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GENOTYPE-ENVIRONMENT INTERACTIONS AND STABILITY ANALYSIS OF YIELD AND YIELD ATTRIBUTES OF TEN CONTEMPORARY WHEAT VARIETIES OF PAKISTAN

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Abstract

Testing of wheat varieties in different agro-ecological zone is essential for evaluation of stability of performance and range of adaptations. The main objective of this study was to determine variety-environment interaction, stability and adaptability of various characters and effect of different environments relationship of characters with grain yield and grain protein percentage in spring wheat (*Triticum aestivum* L.) Ten varieties viz. Kiran-95, Mehran-89, Tandojam-83, Abadgar-93, Anmol-91, Punjab-96, Chakwal 86, Shahkar-87, Parwaz-94 and Pirsabak-85 were evaluated at nine different locations for three years during the 1999-2000, 2000-2001, and 2001-2002 respectively. Data were recorded on various plant characters viz. plant height, peduncle length, flag leaf area, productive tillers per meter, spike length, number of spikelets per spike, rachis segment length, number of grains per spike, 1000-grain weight, grain protein percentage, number of maturity days and grain yield (t/h).

Variety-location (σvl) variety-year (σvy) and variety-location-year (σvly) interactions were highly significant for all characters. The relative magnitude of interaction variance components indicated that relative performance of varieties for plant height, peduncle length, flag leaf area, productive tillers parameter, rachis segment length, 1000-grain weight, grain protein percentage and grain yield were more inconsistent across locations than years. The opposite was true for spike length spikelets per spike, grain per spike and maturity days.

The stability parameters (within variety mean square (Si^2), variety coefficient of variation (CVi %), ecovalence (Wi^2), variety interaction variance (σi^2), regression coefficient (bi), deviation from regression mean square (δi^2) and coefficient of determination (Ri^2)), revealed a range of stability for all characters.

Keywords: agro-ecological zones, water logged and saline soils, variety-environment interaction, stability.

1. Introduction

Wheat (*Triticum aestivum* L.) is most important cereal crop of the world (Manu and Rao, 2008; Asif *et al*., 2005). Wheat is also the major component of Pakistani diet (Siddiqui, 2008; Arif *et al*., 2006). It is mostles consumed in the form of the Tandoori Roti and Chapati (un-leavened bread). Such kinds of breads are mostly prepared from whole meal flour (Arif *et al*., 2006). Wheat being the major crop for agricultural production and due to its different uses and nutritive value, it is the staple food for more than one third of the world's population (Lithourgidis *et al*., 2006). Being the main staple food of rapidly increasing population of Pakistan, wheat occupies central positions in the agricultural policies of this country. (Anon 2003). Wheat production can be enhanced through the development of improved cultivars with wider genetic base capable of producing better yield under various agroclimatic conditions and stresses. Diverse genetic base buffers against the spread of diseases advance in cereals (Zhu *et al.,* 2000).

In the recent past, concerted efforts have resulted in the development of new high yielding cultivars in the context of so-called green revolution (Siddiqui and Arain, 1974). The green revolution also brought forward many problems such as the lack of genetic diversity (Tillman, 1998; Siddiqui and Arain, 1974; Siddiqui, 1997; 1998). Moreover, in Pakistan wheat genotypes are

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facing dual menaces of biotic and abiotic stresses. It is widely accepted that information about germplasm diversity and genetic relatedness among elite breeding material is a fundamental element in plant breeding (Siddiqui, 1994 and Mukhtar *et al*., 2002) Hence breeding wheat genotypes with diverse genetic base is essential to achieve a level of self-sufficiency and sustainability. According to Ashraf *et al.,* (2001) the adaptability of a variety over diverse environment is usually tested by the degree of its interaction with different environments under which it is grown. A variety or genotype is considered to be more adaptive or stable one if it has high mean yield but low degree of fluctuation in yielding ability when grown over diverse environments (Ashraf *et al.,* 2001).

