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ASSESSMENT OF ADAPTABILITY AND STABILITY OF GRAIN YIELD IN BREAD WHEAT GENOTYPES UNDER DIFFERENT SOWING TIMES IN PUNJAB

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Abstract

Twenty advanced lines/genotypes of wheat including two check varieties were sown under two different sowing times through out the Punjab province at 18 different locations with diverse environments to study their stability and adaptability. Normal sowing was done in second week of November 2007 while the delayed sowing was completed during second week of December 2007 during crop season 2007-08. The pooled analysis of variance showed significant differences among environments and genotypes for grain yield demonstrating the presence of considerable variations ($p<0.01$) among genotypes as well as diversity of growing environments at various locations for both normal and late sown wheat crops. The highest average grain yield was obtained at Jalandar Seed Farm, Arifwala and Pak. German Farm, Multan for normal and delayed sown crops, respectively. Most of the locations emerged as high yielding in normal sowing compared to late sown crop. Dendrograms of 18 locations based on the average yield of 20 wheat genotypes grown under normal and late sown crop revealed two main clusters. Under both normal and late sowing, none of the varieties exceeded the check Seher-2006, however, the check was followed by the advanced lines V-04022 and V-05066 for normal sown crop and Shafaq-2006, V-05066 and V-04022 under delayed sowing. All the genotypes revealed decline in grain yield for late sown wheat crop. The analysis of stability based on mean grain yield, regression coefficient and deviation from regression advocated that the cultivars V-05066 and V-03BT007 were most stable and adapted to diverse environmental conditions of Punjab. These cultivars revealed unit regression and non-significant deviations from regression. The check variety Seher-2006 produced maximum yield for both sowing times that suggested its consistent and stable performance across the environments.

Introduction

Wheat is the main crop of Pakistan and cultivated on a huge area every year. It plays a pivotal role in the food security and occupied 14% share of the value added in agriculture and 3% of GDP of the country (Anon., 2006-07). Punjab province is the backbone of wheat production in the country and contributes three fourth of the total area as well as production. In Punjab, in addition to normal sowing, wheat is also sown as late crop due to the delayed harvesting of cotton in southern Punjab and late harvesting of rice in the central Punjab. Delayed sowing of wheat not only affects germination and growth but also affects grain filling and yield (Haq & Khan, 2002), whereas early sowing results in higher grain yields (Arain *et al*., 2001; Sial *et al*., 2001). Ishag (1994) reported that early or normal sowing prolongs the duration of tillering and grain filling followed by high grain yield. The main complexity with late sown wheat and barley crops arises due to high temperature at reproductive stages resulting in lower grain yields (Wardlaw & Wrigley, 1994; Savin *et al*., 1996; Ali *et al*., 2009).

Punjab has great diversity for environmental factors like soil, temperature, relative humidity and rainfall. Although Punjab comprises of very fertile areas, well provided with supplemental irrigation but many parts of it are less productive due to high temperature and relative humidity especially for late sown wheat crop. It reveals that wheat productivity in this region is highly dependant upon genotype × environment (G × E) interaction which might lead to the instability of genotypes over changing environments The perfect wheat cultivar should be high yielding under any environmental circumstances, but as genetic effects are not independent of environmental effects, most genotypes do not perform satisfactorily over varying environments (Carvalho *et al*., 1983). This causes a difficulty for choosing genotypes appreciably superior in grain yield (Stafford, 1982).

The G×E interaction is a most important problem in the study of quantitative traits as it obscures the interpretation of genetic experiments and makes predictions difficult. It is a particular dilemma in plant breeding where genotypes have to be selected in one environment and used in another (Kearsey & Pooni, 1998; Giauffret *et al*., 2000; Farshadfar & Sutka, 2003). Complexities related with environmental variables such as radiation, high temperature, and relative humidity, frequently make it complicated to understand G×E interactions especially for late sown wheat crop (Rane *et al*., 2007). Multiple environment trials are carried out to recognize superior cultivars for the target region (Alizadeh *et al*., 2008).

To identify stable varieties for divergent environments, utilization of G×E interaction is of fundamental importance. G×E interaction increases with more differences among the cultivars in different environments or from changes in relative ranking of the cultivars (Allard & Bradshaw, 1964; Fernandez, 1991).

Various statistical procedures have been proposed to find out the stability of new cultivars. Eberhart & Russell (1966) suggested that regression coefficient 'b' and deviation from regression coefficient 'S^2d' might predict stable genotype. A genotype having $b<1.0$ has above average stability and is especially adaptable to low-performing environments. Conversely, a cultivar with $b>1.0$ has below average stability and is particularly adaptable to high performing locations; however, a variety with $b = 1.0$ has average stability and adaptable to all environments depending on high or low mean performance (Finlay & Wilkinson, 1963). According to Eberhart & Russell (1966) a cultivar with $b = 1$ and $S^2d = 0$ might be stable across divergent environmental conditions.

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The stability of genotype performance across the changing environments has a significant importance for the breeders. It is of utmost importance to evaluate the multi-environmental stability of cultivars under different sowing times as more than 70% of the crop in the province is late sown. This research was aimed to evaluate grain yield stability of different newly bred wheat genotypes under both normal and late sown crops.

