BIOMETRICAL BASED STATISTICAL ANALYSIS OF *HELIANTHUS ANNUUS* CULTIVARS AT DIFFERENT LOCATIONS

Irshad Ahmad Arshad[1], Ijaz Iqbal[2] and Abdul Ghafoor[2]
[1]Department of Mathematics and Statistics, *International Islamic University*, Islamabad
[2]Department of Statistics, *Bahaudin Zakria University*, Multan

ABSTRACT: *The objectives of the study were to access classification of Helianthus Annuus cultivars, during spring and autumn, with respect to oil yield related traits at suitable locations throughout Pakistan, using pattern analysis and Biplot analysis alongwith their comparison. In first step, using ISS algorithm ANOVA for the partitioned sum of squares, it was observed that contribution of (G x L) interaction effect varies from 58.51% to 86.50% and 56.58% to 88.44% for different selected traits during spring and autumn respectively, which means that interpretation of main effects individually is not meaningful because there exists high dependency between genotypes and locations. Moreover clusters of similar cultivars at all locations and clusters of similar locations over all cultivars were defined using Ward's (ISS) agglomerative hierarchical clustering algorithm. In statistical analysis it was observed that variation between genotypes clusters is high as compared to within genotypes clusters for all selected traits, which means that cultivars within groups are homogeneous as compared to the genotypes between groups. In group-wise performance analysis, it was observed that during spring cultivar within each group: (Golden-1, SMH0917) and (NK-Singi, LG-55-25) can perform best w. r. t. seed yield at locations: (Four Brother, Kanzo Lahore) and (NARC, Sygenta Hyderabad, Dera Ismail Khan, UAP) respectively, but performance of spring cultivars (SMH-1026, NK-Tekni, SMH-1027) were observed very poor at locations: (ICI Hyderabad, ORI Faisalabad). Moreover genotype: T-40318, showed maximum performance at locations: ORI-Faisalabad, Dera Ismail Khan, NARC and ORI-Tandojam but performed poorly at RARI Bahawalpur w. r. t. seed yield during autumn. Similarly genotype: SMH-927 showed much better performance at NARC, but not suitable for location: RARI Bahawalpur w. r. t. seed yield during autumn. Finally, G x L data was evaluated using Biplot Analysis with first two PC (captured about 64% of total variation) to separate genotypes performing stable, average and poor at tested locations w. r. t. seed yield. It was observed that Biplot Analysis validated all the suggestions made about adaption of genotypes at specific locations which were suggested in cluster-wise performance.*

Keywords: *Ward's; Clustering; Agglomerative; ANOVA; Locations; Helianthus Annuus.*

1 INTRODUCTION

Helianthus Annuus being a major oilseed crop was introduced in Pakistan during 1965 and lot of efforts has been made to increase its area and domestic production of edible oil. According to [1], about 42.5 (000 tonnes) of Helianthus Annuus seed was produced up to 1988, which was the highest in the history till now with appreciable growth rate at 25.75 % in 1989. In Pakistan, oilseed crops such as cottonseed, brassica species, groundnuts, Helianthus Annuus etc. are cultivated for edible oil which fulfills collectively about 50% to 60% of local consumption of edible oil and remaining gap is filled through imports as reported in [2]. Moreover the imports of edible oil to fill the gap between production and consumption has been increasing at 8% per annum and imports has increased from Rs. 135.0 million to more than Rs. 20 billion during last two decades.

According to [3], statistics given in Table 1.1, Helianthus Annuus production is lowest one since many years in the past as compared to other regional countries such as India, China, Russia etc. Helianthus Annuus production in Pakistan remained at 404.3 (000 tonnes) which was much below as compared to 2313 (000, tonnes) in China and 9698 (000, tonnes) in Russia during 2011.

Table 1.1 *Helianthus Annuus* production in (000) metric tons

Year	Pak	China	India	Russia	Pak. Import Bill (Tons)_(000$)
2011	404.3	2313	517	9698	158955 _104880
2010	325.5	2298	651	5345	160750_64916
2009	420.5	1956	851	6454	156637_61432
2008	603.9	1792	1158	7350	318098_106555

Source: FAOSTAT (2013).

On the other hand Pakistan imported 158955 tonnes of Helianthus Annuus seed of amount (000) US$104,880 during 2011, which was maximum as compared to the preceding years. These statistics demands concerted and continuous efforts so as to reduce the imports and to arrest the gap between production and consumption of edible oil. In present study an attempt has been made to test the performance of existing Helianthus Annuus hybrids over various locations/environments w. r. t oil yield related traits such as: seed yield (SY_kg), oil content (OC%), head diameter (HD_cm) and 100-seeds weight (100-SW_gm), using Pattern Analysis and Biplot Analysis.