Eberhart and Russell (1966) proposed a model to test a stability of varieties under various environments. They defined a stable variety as having unite regression over the environments (bi=1) and minimum deviation from the regression (S^2 di = 0). The problems created by the green revolution were systematically solved by inducing significant variability for useful agronomic traits in bread wheat (Siddiqui *et al*., 1978, 1979, Siddiqui, 1983). Pragmatic solutions were found by improving yield and yield components through the studies of developmental allometry (Siddiqui *et al.,* 1985) and use of path coefficient (Siddiqui *et al*., 1979, 1980) Therefore, a variety with a high yield over the environments, and regression coefficient (b=1) and deviation from regression as small as possible (S^2di=0), will be a better choice for a stable variety (Ashraf *et al.,* 2001). The stability parameter studied in three cereals by Yue *et al*., (1990) indicated that wheat crop in general was more stable in yield than maize and sorghum. Similarly Bakhsh *et al.,* (1995) reported low stability in chick pea. The yield of some varieties in wheat were found more stable by Gogas (1989). Some investigation on stability parameters in barley is reported by Rasmusson and Lamhert (1961) and Verma *et al.,* (1987). The yield of barley varieties vary widely in the Punjab Province due to variation in soil and climatic factors which complicated identification of superior barley varieties (Qazi *et al*., 1990). Since the yield of wheat crop also fluctuate yearly (Siddiqui, 2008, Ashraf, 1998; Arain and Siddiqui, 1977) it is necessary to identify wheat genotype with specific and wide adaptability. The present investigation was therefore pragmatically designed to study the genotype-environment interaction of ten contemporary wheat varieties grown in Sindh, Punjab, and Balochistan.

2. Material and Methods

Ten (*Triticum aestivum* L.) spring bread wheat genotypes viz. Kiran-95, Mehran-89, Tandojam-83, Abadgar-93, Anmol-91, Punjab-96, Chakwal-86, Shahkar-87, Parwaz-94 and Pirsabak-85 were tested in years (1999-2000, 2000-2001 and 2001-2002) at nine different locations of Pakistan including. Tandojam, Sakrand, Sukkur, Rahimyar Khan, Khanewal, Sahiwal, Jacobabad, Dokri and Quetta.

The experiments were conducted in randomized complete block design with three replications on well-prepared soil at each location every year. Automatic Rabi Drill was used for seeding 100 g of seed of each genotype on plot size of 1.5 x 5.0m consisting of six rows of 5m lengths. The row-to-row distance was 30 cm. sowing was done from 1st to 30th November in accordance with the optimum time recommended for each location. The crop was grown under normal field conditions using a uniform package of production technology covering input management and crop husbandry. Number of grains per spike and 1000 – grain weight (at 15% moisture level) were recorded from the main tillers of the middle four rows of each plot. The central 1-meter square area of each plot was harvested to determine plot grain yield (converted into tonnage per hectare at 15% moisture level). Kjeltic Auto 1030 Analyzer, was used to determine the grain protein% of each plot.

The variance components for genotype-location δ^2_{gl}, genotype-year (δ^2_{gy}) and genotype-location-year were recorded and stability and adaptability of genotypical characters were determined using the observed means in a two way genotype- environment table as described by Petersen (1989). The statistics used to assess the stability and adaptability of genotypical characters were genotype mean square (S_i^2), genotypical co-efficient of variation (CVị%) as used by Francis and Kennenberg (1987), eccovalence

(W_i^2) as proposed by Wricke (1962), interaction variance (δ_i^2) as suggested by Shukla, (1972) regression co efficient (b_1) as suggested by Eberhart & Russell (1966), deviation from regression mean square (δ_i^2) and coefficient of determination (R_i^2). The genotype is considered stable if b_i value is equal or close to 1.00 (Eberhart and Russell 1966), Wheat genotypes possessing b_i value > 1.00 show adaptability in high yielding environments and genotypes having b_i values < 1.00 exhibit adaptability in low yielding environments (Finlay and Wilkinson, 1963). The genotype is considered more stable that has b_i value equal or very close to 1.00 and minimizes rest of the statistics except R_i^2 which ranges from zero to 1.00 and its high value determines the stability of a genotype (Petersen, 1989).