Material and Methods

Twenty advanced wheat lines/genotypes including two check varieties, Seher-2006 and Shafaq-2006 (Table 1) were planted on two different sowing times through out the Punjab province at 18 different locations, considerably different for environmental factors such as soil, temperature etc (Table 2). Normal sowing was carried in second week of November 2007 while delayed sowing was completed during second week of December 2007 during crop season 2007-08. The experiment was laid out using Randomized Complete Block Design with three replications. The gross experimental plot for each entry comprised of 6 rows each, 3 meter long and rows were 30 cm apart (1.80 m^2). The seed rate used was 100 kg ha^{-1} and NPK fertilizers were applied @ 100-100-0 kg ha^{-1} at each location uniformly. At maturity a net plot size of 1.20 m^2 was harvested from each entry and the data was recorded for grain yield as tones per hectare (t ha^{-1}).

Table 1. Twenty wheat advanced lines/genotypes, two check varieties Seher-2006 and Shafaq-2006 along with their parentage.

Sr. No.	Genotype	Parentage
V-1	V-05044	FLK ‘S’/ HORK /6/WA 4767/391//56D81-4/53/3/1015-6410/4/W 22/5/ANA/7/CHIL ‘S’
V-2	V-TWS69019	TWS 9601/TWO 135
V-3	V-05048	FLK ‘S’/ HORK /6/WA 4767/391//56D81-4/53/3/1015-6410/4/W 22/5/ANA/7/CHIL ‘S’
V-4	V-9268	712/ PBW 222
V-5	V-05055	AMSEL / ATTILA // CHAM-4
V-6	V-056132	CAL/ WH/ H 567.71 /3/ SERI /4/ CAL/ WH // H 567.71
V-7	V-05066	AMSEL / ATTILA// PEW ‘S’
V-8	V-066205	INQ. 91*2 / TUKURU
V-9	V-05082	CHENAB 2000 / INQ. 91
V-10	V-056037	URES / BB // KAUZ /3/ KAUZ /4/ CHEN
V-11	V-06129	WBLL 1 *2 / KKTS
V-12	V-05BT006	MAYA / MONS // HORK / FSD 85
V-13	V-05115	OTUS / TOBA 97
V-14	Seher-2006	CHECK
V-15	V-04022	INQ. 91 /3/ CROW / NAC // BOW ‘S’
V-16	V-03BT007	V. 87094 / ALD ‘S’ /3/ BOW / CROW // WATTAN 94
V-17	V-06140	REBECA F 2000
V-18	Shafaq-2006	CHECK
V-19	V-05121	85205 / CHENAB 2000 // HD 2169
V-20	V-05100	KAUZ / SITE

Table 2. Eighteen locations throughout the Punjab province along with soil classification.

Sr. No.	Location	Latitude	Longitude	Soil classification	Location in the Punjab
L-1	Faisalabad	31º24´ N	73º02´ E	Loam	Central Punjab
L-2	Khanewal	30º17´ N	71º56´ E	Sandy loam	Southern Punjab
L-3	Mian Channu	30º27´ N	72º21´ E	Silt loam	Southern Punjab
L-4	Vehari	30º01´ N	72º20´ E	Clay loam	Southern Punjab
L-5	Lodhran	29º32´ N	71º37´ E	Silt loam	Southern Punjab
L-6	Multan	30º18´ N	71º29´ E	Loam	Southern Punjab
L-7	Pir Jhangir Sharif, Layyah	30º28´ N	70º57´ E	Sandy loam	Southern Punjab
L-8	Chak No. 219 TDA, Layyah	30º59´ N	71º12´ E	Silt loam	Southern Punjab
L-9	Sargodha	32º09´ N	74º21´ E	Clay loam	Central Punjab
L-10	Chiniot, Jhang	31º43´ N	72º59´ E	Loam	Central Punjab
L-11	Gojra, Toba Tek Singh	31º08´ N	72º41´ E	Clay loam	Central Punjab
L-12	Okara	30º48´ N	73º28´ E	Loam	Central Punjab
L-13	Harappa, Sahiwal	30º37´ N	72º52´ E	Silt loam	Central Punjab
L-14	Arifwala	30º17´ N	73º04´ E	Silt loam	Southern Punjab
L-15	Karur	31º13´ N	70º57´ E	Sandy loam	Southern Punjab
L-16	Gujranwala	32º10´ N	74º10´ E	Loam	Central Punjab
L-17	Deska, Sialkot	32º19´ N	74º21´ E	Silt loam	Central Punjab
L-18	Farroqabad, Sheikhupura	31º43´ N	73º59´ E	Clay loam	Central Punjab

Analysis of variance for each location and pooled analysis over locations were computed assuming replication and location effects as random and genotypes were regarded as fixed variable (Steel *et al*., 1997) and yield stability parameters were calculated according to Eberhart & Russell (1966). The average yield of each variety was regressed on the environmental index. Regression coefficient (bi) and deviation from regression (S^2d) were calculated and used as stability parameters for evaluating the yield stability over various locations all over the Punjab. Cluster diagrams were developed by STATISTICA 5.0 program based on linkage distances using Ward's method. A genotype, which had high mean yield, regression coefficient (bi) close to unity and deviation from regression (S^2d) near to zero, was defined as a stable cultivar (Eberhart & Russell, 1966).