Combined stability analysis using parametric and nonparametric measures was conducted in [4] to assess GEI and stability of linseed cultivars over selected environments in Ethiopia. The parametric stability measures, coefficient of variability and the stability variance showed that R12_N10D was most stable genotype. The stability variance and variance of ranks were significantly correlated and were the best in determining the comparative stability of linseed genotypes.

Twenty three genotypes of durum wheat across 12 environments using combined ANOVA analyzed by [5] and showed that the high percentage of location sums of squares and the variability among genotypes for grain yield was observed small. The best genotype: DBSP02/8 out yielded the check by 0.24 tonnes/hector. Moreover G x L interaction was analyzed using parametric, AMMI and Joint LR models alongwith comparison of their relative efficiency.

Trial of thirteen spring wheat cultivars conducted by [6], grown at six locations to define the location in which a hybrid can perform its maximum yield. The interest was to suggest most efficient method for cultivars response in Multi Location (ML) trials to analyze the adaptability, stability and Genotype x Locations (G x L) interaction effect for grain yield.

In Iran comparison of non-parametric stability measures and application of various tests for GLI on grain yield for 15 durum wheat hybrids was tested at 12 locations in [7]. Non-parametric tests on G x L interaction and ANOVA across locations indicated the presence of both crossover and non-crossover interactions and cultivars varied significantly for grain yield.

The objectives of the present study are to group Helianthus Annuus cultivars w. r. t. performance across tested locations and to analyze adaptability/stability of hybrids at suitable locations. It also includes evaluation of performance of various hybrid groups at tested locations.

2 MATERIALS AND METHODS

Helianthus Annuus hybrids were grown during spring/autumn 2011-2012 at various locations throughout Pakistan under National Uniform Seed Yield Trials (NUSYT) program and its two way classified Genotype cross Location (G x L) data is considered to evaluate stability, adaptability and to cluster similar hybrids of Helianthus Annuus with respect to yield related traits at tested locations.

The following Helianthus Annuus genotypes which were grown during spring are listed along with their codes as: Genotype//code:SMH-1026//SNF1, SMH-1007//SNF2, NK-Tekni//SNF3, Ausigold-4//SNF4, Golden-1//SNF5, FSS-60//SNF6, Pan-08-101//SNF7, T-40318//SNF8, NK-Singi//SNF9, LG-55-25//SNF10, FSS-58//SNF11, FH-417//SNF12, SMH-1027//SNF13, Ausigold-7//SNF14, Aditya//SNF15, SMH-0917//SNF16, Hysun-33//SNF17, NK-S-278//SNF18 and tested across the following locations//code-S (stands for spring): NARC//E111S, Sygenta Hyderabad//E811S, Sygenta Multan//E911S, ORI Faisalabad//E611S, RARI Bahawalpur//E311S, AliAkbar Multan//E711S, Four-Brothers//E211S, ICI-Sahiwal//E411S, ICI-Hyderabad//E511S, UAP//E1111S, Dera Ismail Khan//E1011S, Kanzo Lahore//E1211S.

During autumn, following Helianthus Annuus genotypes were grown during 2011-2012, are listed along with their codes as: Genotype//code: SH-K-6//SNF1, SH-K-4//SNF2, SMH-916//SNF3, SMH-1028//SNF4, SMH-1023//SNF5, SMH-917//SNF6, SMH-907//SNF7, SMH-927//SNF8, Hysun-33//SNF9, SMH-934//SNF10, T-40318//SNF11, SunStar-333//SNF12, SMH-821//SNF13, SMH-945//SNF14 across the following locations//code: NARC//E111A, RARI Bahawalpur//E311A, Dera Ismail Khan//E1011A, ORI Faisalabad//E611A, ORI Tandojam//E211A.

In order to group similar Helianthus Annuus cultivars w. r. t. oil yield related traits at tested locations and to group similar locations for Helianthus Annuus cultivars, the most efficient clustering algorithm known as Incremental Sum of Squares (ISS) or Ward’s method of agglomerative hierarchical algorithms is used to analyze two way G x L data. Hierarchical algorithms consist of series of decisions (based on similarity or distance) to group objects/items into a hierarchy/treelike structure, known as dendrograms. Agglomerative hierarchical clustering algorithms are exploratory in nature in which initially each item/object is considered as its own cluster and in next steps by repeated application of merging process based on similarity measures, the number of clusters finally reduces to single cluster containing all objects. In present study it is decided to use Incremental Sum of Square (ISS) method to cluster genotypes and its tested locations. ISS clustering algorithm is different and efficient as compared to other algorithms because in ISS algorithm, the selection of which two clusters to combine is based on which combination of cluster minimizes within cluster sum of square across complete set of disjoint clusters. In every step two clusters are merged for which increase in total sum of square will minimum across all objects in all clusters and for more detail one can refer [8] and [9].