Regression lines were drawn using the equation $Y_{ij} = Y_i + b_i 1$, as suggested by Eberhart and Russell (1966). Correlation of grain yield with other characters was calculated by the procedure

$$r = \sum XY \Big/ \sqrt{\sum X^2 , \sum Y^2}$$

suggested by Gomez and Gomez (1984).

3. Results and Discussion

The analysis of variance **(Table-1)** revealed significant (P<0.01) differences for genotype-location, genotype-year and genotype-location-year interactions for all the characters studied. It indicates that performance of these characters were highly inconsistent over the locations and years. Genotypes have to be tested across more locations and years for evaluation of these characters. The performance for the character grains per spike was more inconsistent across the years than locations. The significance of genotype term suggested that genetic differences exist among genotypical response. This suggests that, genotypes need thorough and repeated testing before they can be recommended for particular environments or set of environments.

Testing at more locations, thus seems more efficient, than testing in more years for the evaluation of relative performance of these characters. Genotype x environment interaction as such do not provide the individual genotypical behavior, thus regression analysis using Eberhart and Russell's (1966) model was needed to be accomplished so as to ascertain stability and adaptability of varieties.

The bi values **(Table 2, 3, 4 and 5)** indicated a range of stability among wheat genotypes for all characters. In the previous research studies, similar results for grains per spike (Kinyua and Ayiecho, 1992), 1000-grain weight (Mandal and Das, 1989) , grain protein percentage (Bangarwa *et al.*, 1987) and grain yield (Chandorah, 1989) have been reported. However, in the present studies Chakwal –86 and Parwaz –94 have the lowest values of δ_i^2 and CV_i % respectively for grain per spike **(Table-2)**. The varieties have also contributed the least by variety environment interaction measured by W_i^2. The other two statistics i-e δ_i^2 and R_i^2 also showed low and high values respectively.

As b_i value of Mehran and Shahkar are < 1.00, hence these genotypes can be considered stable for this character in low yielding environments. Statistics also favoured Pirsabak–85, Parwaz–94, and Abadgar–93 respectively for the stability of this character in high yielding environments as b1 values of these above genotypes are 1.00 Similarly Kiran–95 (b_i 1.00) and Punjab–96 (b_i < 1.00) indicated stability for 1000–grain weight in high yielding and low yielding environments respectively **(Table-3)**. For grain protein percentage Punjab–96 (b_i close to 1.00) and Mehran–89 (b_i < 1.00) revealed stability in all environments **(Table-4)**. Shahkar–87 and Chakwal–86 (b_i < 1.00) showed stability for grain yield under unfavorable environments **(Table-5).**

The regression lines of mean performance of wheat genotypes over environmental index **(Figs. 1,2,3 and 4)** revealed that those genotypes, which possess small b_i values were less efficient in taking advantage of better conditions. While those genotypes which possess bi values close to unity, increased their performance with an average amount as environmental condition improved. Those genotypes, which possess large b_i values decreased their performance seriously in unfavorable conditions.

Those genotypes which possess more number of grains per spike, high protein percentage and high grain yield were more sensitive to changing environments as revealed by the positive association of b1 with grains per spike (r = 0.42), grain protein percentage (r = 0.46) and grain yield (r = 0.28). However the negative association between bı and 1000 – grain weight (r = 0.47) showed that varieties with high 1000 – grain weight were less sensitive to changing environments as suggested by Faris *et al*., (1981). Hence stability may be in those varieties possessing relatively less number of grains, low protein percentage, low grain yield and high 1000–grain weight.

The inconsistency in the association of grain yield with grains per spike, 1000–grain weight and grain protein percentage at different locations **(Table-6)** revealed significant environmental effect on the performance of varieties.

