI analysis: In the AMM1 analysis of variance (Table 2), the model sum of squares was partitioned into three components: 85 percent due to the locations, only 2 percent for genotypes and 13 percent for genotypes x locations interaction.

Figure 4 summarizes information on main effects and interactions (PCA1) for both genotypes and locations simultaneously. Genotypes V-5300 and V-5200 showed highly contrasting adaptation especially V-5200 for poor location. V-8829 is relatively stable, occurring near the zero PCA1 line, as confirmed by the stratified ranking procedure, as well as having high yield on overall basis.

Ranking analysis: The stratified ranking procedure identified genotypes with desirable adaptation (Table 3). Figure 5 presents three contrasting genotypes, of which NR-30 was generally in the bottom third more often than the other two genotypes, but occurred four times on top and ten times in the middle. Both V-8829 and V-87094, were on top 19 times, but V-8829 occurred more times in the middle, while WS-56 occurred in the middle 19 times, on top 10 times and in the bottom 8 times. Figure 6 presents consistency in the ranking analysis.

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