In order to suggest particular/group of cultivar(s) at specific/group of location (s), Biplot technique and performance plot analysis are applied to G x L data. Biplot analysis is an exploratory graphical representation for multivariate data and first developed by [10] and then [11], enhanced the methodology by introducing various methods to interpret and described biplots visually. Biplot is a generalization of simple scatter plot of bivariate data and displays two way G x L data with multiple variables each having “n” observations, used to evaluate suitability and stability of genotypes at locations. Biplot analysis in helpful tool to separate the hybrids according to stability in performance over specific/group of location(s) included in experiment. Biplot is based on Principal Component Analysis (PCA) and detail about how to construct can be viewed in [12].

Performance plot analysis is also a graphical device to evaluate the performance of hybrid groups over location groups formed by ISS method using software developed by [13].

3 RESULTS AND DISCUSSIONS

Helianthus Annuus, hybrids data, during spring and autumn w. r. t. selected oil yield related traits such as seed yield(kg), oil content(%), head diameter (cm) and 100-seed weight(gm) at selected locations throughout Pakistan, was analyzed using biometrical based software [14]. In the first step summary of Analysis of Variance (ANOVA) of partitioned sum of squares for different effects in G x L model using ISS algorithm for selected traits during spring and autumn were presented in Table 3.1 and Table 3.2 respectively.

Table 3.1 %Contribution in variation for H. A. (spring)

SOV	Df	Seed Yield	Head Diam	OC%	100SW
Gen (G)	17	19.92	13.50	25.14	41.49
BGG	4	58.65	52.20	47.51	83.37
WGG	13	41.35	47.80	52.49	16.63
BLG	4	34.60	32.54	78.07	37.56
WLG	7	65.40	67.46	21.93	62.44
G x L	187	80.06	86.50	74.85	58.51
BGGxBLG	16	36.32	34.80	34.43	38.41
WGGxWLG	91	29.65	26.82	21.78	22.97

It can be observed in Tables 3.1 and 3.2 that contribution of (G x L) interaction effect in total variation varies from 58.51% to 86.50% and 56.58% to 88.44% during spring and autumn respectively and maximum for HD (cm) during both seasons. So individual interpretation of main effects such as genotypes and locations is not meaningful because there exists, high degree of dependency between genotypes and locations for selected yield traits.

Moreover contribution for other partitioned effects given in both Table 3.1 and Table 3.2 are also helpful to interpret cluster of genotypes as well as of locations, which would be formed using ISS algorithm in next section.

3.1 Clusters of Helianthus Annuus Hybrids

In previous section it was observed that G x L effect varies with high percentage i.e. a high degree of dependency exists between Helianthus Annuus genotypes and its tested locations, so this situation demands to cluster similar genotypes w. r. t. selected traits at tested locations.

For this purpose, Ward's (ISS) algorithm is used and clusters of similar genotypes and similar locations during spring and autumn which are listed in Table 3.3 and Table 3.4 respectively. In ANOVA described previously, it was observed that %variation in BGG (Between Genotypes Groups) is high as compared to the WGG (Within Genotypes Groups) variation for all selected traits except in case of OC(%), which means that cultivars within groups are homogeneous as compared to the genotypes between groups. It can also be observed in Table 3.3 that genotypes within (Golden-1//SNF5, SMH-0917//SNF16) were found similar in performance for SY(kg) and HD(cm). Moreover the genotypes within group: G_12(NK-Tekni//SNF3, Ausigold each group: (SMH-1007//SNF2, Pan-08-101// SNF7) and -4//SNF4, NK Singi//SNF9, LG-55-25//SNF10) were also found similar in performance for HD(cm) and OC(%) but genotypes: Pan-08-101//SNF7, Ausigold-7//SNF14, NK-S-278//SNF18 can be suggested as similar in performance for OC(%) and 100-SW(gm). The stepwise fusions to form clusters of similar genotypes using ISS Algorithm,

Table3.2 %Contribution in variation for H. A (autumn)

SOV	d.f.	Seed Yield	Head Diam	OC%	100SW
Gen (G)	13	24.72	11.57	39.98	43.42
BGG	4	79.55	32.03	85.32	84.84
WGG	9	20.45	67.97	14.68	15.16
BLG	2	34.60	1.77	31.46	78.85
WLG	2	65.40	98.23	68.54	21.15
G x L	52	76.84	88.44	59.95	56.58
BGGxBLG	8	71.88	52.39	47.33	74.39
WGGxWLG	18	29.65	5.24	16.08	9.35

Table 3.3 Clusters of Helianthus Annuus (spring 2011-12).