The results indicated that grain yield could be improved by increasing number of grains per spike and 1000 – grain weight at most of the locations but care should be taken in case of 1000-grain weight due to the presence of negative association at certain locations.

The grain protein percentage will decrease at different rates at different locations by measuring grain yield, however reduction in protein percentage can be minimized by selecting locations with appropriate environmental conditions.

Similarly relationship of grain yield with grains per spike (Kinyua and Ayiecho 1992), 1000 grain weight (Mahmood and Shahid 1993) and grain protein percentage (Campana and Sempe, 1984) has also been reported in the previous research studies.

Our results suggest that due to the inconsistent relationship of these characters, selection for the improvement of grain yield on the basis of these characters should not be exercised as a routine procedure. It would be desirable to explore the effects of environmental factors such as temperature, precipitation, soil fertility and their interactions in the development of these characters. Such information would be instrumental in enhancing our understanding of the nature of their relationship in future breeding programmers (Siddiqui, 1990, 1992, 1994, 2008).

Table-1 Analysis of variance for number of grains per spike, 1000-grain weight, grain protein percentage and grain yield

Source	**DF**	**No. Of Grains/ Spike**	**1000 – Grain Weight**	**Grain Protein Percentage**	**Grain Yield (t/h)**
Year	1	474.141**	438.355**	21.7928**	3.14493 NS
Location	8	1689.38**	721.788**	86.1029**	29.1825**
Genotype	9	1152.80**	489.067**	12.9546**	19.0965**
Genotype – years	9	1074.08**	45.5422**	1.45804*	9.54713**
Genotype – location	72	212.126**	71.3586**	5.96371**	8.49692**
Genotype- location –Year	72	183.201**	69.5317**	2.32793**	9.85370**
Error	358	13.7980	2.70639	0.68248	2.06405

NS = Non – Significant
* = Significant at 5% level
** = Significant at 1% level of Probability

Table-2 Mean number of grains per spike and stability statistics of genotypes over locations and years

No.	Genotypes	Yi	S_i^2	CV%	W_i^2	b_i	δ_i^2	R_i^2
1	Punjab-96	58.389	11.022	18.877	36.208	1.332	0.401	0.612
2	Kiran-95	51.833	9.6832	18.681	13.629	1.238	0.246	0.783
3	Mehran-89	51.833	9.6832	18.681	13.053	0.776	0.241	0.597
4	Shahkar-87	49.500	10.891	21.856	48.681	0.575	0.465	0.180
5	Pirsabak-85	57.926	10.761	18.578	42.270	1.115	0.433	0.486
6	Parwaz-94	61.574	10.014	16.264	25.628	1.230	0.337	0.655
7	Tando Jam-83	51.426	10.395	20.214	51.799	1.061	0.480	0.411
8	Abadgar-93	53.296	9.9349	18.641	9.957	0.974	0.210	0.758
9	Chakwal-86	53.019	9.3314	17.600	16.720	0.818	0.727	0.563
10	Anmol-91	62.944	12.494	19.849	89.034	0.870	0.629	0.215

Table-3 Mean 1000-grain weight and stability statistics of genotypes over locations and years

No.	Genotypes	Y_i(g)	S_i^2	CV%	W_i^2	b_i	δ_i^2	R_i^2
1	Punjab-96	43.981	6.4811	18.877	27.161	0.531	0.459	0.439
2	Kiran-95	40.347	5.4049	13.396	12.996	1.776	0.367	0.769
3	Mehran-89	40.347	5.4049	13.396	4.477	0.169	0.216	0.080
4	Shahkar-87	37.107	6.4806	17.464	4.392	0.778	0.214	0.654
5	Pirsabak-85	44.709	8.5135	19.042	2.682	1.320	0.167	0.899
6	Parwaz-94	44.798	8.4873	18.946	16.644	0.987	0.416	0.446
7	Tando Jam-83	43.115	4.2180	9.7833	-18.771	1.083	0.132	0.905
8	Abadgar-93	38.520	5.6062	14.554	-11.380	0.790	0.103	0.894
9	Chakwal-86	41.186	6.7520	16.394	-11.711	0.964	0.105	0.924
10	Anmol-91	39.306	6.3649	16.193	-19.044	1.156	0.133	0.915