Results and Discussion

The pooled analysis of variance (Table 3) showed that there were significant differences among environments and genotypes for grain yield demonstrating the presence of considerable variability in genotypes as well as diversity of growing environments at various locations for both normally and late sown wheat crops. The pooled ANOVA also revealed highly significant ($p<0.01$) G x E interaction reflecting the differential response of genotypes in various environments.

The G x E interaction was partitioned into linear {environment (linear) and GxE (linear)} and nonlinear (pooled deviation) components. The combined analysis of variance for grain yield (Table 3) showed significant diversity for the environment components including environment + (G × E) and environments (linear) under normal as well as late sown crop. This suggested enough involvement of environmental effects in the determination of grain yield at various locations all over the Punjab for both the sowing times. Highly significant differences between environments (environment linear) also indicated the genetic control of genotypic response to environments (Zubair *et al*., 2001; Rasul *et al*., 2006). The mean squares of environments were of greater magnitude than genotypes and the G x E interaction. The significant G x E (linear) interactions in combined analysis indicated that the linear grain yield response of genotypes was not the similar at diverse environments for late sown crop, however, for normally sown crop it was non significant which suggested that most of the genotypes performed likely in the changing environments. This also reflected lack of genetic differences among genotypes for their response to varying environments for the crop sown at normal sowing time (Rasul *et al*., 2006).

The nonlinear (pooled deviation) component was also highly significant when tested against the pooled experimental error at both sowing times showing that the differences in stability was due to deviation from linear regression only (Khan *et al*., 1988; Ashraf *et al*., 2001; Rasul *et al*., 2006). This revealed that a degree of non-linearity still was present in the relationship between G x E.

The average grain yield of all the genotypes over various locations was assessed (Table 4) and the highest grain yield was obtained at Jalandar Seed Farm, Arifwala (5.31 t ha^{-1}) followed by Lodhran (5.17 t ha^{-1}) and In-service Training Institute, Sargodha (4.82 t ha^{-1}) for normally sown wheat crop. Similarly, for delayed sown crop, the highest average grain yield of different genotypes over locations was produced at Pak. German Farm, Multan (5.32 t ha^{-1}) followed by Sharif Model Farm, Chiniot, Jhang (4.62 t ha^{-1}) and Deska, Sialkot (4.21 t ha^{-1}). Overall average yield for normally as well as late sown crop also was the highest at Pak. German Farm, Multan (4.79 t ha^{-1}) followed by Jalandar Seed Farm, Arifwala (4.65 t ha^{-1}) and Lodhran (4.47 t ha^{-1}). Normally sown crop produced mainly 48.98, 39.14 and 37.82% more grain yield than late sown at Toba Tek Singh, Chak No. 219 TDA, Layyah and Sahiwal, respectively (Table 4). On the other hand grain yield declined at maximum by 31.87, 24.91 and 12.29% at Sialkot, Multan and Jhang, respectively. Most of the locations emerged as high yielding in normal sowing compared to late sown crop. This might be the function of high temperature at grain formation stage (Wardlaw & Wrigley, 1994; Savin *et al*., 1996). So, genotypes performing better under heat stressed environments at one location may perform better at similar locations elsewhere (Reynolds *et al*., 1994) as in this experiment most of the cultivars did better at Pak. German Farm, Multan followed by Sharif Model Farm and Chiniot, Jhang for late sown crop.

Table 3. Pooled analysis of variance of 20 advance lines/genotypes over 18 locations.

Source of variation	df	Mean squares	
		Normally sown	Late sown
Replications	2	0.013	0.083
Environments	17	25.408**	44.086**
Genotypes	19	3.661**	2.557**
Genotype × Environment	323	0.556**	0.324**
Environment + (G × E)	340	0.599**	0.838**
Environment (Linear)	1	143.982**	249.835**
G × E (Linear)	19	0.146	0.179*
Pooled deviation	320	0.178**	0.099**
Pooled error	720	0.009	0.009

* and ** = Significant at 5% and 1%, respectively

Tree diagram of 18 locations based on the average yield of 20 wheat genotypes grown under normal sowing revealed two main clusters (Fig. 1). L-1, L-3, L-10 and L-12, (about 4.0 t ha^{-1}) emerged as similar yielding locations while L-2, L-4, L-8, L-13 and L-18 raised nearly comparable mean yield (around 3.50 t ha^{-1}). The locations L-16, L-17 (around 3.0 t ha^{-1}) and L-5, L-14 (around 5.0 t ha^{-1}) which were related to two different clusters produced extreme grain yields under normal sowing. However, L-6, L-7, L-9, L-11 and L-15 gave rise to medium grain yield (around 4.5 t ha^{-1}) for normally sown wheat crop. This suggested that the locations giving rise to same grain yield might be considered responding similarly to various cultivars (Roustaii *et al*., 2003). The divergence of various locations in their ability to produce grain yield might be due to variation in soil fertility, water holding capacity, latitude, uneven agronomic practices and diversity in other agro-climatic conditions prevailing at the location throughout the crop season (Rane *et al*., 2007).