<table>
<tr><th colspan="2">Traits</th><th>Genotypes/Locations Clusters</th></tr>
<tr><td rowspan="2">Seed Yield</td><td>Hybr.</td><td>G_13(SNF6, SNF8, SNF11, SNF17) G_9(SNF9, SNF10) G_12(SNF2, SNF4, SNF7, SNF12, SNF14, SNF15, SNF18) G_5(SNF1, SNF3, SNF13) G_11(SNF5, SNF16)</td></tr>
<tr><td>Loct.</td><td>G_6(E111S, E811S, E1011S, E1111S), G_4(E211S, E1211S), G_7(E511S, E611S), G_3(E311S, E911S), G_2(E411S, E711S)</td></tr>
<tr><td rowspan="2">Head Diameter</td><td>Hybr.</td><td>G_7(SNF1, SNF2, SNF5, SNF7, SNF16) G_13(SNF6, SNF8, SNF18) G_12(SNF3, SNF4, SNF9, SNF10, SNF12, SNF15, SNF17) G_9(SNF11, SNF13) Invd_14(SNF14)</td></tr>
<tr><td>Loct.</td><td>G_6(E311S, E411S, E511S, E1111S), G_3(E911S, E1011S), Invd_1(E111S), G_4(E211S, E611S, E811S), Invd_6(E711S)</td></tr>
<tr><td rowspan="2">Oil Content%</td><td>Hybr.</td><td>G_13(SNF1, SNF7, SNF14, SNF18) G_12(SNF2, SNF13, SNF16) G_9(SNF12, SNF17) G_11(SNF3, SNF10) G_10(SNF4, SNF5, SNF6, SNF8, SNF9, SNF11, SNF15)</td></tr>
<tr><td>Loct.</td><td>G_4(E611S, E711S), Invd_1(E111S), G_5(E411S, E511S, E811S,), G_1(E911S, E1011S), G_3(E211S, E311S)</td></tr>
<tr><td rowspan="2">100 SW</td><td>Hybr.</td><td>G_13(SNF4, SNF7, SNF13, SNF14, SNF15, SNF16, SNF17, SNF18) G_10(SNF1, SNF3, SNF6, SNF9, SNF12) G_11(SNF5, SNF11) Invd_2(SNF2) G_6(SNF8, SNF10)</td></tr>
<tr><td>Loct.</td><td>Invd_4(E611S), G_3(E111S, E1111S), G_6(E211S, E311S, E411S, E811S, E911S, E1011S,), Invd_6(E711S), Invd_9(E511S)</td></tr>
</table>

dendrograms are shown in Fig 3.1(a-d) in which cultivars are placed along horizontal-axis while various fusion levels are taken along vertical axis. In clustering of similar location over all set of cultivars, it was also observed that locations within each group: (NARC//E111S, Sygenta Hyderabad//E811S, Dera Ismail Khan//E1011S, UAP//E1111S) and (RARI Bahawalpur//E311S, Sygenta Multan//E911S) can be suggested similar locations w. r. t. response for SY(kg) and 100-SW(gm) over all set of cultivars.

Also location within each group: (ICI Sahiwal//E411S, ICI Hyderabad//E511S), (Sygenta Multan//E911S, Dera Ismail Khan//E1011S) and (NARC//E111S) can be declared as similar in performance w. r. t. HD(cm) and OC(%) but locations: Four-Brothers//E211S, Sygenta-Hyderabad//E811S can be suggested as similar in performance for HD(cm) and 100-SW(gm) over all tested cultivars. Clusters of similar cultivars and locations during autumn for selected traits are also shown in Table 3.4

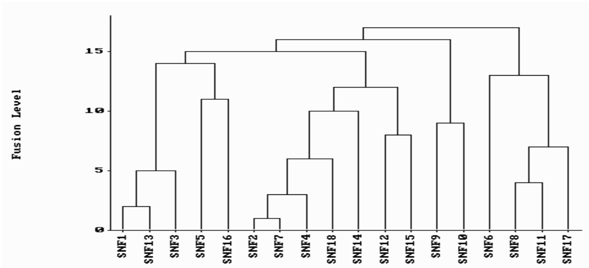

Fig 3.1(a): Seed_Yield for2011-12 (spring)

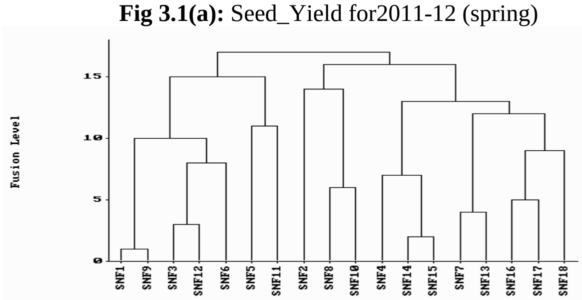

Fig 3.1(b): 100_Seed_Weight for2011-12 (spring)