Table-4 Mean grain protein percentage and stability statistics of genotypes over locations and years

No	Genotypes	Y_i(%)	S_i^2	CV%	W_i^2	b_i	δ_i^2	R_i^2
1	Punjab-96	11.128	1.5462	13.895	0.320	0.970	0.167	0.828
2	Kiran-95	11.461	1.5698	13.697	1.030	0.832	0.300	0.524
3	Mehran-89	11.461	1.5698	13.697	1.548	0.511	0.367	0.217
4	Shahkar-87	11.701	1.7163	14.668	0.450	0.82	0.198	0.711
5	Pirsabak-85	11.566	1.9781	17.102	1.031	1.117	0.300	0.665
6	Parwaz-94	11.820	1.7688	14.964	0.920	1.116	0.283	0.690
7	Tando Jam-83	12.048	1.8396	15.269	0.402	0.944	0.187	0.784
8	Abadgar-93	12.610	1.8904	14.991	0.894	1.233	0.279	0.736
9	Chakwal-86	12.577	2.1634	17.202	0.502	0.912	0.286	0.725
10	Anmol-91	11.491	1.6960	14.759	0.503	0.943	0.186	0.763

Table-5 Mean grain yield and stability statistics of genotypes over locations and years

No.	Genotypes	Yi(t/h)	S_i^2	CV%	W_i^2	b_i	δ_i^2	R_i^2
1	Punjab-96	5.0909	1.3272	26.070	0.345	0.838	0.298	0.531
2	Kiran-95	4.2631	0.9819	23.031	0.456	0.484	0.343	0.222
3	Mehran-89	4.2631	0.9819	23.031	0.109	0.716	0.168	0.723
4	Shahkar-87	4.0372	1.1802	29.232	0.590	0.447	0.389	0.159
5	Pirsabak-85	5.1730	1.2133	23.454	0.606	0.796	0.395	0.367
6	Parwaz-94	5.3693	1.2196	22.714	0.198	1.176	0.226	0.795
7	Tando Jam-83	5.9556	6.0529	101.63	9.040	2.560	1.524	0.287
8	Abadgar-93	4.1933	1.1459	27.327	0.292	1.037	0.274	0.672
9	Chakwal-86	4.6278	1.1392	24.616	0.674	0.820	0.416	0.357
10	Anmol-91	5.0606	1.2917	25.524	0.894	1.125	0.343	0.606

Table-6 Correlation of grain characters with grain yield under different environments.

Location	Grain per spike	1000 grain weight	Grain protein %
Tando Jam	- 052 NS	.826 **	- 469**
Sakrand	.743**	.431**	.046 NS
Sukkur	.680**	.038NS	.192 NS
Rahimyar Khan	.531**	-417**	-187 NS
Khanewal	.074 NS	.093 NS	.030 NS
Sahiwal	.469 **	.0623**	-441 **
Quetta	.690**	.192 NS	-187 NS
Jaccobabad	.177 NS	.006 NS	.023 NS
Dokri	.619 **	.306*	.246 NS

* = Correlation is significant at the 0.05 level (2-Tailed)
** = Correlation is significant at the 0.01 level (2-Tailed)
NS = Non Significant.