The dendrogram of the locations based on grain yield of 20 genotypes for late sown wheat crop also resulted in two main clusters but with different pattern (Fig. 2). First cluster was further partitioned into two sub clusters, one of which included L-1, L-8, L-11, L-13 and L-16 producing grain yield near to 2.2 t ha^{-1} while the other comprised of L-2, L-9, L-7 and L-15 with grain yield of around 3.2 t ha^{-1}. Similarly, second cluster again divided into two sub groups, one consisted of the single location (L-6) producing the maximum grain yield (5.32 t ha^{-1}) and the other sub cluster comprised the locations (L-3, L-4, L-5, L-10, L-12, L-14, L-17 and L-18) with adequate grain yield (around 4.0 t ha^{-1}). This divergence among various locations might be due to the heterogeneous soils and imprecision in field operations (Crossa *et al*., 1991).

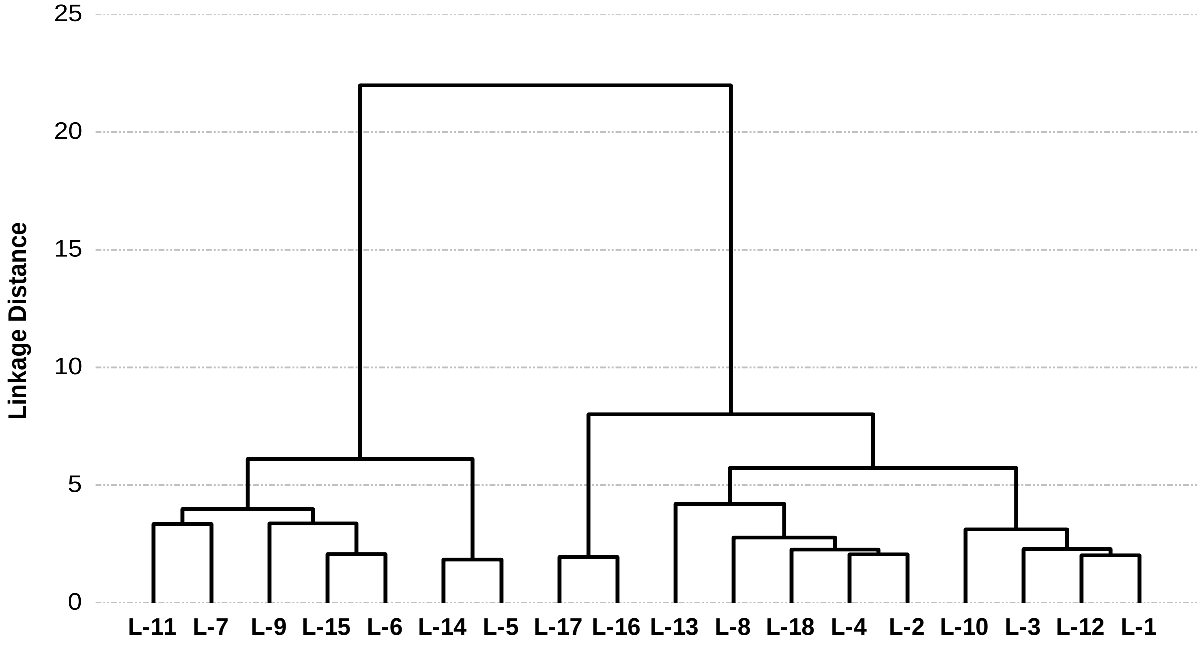

Fig. 1. Dendrogram for 18 locations based on grain yield under normal sowing Ward's method.