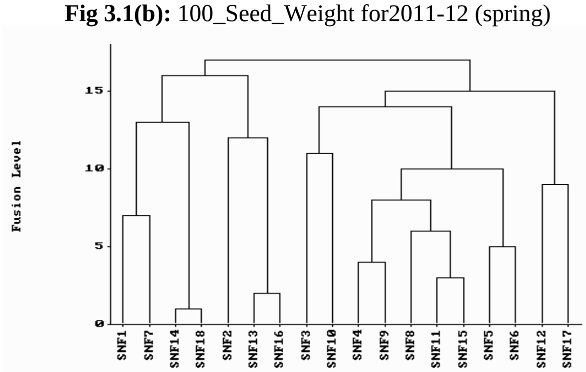

Fig 3.1(c): Oil_Content% for2011-12 (spring)

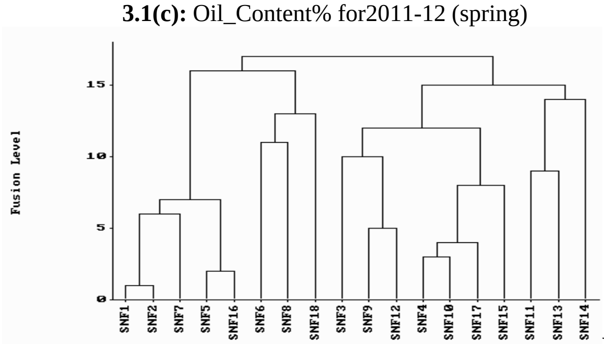

Fig 3.1(d): Head_Diameter for 2011-12 (spring)

In Table 3.4, genotypes within each group: (SH-K-6//SNF1, SMH-1028//SNF4, SMH-907//SNF7, Hysun-33//SNF9, SMH-821//SNF13) and (SH-K-4//SNF2, SMH-934//SNF10) were found similar in performance for SY(kg) and HD(cm). Moreover the genotypes SH-K-4//SNF2, SMH-934//SNF10 were also found similar in performance for OC(%) and 100-SW(gm).

Table 3.4 Clusters of *Helianthus Annuus* (autumn 2011-12).

Traits		Genotypes/Locations Clusters
Seed Yield	Hybr	G-9(SNF1,SNF5,SNF6,SNF12,SNF13, SNF14)G_7(SNF2,SNF10),Invd_8(SNF8), Invd_11(SNF11)G_5(SNF3,SNF4,SNF7,SNF9)
	L	I_2(E311A), G_1(E611A, E1011A), G_2(E111A, E211A)
Head Diam	Hybr	Invd_14(SNF14)G_7(SNF3,SNF11), G_9(SNF1,SNF4,SNF7,SNF9,SNF13)G_8(SN F2,SNF5,SNF6,SNF10)G_6(SNF8, SNF12)
	L	G_1(E1011A, E211A), Invd_1(E111A), Invd_2(E311A)
Oil Con%	Hybr	Invd_2(SNF2), Invd_5(SNF5) G_7(SNF1, SNF6, SNF9, SNF12) G_8(SNF3, SNF11, SNF13)G_9(SNF4,SNF8,SNF7,SNF10,SNF14)
	L	G_2(E311A, E211A, E1011A), Invd_1(E111A), Invd_4(E611A)
100 SW	Hybr	Invd_13(SNF13) G_9(SNF1, SNF3, SNF9) G_7(SNF5, SNF6, SNF7, SNF12) G_8(SNF2, SNF8, SNF10, SNF11, SNF14) Invd_4(SNF4)
	L	G_1(E311A, E611A), Invd_1(E111A), Invd_3(E1011A)

.

As far as clustering of location is concerned, in Table 3.4, it can be concluded that NARC//E111A is individually different location over all cultivars during autumn as compared to others for all selected traits. Also the location: RARI Bahawalpur//E311A can be concluded as individually different for SY(kg) and HD(cm) and ORI Faisalabad//E611A is individually different for SY(kg) and OC(%) over all autumn cultivars. The formation of cluster of autumn cultivars using Ward's Agglomerative hierarchical clustering algorithm can be viewed in the form of dendrograms shown in Fig 3.2(a-d).