Fig. 1. Regression Lines of No. of grains per spike over the Environmental index

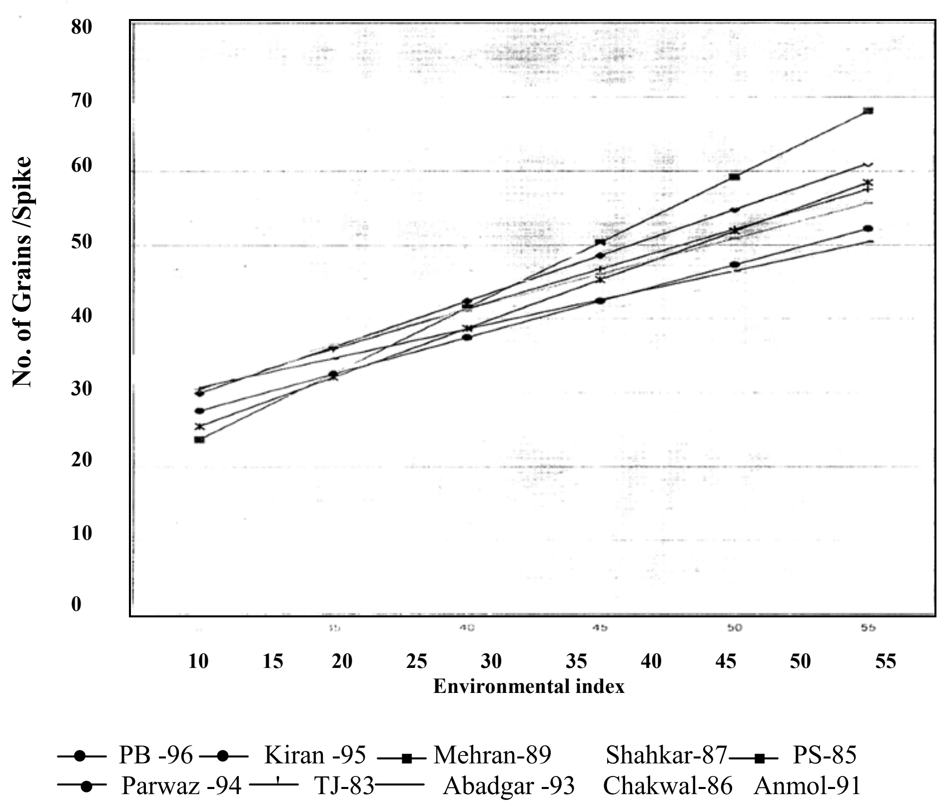


Fig. 2. Regression Lines of 1000-grain weight the Environmental index