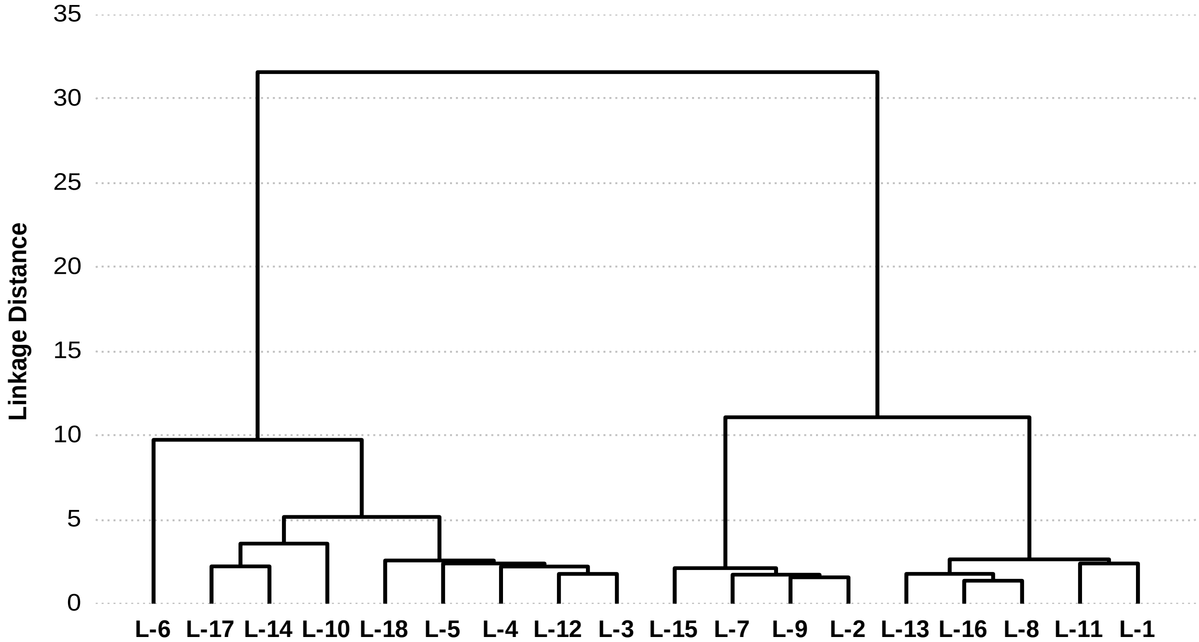

Fig. 2. Dendrogram for 18 locations based on grain yield under late sowing Ward's method.

Table 4. Average performance of locations for grain yield produced by 20 genotypes.

Locations	Mean grain yield (Tons per hectare)			
	Normal	Late	Overall	% Increase or decline[1]
L-1	4.05 d	2.67 i	3.36 h	34.02
L-2	3.68 ef	3.13 gh	3.41 h	14.96
L-3	4.13 d	3.74 e	3.93 de	9.53
L-4	3.78 e	3.70 e	3.74 f	2.31
L-5	5.17 a	3.78 e	4.47 c	26.94
L-6	4.26 d	5.32 a	4.79 a	-24.91
L-7	4.72 b	3.02 h	3.87 e	36.03
L-8	3.64 ef	2.22 k	2.93 i	39.14
L-9	4.82 b	3.24 fg	4.03 d	32.85
L-10	4.11 d	4.62 b	4.36 c	-12.29
L-11	4.63 b c	2.36 jk	3.50 gh	48.98
L-12	4.07 d	3.98 d	4.03 d	2.26
L-13	3.56 f	2.22 k	2.89 i	37.82
L-14	5.31 a	4.00 d	4.65 b	24.64
L-15	4.46 c	3.37 f	3.91 de	24.47
L-16	2.96 h	2.43 j	2.70 j	17.82
L-17	3.19 g	4.21 c	3.70 f	-31.87
L-18	3.50 f	3.64 e	3.57 g	-4.11

[1] % increase or decline of normally sown crop over that of late sown crop.

As the performance of different advance lines is concerned under normal sowing, none of the varieties exceeded from the check Seher-2006 which produced an average of 4.80 t ha^{-1} over 18 locations (Table 5). However the advanced line V-04022 produced maximum grain yield (4.50 t ha^{-1}) after Seher-2006 followed by V-05066 and 05BT006 both of which gave 4.43 t ha^{-1} for timely sown crop. In late crop again Seher-2006 (3.94 t ha^{-1}), the check variety hold the lead followed by the second check Shafaq-2006 (3.83 t ha^{-1}). In case of advance lines V-05066 gain the highest yield followed by V-04022 under delayed sowing (Table 5). These cultivars displayed greater and stable yield under late-sown condition across diverse environments and these should be used as contributing parents in the current breeding programs to develop heat tolerant wheat varieties (Rane & Chauhan, 2002; Rane *et al*., 2007). Overall mean grain yield of the genotypes over 18 environments (Table 5) for both normal as well as late sowing demonstrated Seher-2006 (4.37 t ha^{-1}) as the highest producer which was well chased by V-04022 (4.08 t ha^{-1}) and V-05066 (4.06 t ha^{-1}). All the genotypes revealed decline in grain yield for late sown wheat crop. Maximum yield decline was exhibited by 03BT007 (21.39%) followed by V-06129 (21.31%) and V-05082 (21.29%). Shafaq-2006 the check displayed stable yield for both timely and late sown crop and exhibited minimum yield decline (4.06%). This variable performance of the genotypes was the function of their different genetic makeup and difference in the extent of G E interaction across the environments (Farshadfar & Sutka, 2003).

Table 5. Mean performance of 20 genotypes over 18 locations throughout Punjab.

Sr. No.	Genotype	Mean grain yield (Tons per hectare)			
		Normal	Late	Overall	% Decline
V-1	V-05044	3.89 ef	3.36 ef	3.63 fghi	13.71
V-2	TWS69019	3.77 fg	3.23 ghi	3.50 i	14.32
V-3	V-05048	4.05 def	3.24 efgdi	3.64 fghi	20.05
V-4	V-9268	3.97 def	3.18 i	3.58 ghi	19.91
V-5	V-05055	4.10 de	3.54 cd	3.82 de	13.56
V-6	V-056132	3.89 ef	3.34 efg	3.62 ghi	14.09
V-7	V-05066	4.43 bc	3.69 b	4.06 bc	16.75
V-8	V-066205	4.01 def	3.30 efgh	3.66 fgh	17.72
V-9	V-05082	4.22 bcd	3.32 efgh	3.77 ef	21.29
V-10	V-056037	4.10 de	3.23 fghi	3.67 efgh	21.22
V-11	V-06129	4.08 de	3.21 hi	3.64 fghi	21.31
V-12	05BT006	4.43 b	3.57 bc	4.00 bc	19.58
V-13	V-05115	3.90 ef	3.35 e	3.62 fghi	14.13
V-14	Seher-2006	4.80 a	3.94 a	4.37 a	17.91
V-15	V-04022	4.50 b	3.65 b	4.08 b	18.95
V-16	03BT007	4.16 cde	3.27 efghi	3.71 efg	21.39
V-17	V-06140	3.75 fg	3.27 efghi	3.51 hi	12.74
V-18	Shafaq-2006	3.99 def	3.83 a	3.91 cd	4.06
V-19	V-05121	3.58 g	3.50 cd	3.55 hi	2.23
V-20	V-05100	4.14 cde	3.46 d	3.80 de	16.50