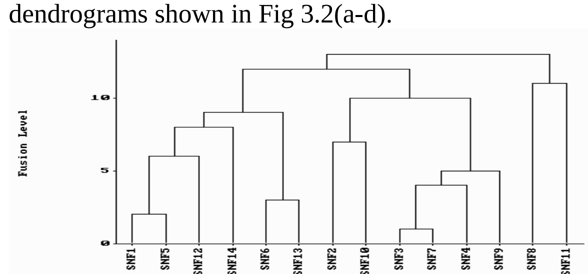

Fig 3.2(a): Seed Yield for 2011-12(autumn)

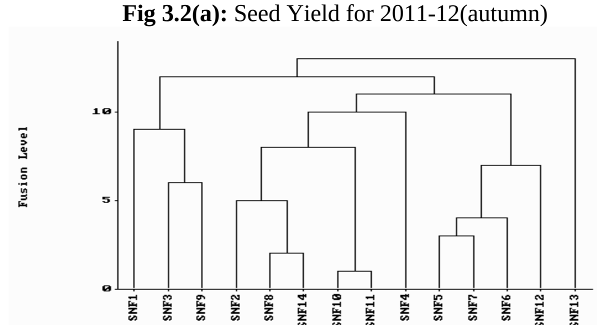

Fig. 3.2(b): 100-Seed Weight for 2011-12(autumn)

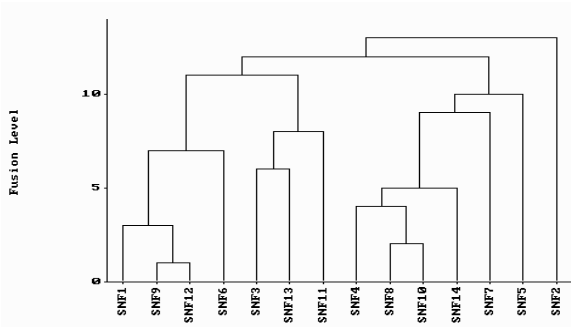

Fig 3.2(c) Oil content% for 2011-12(autumn)

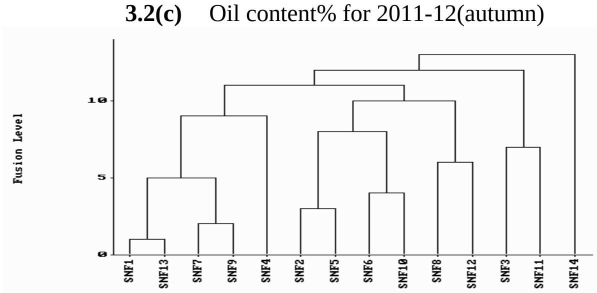

Fig 3.2(d) Head Diameter for 2011-12(autumn)

3.2 Cluster-wise comparison

To evaluate cluster wise performance of genotypes performance plots are drawn for SY(kg) and OC(%) during spring and autumn and presented in Fig 3.3(a-d). In Fig 3.3(a), it can be observed that spring cultivars within in group: G_11(Golden-1//SNF5, SMH0917//SNF16) is performing maximum w. r. t. seed yield at location within groups G_4(Four Brothers//E211S, Kanzo-Lahore//E1211S) and cultivar in G_9(NK-Singi//SNF9, LG-55-25//SNF10) seems to be more suitable at locations in groups: G_6(NARC//E111S, Sygenta Hyderabad//E811S, Dera Ismail Khan//E1011S, UAP//E1111S) and G_2(ICI Sahiwal//E411S, Ali Akbar Multan//E711S). Similarly performance of spring cultivars within group: G_13(FSS-60//SNF6, T-40318//SNF8, FSS-58//SNF11, Hysun-33//SNF17) seems to be more consistent at all location groups except the locations in: G_4(Four Broth//E211S, Kanzo Lahore//E1211S) while performance of cultivars within group: G_5(SMH-1026//SNF1, NK-Tekni//SNF3, SMH-1027//SNF13) was observed very poor at locations: G_7(ICI Hyderabad//E511S, ORI Faisalabad//E611S).

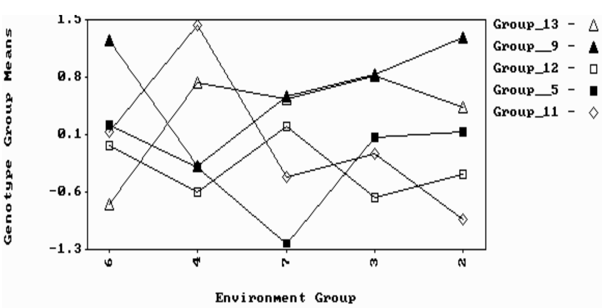

Fig 3.3(a): Seed yield for 2011-12 (spring)

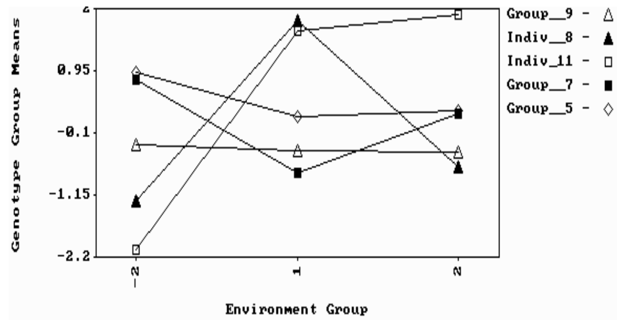

Fig 3.3(b): Seed yield for 2011-12 (autumn)