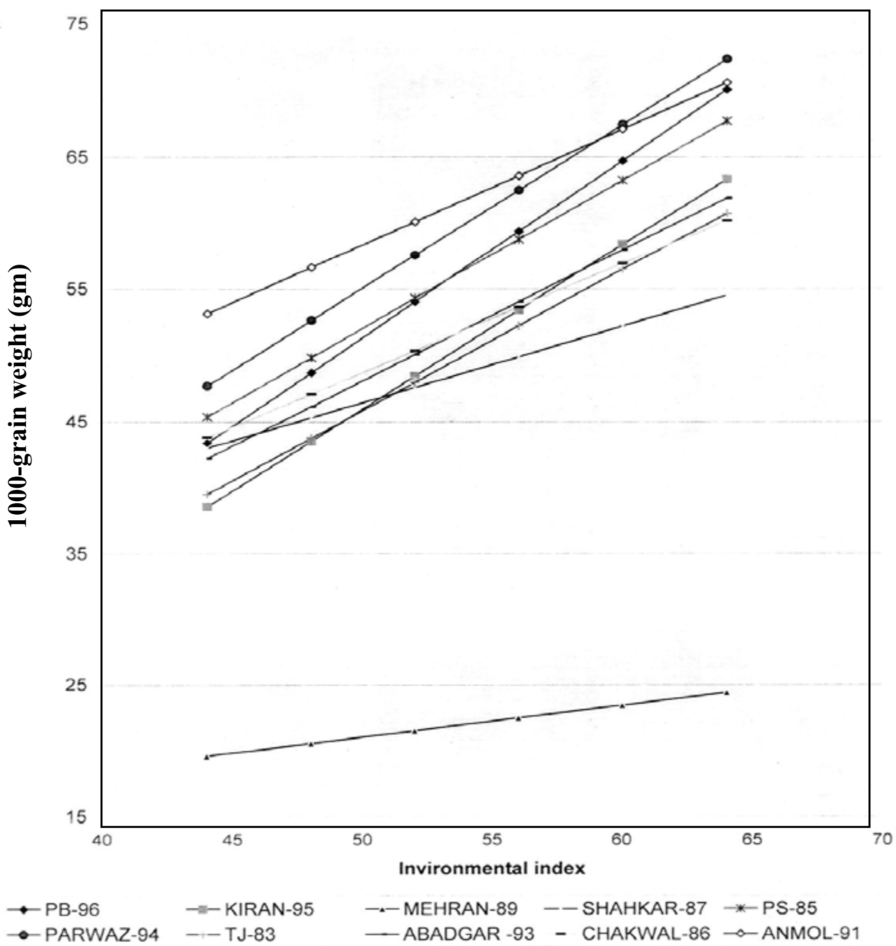


Fig. 3 Regression Lines of grain protein percentage over the Environmental index

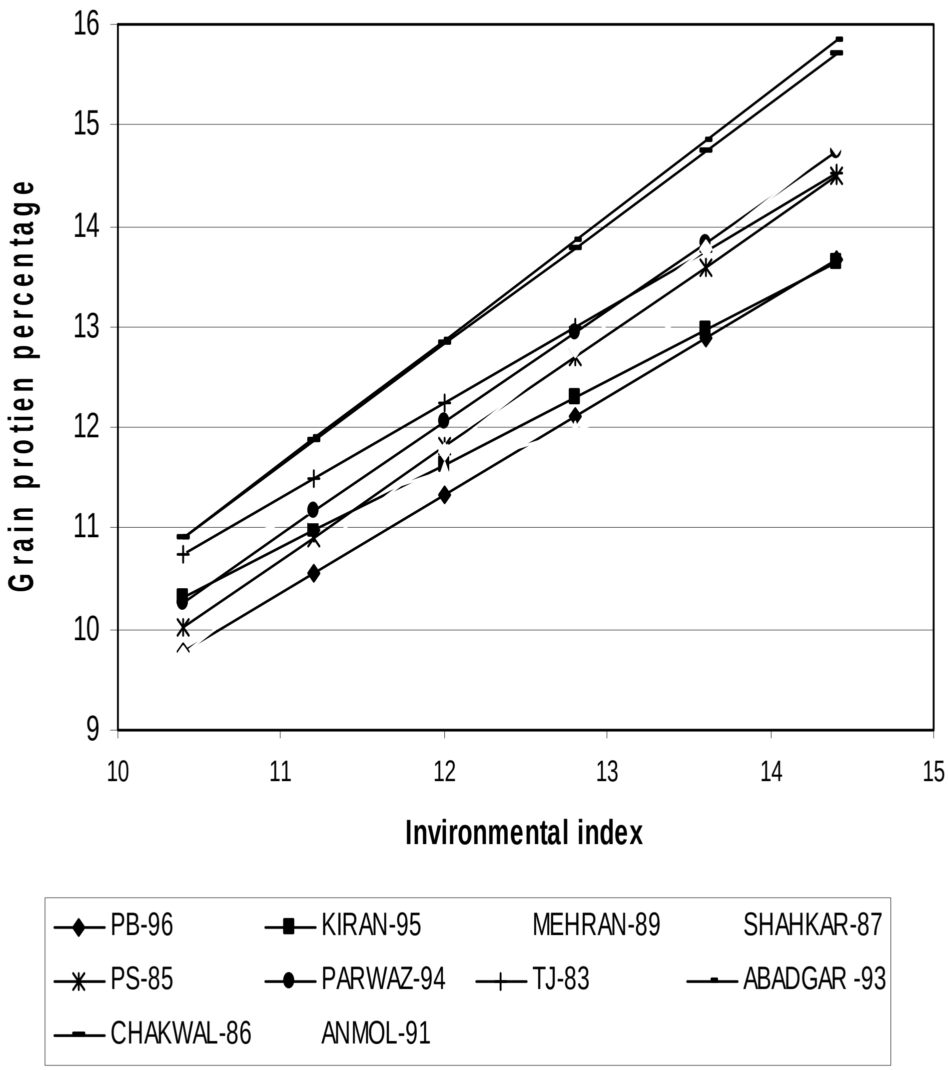