The cluster diagram of genotypes based on average grain yield produced at all the location in Punjab showed three main groups for normally sown crop (Fig. 3). First group comprised of V-7, V-12, V-14 and V-15 with mean grain yield approximately 4.50 t ha^{-1} thus, this group included all the top scorers. Second cluster consisted of V-4, V-6, V-8, V-10, V-11, V-13, V- 19 and V-20 with yield of about 4.0 t ha^{-1}. Similarly cluster three under normal sowing included all the medium and low yielding cultivars such as V-1 and V-17 (3.80 t ha^{-1}), V-2, V-3 and V-18 (3.90 t ha^{-1}), V-5, V-9, and V-16 (4.10 t ha^{-1}). On the other hand, two groups of genotypes were derived in case of late sown crop (Fig. 4). Group one included genotypes (V-5, V-7, V-12, V-14, V-15, V-18, V-19 and V-20) with the maximum grain yield 3.46 to 3.94 t ha^{-1} over all locations. Likewise group two comprised of V-1, V-2, V-3, V-4, V-6, V-8, V-9, V-10, V-11, V-13, V-16 and V-17 with average yield of 3.18 to 3.36 t ha^{-1}.

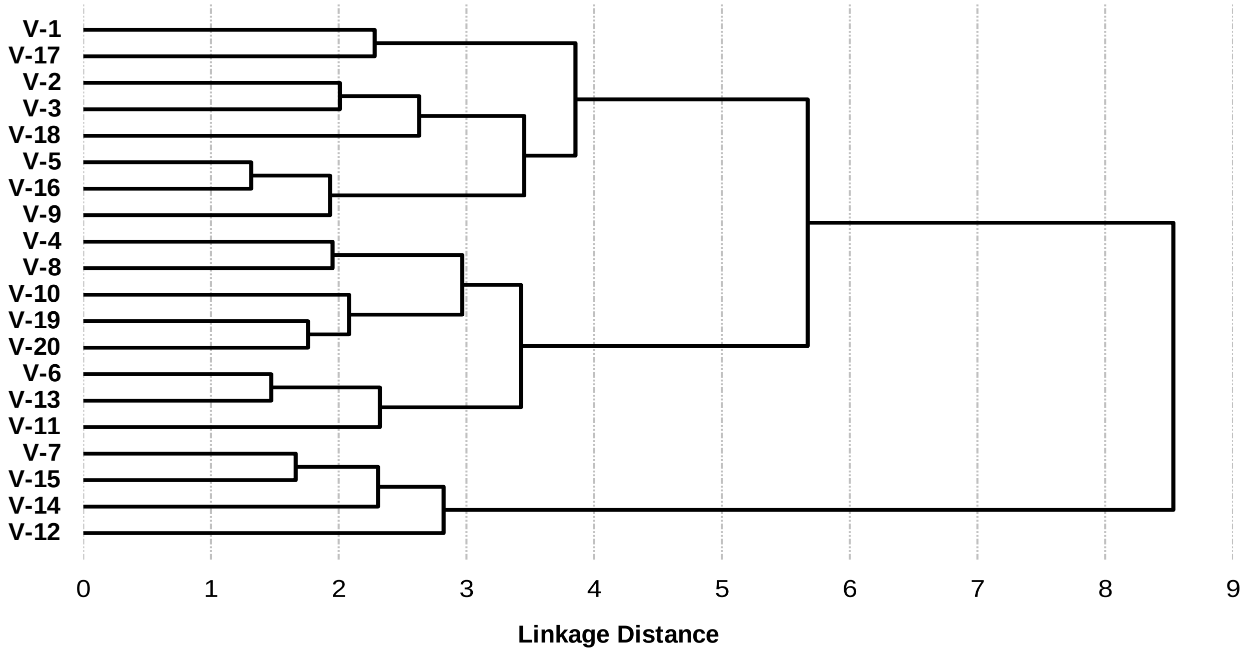

Fig. 3. Dendrogram for 20 genotypes grown at 18 locations under normal sowing Ward's method.