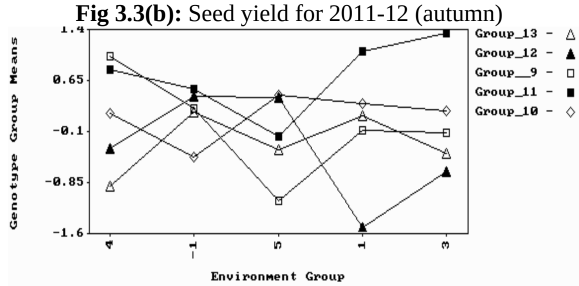

Fig 3.3(c): Oil content% for 2011-12 (spring)

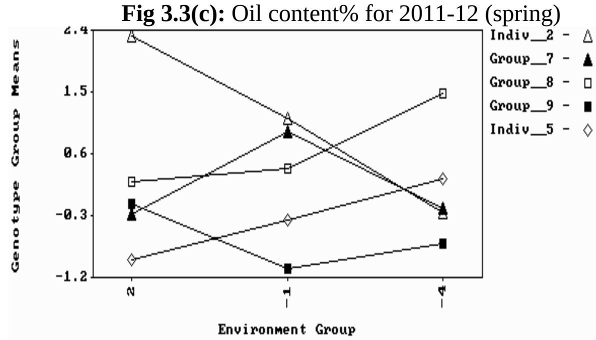

Fig 3.3(d) Oil content% for 2011-12 (autumn)

On the other hand in performance evaluation of autumn cultivars, it is clear in Fig 3.3(b) that genotype: Invd_11(T-40318//SNF11) showed maximum performance at location groups: G_1(ORI Faisalabad//E611A, Dera Ismail Khan//E1011A) and G_2(NARC//E111A, ORI-Tandojam//E211A) but performed poorly at Invd_2(RARI Bahawalpur//E311A) w. r. t. seed yield. Similarly cultivar: Invd_8(SMH-927//SNF8) showed best performance at location: Invd_1(NARC//E111A) but not suitable at location groups such as: G_2(NARC//E111A, ORI-Tandojam//E211A) and Invd_2(RARI- Bahawalpur//E311A) for SY(kg).

In addition to separate cultivars at suitable locations w. r. t. SY(kg), suitability of cultivars at different locations w. r. t. OC(%), during spring and autumn, was also analyzed in Fig 3.3(c-d). In Fig. 3.3(c), cultivar within groups: G_11(NK-Tekni//SNF3, LG-55-25//SNF10) and G_10(Ausigold-4//SNF4, Golden-1//SNF5, FSS-60//SNF6, T-40318//SNF8, NK-Singi//SNF9, FSS-58//SNF11, Aditya//SNF15) performed consistently at all location groups listed in Table 3.3 except at locations within groups: G_5(ICI Sahiwal//E411S, ICI Hyderabad//E511S, Sygenta Hyderabad//E811S) and Invd_1(NARC//E111S) respectively. Also during spring, cultivars within groups: G_12 (SMH-1007//SNF2, SMH-1027//SNF13, SMH-0917//SNF16) and G_13 (SMH-1026//SNF1, Pan-08-101//SNF7, Ausigold-7//SNF14, NK-S-278//SNF18) performed much poorly at locations within groups: G_1(Sygenta-Multan//E911S, DIK//E1011S) and G_4(E611S, E711S) respectively. Now again it can be observed in Fig 3.3(d) that cultivars within groups Invd_2(SH-K-4//SNF2) and G_8(SMH-916//SNF3, T-40318//SNF11, SMH-821//SNF13) performed best w. r. t. OC(%) during autumn at locations within groups: G_2(RARI-Bahawalpur//E311A, ORI-Tandojam//E211A, Dera Ismail Khan//E1011A E1011A) and Indv_4(ORI-Faisalabad//E611A) respectively, while cultivars within group: G_9(SMH-1028//SNF4, SMH-927//SNF8, SMH-907//SNF7, SMH-934//SNF10, SMH-945//SNF14) performed very poorly for OC(%) in almost all location groups listed in Table 3.4.