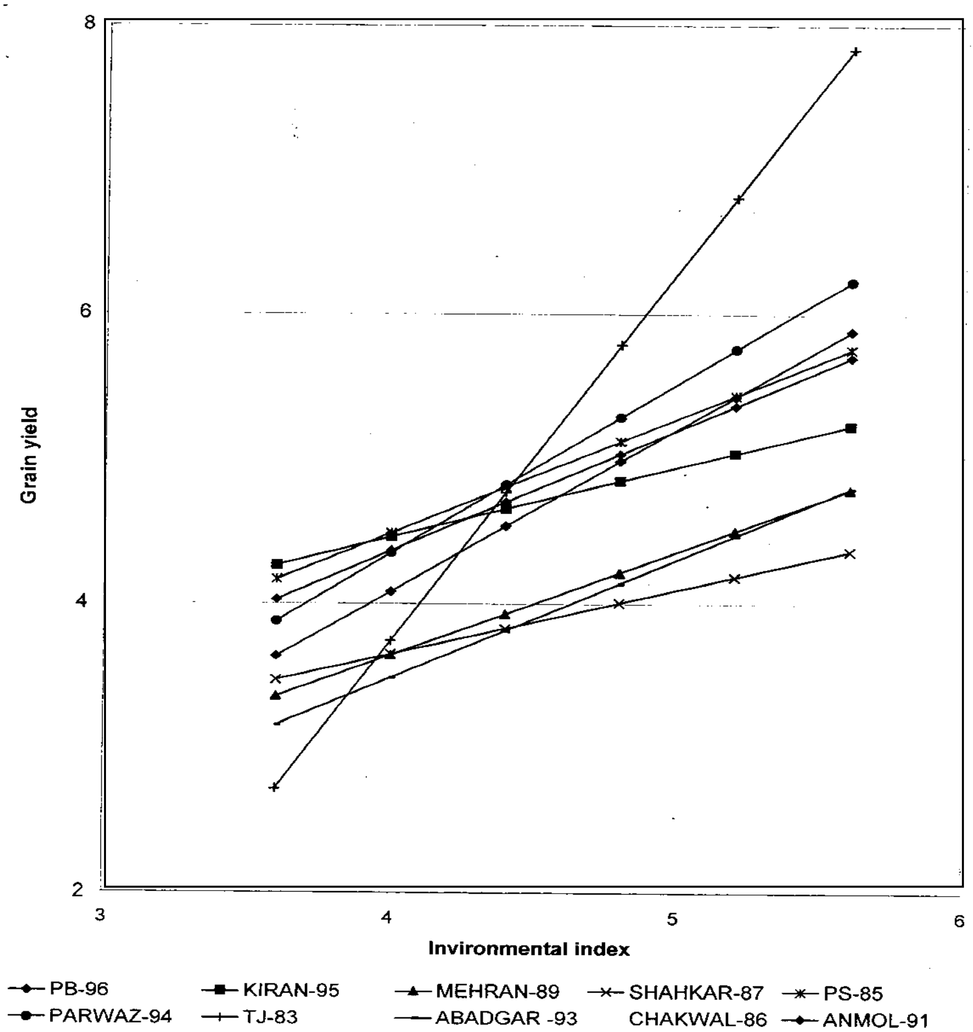


Fig. 4 Regression Lines of Grain yield over the Environmental index



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