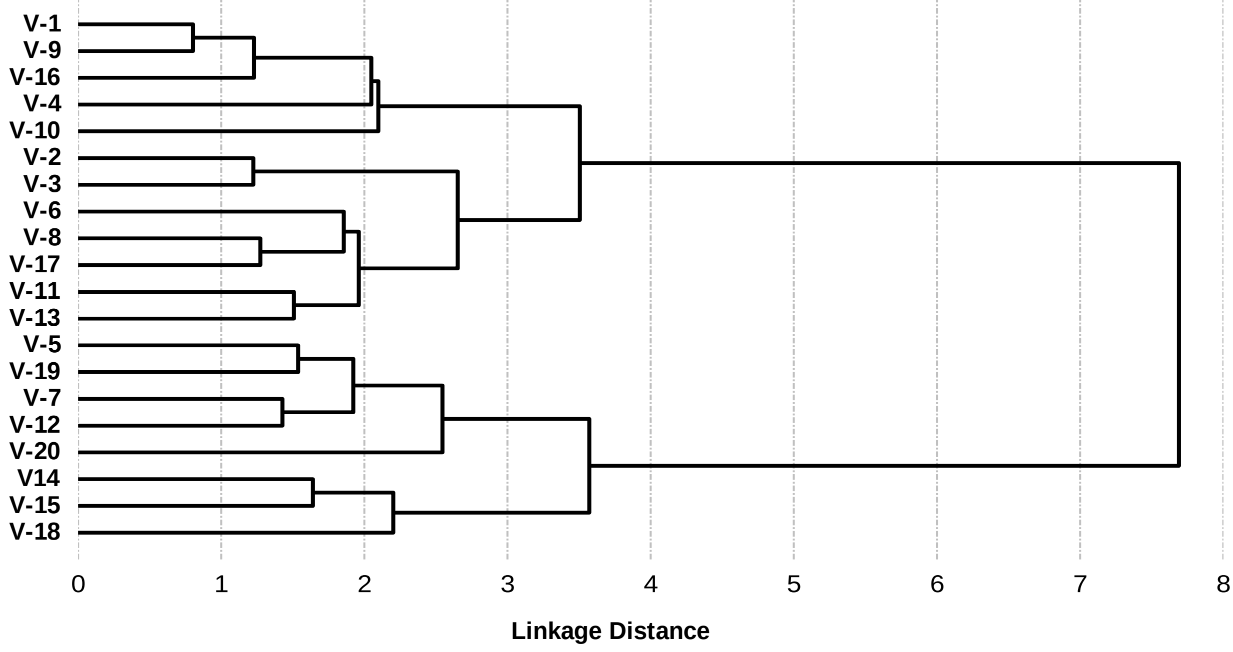

Fig. 4. Dendrogram for 20 genotypes at 18 locations under late sowing Ward's method.

The assessment of stability of various genotypes through joint regression analysis was first discussed by Yates & Cochran (1938) and was later modified and used by Finlay & Wilkinson (1963) and Eberhart & Russell (1966). Part of the genotype stability is expressed in terms of three empirical parameters: the mean performance, the slope of regression line (bi), and the sum of squares deviation from regression (S^{2}di) (Crossa, 1990; Flores *et al.*, 1998).

There remained various schools of thoughts regarding the assessment of stability for genotypes grown under diverse environmental regimes. According to Finlay &

Wilkinson (1963), who focused on only regression coefficient (bi) and defined varieties with general adaptability with average stability (bi = 1.0) associated with high mean yield over tested environments. However, they also recognized that above average stability (bi near to zero) is associated with increasing adaptability to low yielding environment. On the other hand, Eberhart & Russell (1966), advocated that high average performance over environments, unit regression coefficient and minimum (zero) deviation from regression were the criteria to sort stable cultivars. They suggested that the cultivars exhibiting high regression coefficient (bi>1) have below average stability and such varieties are expected to execute well under favorable environments. In the same way, cultivars with low regression coefficient (bi<1) have above average stability and are expected to perform better in less conducive environments. Eberhart & Russell (1966) revealed that the cultivars with a bi = 1.0 and S^2d near to 0.0 react weakly to divergent environmental conditions and are considered to be stable in yield changes (Shindin & Lokteva, 2000; Amin *et al*., 2005). Another school of thought was that of Baker (1988) who regarded deviation from regression (S^2d) to be the most appropriate criteria for measuring phenotypic stability, because this parameter measures the predictability of genotypic reaction to environment. High and desirable per se performance of a variety over environment is also a positive point to rate the variety as a better and highly stable genotype (Rasul *et al*., 2006; Akcura *et al*., 2006). Moreover, adaptability patterns of crop cultivar require different interpretation and approach to the stability analysis procedure for specific adaptability in an environment (Kakar *et al*., 2003).

In case of timely sown wheat crop (Table 6) high mean yield combined with high value of regression coefficient (b>1) in case of V-05BT006, Seher- 2006, V-05055, V-04022 indicated their good response to favourable conditions (Finally & Wilkinson, 1963; Eberhart & Russell, 1966). Medium grain yield combined with high value of ‘b’ in case of V-05066, V-056037, V-06129, V-05BT007 and V-05100 revealed that these cultivars were adapted to high performing environments. Regression values above 1.0 described genotypes with higher sensitivity to environmental change (below average stability), and greater specificity of adaptability to high yielding environments (Akcura *et al*., 2006). However, the genotypes V-05044, V-TWS69019, V-9268, V-056132, V-05115, Shafaq-2006 and V-06140 exhibited lower grain yield with regression coefficient below one for normally sown crop, were found adaptable to low performing environments. The bi value decreasing below 1.0 provided a measure of greater resistance to environmental change (above average stability), and thus increasing specificity of adaptability to low yielding environments (Eberhart & Russell, 1966; Akcura *et al*., 2006).

High mean yield coupled with regression coefficient exceeding unity in case of Shafaq- 2006, V-05100, V-05121, V-05BT006, V-05066 and V-05055 and signified their excellent response to conducive conditions for delayed sown crop (Table 6). Medium grain yield coupled with high value of ‘b’ for the cultivars V-06140, V-05048, V-056037, V-03BT007 and V-TWS69019 showed their below average stability as well as adaptability to high performing environments for late sown wheat crop. Some of the cultivars such as V-4022, V-05044, V-056132, V-066205, V-05082, and V-05115 exhibited medium grain yield for late crop with regression value of less than unity. This displayed that these genotypes were well adapted to medium performing locations. However, above average stability was demonstrated by the genotypes V-06129 and V-9268 which revealed lower grain yield united with bi<1.0 for late sown crop and were found adaptable to low performing environments.

Table 6. Estimates of stability parameters of 20 advance lines/ genotypes grown under normal and late sowing times over 18 locations.

Genotype	mi		bi		S^2 di	
	Normally sown	Late sown	Normally sown	Late sown	Normally sown	Late sown
V-05044	3.89	3.36	0.68	0.93	0.24**	0.05
TWS69019	3.77	3.23	0.82	1.02	0.20**	0.10**
V-05048	4.05	3.24	0.98	1.20	0.15**	0.06*
V-9268	3.97	3.18	0.85	0.80	0.27**	0.10**
V-05055	4.10	3.54	1.04	1.05	0.12**	0.12**
V-056132	3.89	3.34	0.87	0.96	0.23**	0.15**
V-05066	4.43	3.69	1.08	1.03	0.04	0.04
V-066205	4.01	3.30	0.97	0.83	0.18**	0.08*
V-05082	4.22	3.32	0.97	0.94	0.18**	0.05
V-056037	4.10	3.23	1.27	1.06	0.12**	0.11**
V-06129	4.08	3.21	1.23	0.93	0.17**	0.11**
05BT006	4.43	3.57	1.17	1.05	0.35**	0.05
V-05115	3.90	3.35	1.00	0.96	0.15**	0.10**
Seher-2006	4.80	3.94	1.14	0.96	0.15**	0.08*
V-04022	4.50	3.65	1.07	0.80	0.08*	0.10**
03BT007	4.16	3.27	0.99	1.01	0.05	0.03
V-06140	3.75	3.27	0.97	1.05	0.15**	0.09**
Shafaq-2006	3.99	3.83	0.89	1.08	0.27**	0.15**
V-05121	3.58	3.50	0.93	1.01	0.14**	0.09**
V-05100	4.14	3.46	1.08	1.30	0.12**	0.13**

mi = Average grain yield (t ha^{-1}), bi= Regression coefficient, S^2 di= Standard deviation from regression coefficient, * and ** = Significant at 5% and 1%, respectively

Estimates of standard deviation from regression (S^2di) displayed that for normally sown wheat crop the cultivars V-05066 and V-03BT007 showed S^2di value near to zero (0.04) which were soundly coupled with about unit regression (1.08 and 0.99). Although the check variety Seher-2006 performed best across 18 locations in the timely sown trial, both these cultivars (V-05066 and V-03BT007) also performed well raising the grain yield 4.43 and 4.16 t ha^{-1}, respectively which is more than the trial mean (4.11 t ha^{-1}). The association of b=1.0 and $S^2di=0$ with the high mean grain yield revealed genotypes have general adaptability and when associated with low mean grain yield, genotypes are poorly adapted to all environments (Singh & Chaudhary, 1985). This revealed that the cultivars V-05066 and V-03BT007 were stable and adapted across all the environments for normally sown crop according to Eberhart & Russell (1966). The check Seher-2006 demonstrated highest mean yield over the locations coupled with over unit regression but significant S^2di, was also suggested to be stable due to its best average yield under normal sowing (Cheema *et al*., 2010; Khalil *et al*., 2010).

Similar findings were observed from the late sown wheat trial in which the check variety Seher-2006 gave the highest mean yield joined with b=0.96 and significant $S^2di=0.08$ at $p<0.05$ probability level. However the cultivars V-05066 and V-03BT007 showed unit regression (1.03 and 1.01 respectively) and non-significant, about zero standard deviation from regression (0.04 and 0.03, respectively) indicated them to be the most stable cultivars all over the Punjab for both normal and late sown crop.

It is therefore concluded that there were considerable contributions of both genetic makeup of genotypes and environmental factor to the variation in mean yield for normal as well as late sown crop. The stability based on mean grain yield, regression coefficient and deviation from regression advocated that the cultivars V-05066 and V-03BT007 were most stable and adapted to diverse environments of Punjab along with the check variety Seher-2006 which produced maximum yield for both sowing times.

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