3.3 Biplots analysis

Helianthus Annuus "G x L" seed yield data during spring and autumn at selected locations were also analyzed using Biplot Analysis to decide about cultivars performing stable, average and poor over tested locations. For this purpose only Biplots of G x L data for both seasons are shown in Fig. 3.4 and Fig. 3.5. Biplot displayed in Fig. 3.4, revealed that the IPCA1 (first interaction principal component axis) captured 43.59% of GEI (Genotype Environment Interaction) variation, while IPCA2 covered 20.62% and both PC captured about 64.21% of GEI variation. On the other hand in biplot for autumn cultivars shown in Fig. 3.5, IPCA1 covered 46.78% of GEI variation while IPCA2 covered 21.05% and both components contributed 67.83% of GEI variation collectively.

In Fig. 3.4, that first two IPC axes partitioned the Biplot into four location quadrants (groups) having similar locations within each group: G_1(Four Brothers//E211S_E7, RARI Bahawalpur//E311S_E5, ICI Hyderabad//E511S_E9, ORI Faisalabad//E611S_E4, Ali Akbar Multan//E711S_E6, Sygenta-Multan//E911S_E3), G_3(Kanzo-Lahore//E1211S_E12)and

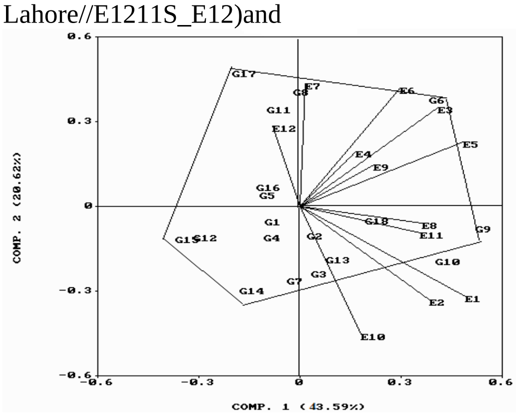

Fig. 3.4: Biplot of Helianthus Annuus during spring.

G_2(NARC//E111_E1, ICI Sahiwal//E411S_E8, Sygenta-Hyderabad//E811S_E2, Dera Ismail Khan//E1011_E11, UAP//E1111S_E10). The group of location G_2 w. r. t. seed yield, formed in Biplot Analysis is exactly same as the groups G_6, except the location Sahiwal//E411S_E8, in pattern analysis given in Table 3.3 and also G_1 in Biplot analysis is the combination of G_3 and G_7 given in pattern analysis. Now genotypes in Fig. 3.4, such as FSS-60//SNF6, NK- Singi//SNF9 and LG-55-25//SNF10 can be suggested as best performing cultivars during spring at locations within groups: (Sygenta Multan//E911S_E3, RARI Bahawalpur//E311S_E5 and Ali-Akbar-Multan//E711S_E6), (ICI Sahiwal//E411_E8, Dera Ismail Khan//E1011S_E11) and (NARC//E111S_E1, Sygenta Hyderabad//E811S_E2) respectively and these suggestions about cultivars at specific locations validates the conclusion drawn previously in section 3.2. But on the other hand SMH-1026//SNF1, SMH-1007//SNF2, Ausigold-4//SNF4 Golden-1//SNF5 and SMH-0917//SNF16 lie very close to the origin because of having small values for IPCA1 and IPCA2, so all these are low yielding cultivars at tested locations. It can also be seen that genotypes such as: FSS-58//SNF11, FH-417//SNF12, Ausigold-7//SNF14, Aditya//SNF15, and Hysun-33//SNF17 all have negative values for IPCA1 and lies at left side of Biplot so these spring cultivars can be declared as unstable and have below average SY(kg) at tested locations as described by [15]. However the cultivars: SMH-1007//SNF2, SMH-1027//SNF13 and NK-S-278//SNF18 have small positive values for IPCA1 and can be suggested as stable with average seed yield during spring at tested locations.

Now Biplot given in Fig.3.5, for autumn cultivars w. r. t. seed yield, it can be seen that IPCA divided the Biplot into four groups each having similar locations within each group: G_1(ORI Faisalabad//E611A_E4, ORI-Tandojam//E211A_E5), G_2(NARC//E111A_E1, RI-Dera Ismail khan//E1011A_E3) and G_3(RARI

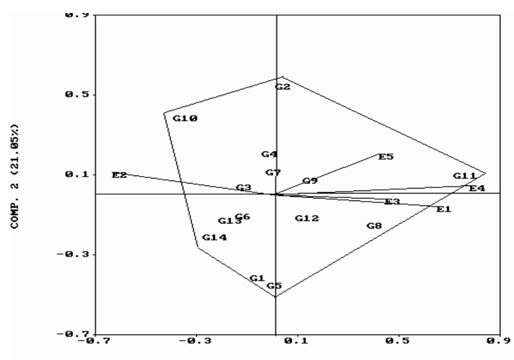

Fig 3.5: Biplot of Helianthus Annuus during autumn.

Bahawalpur//E311A_E2). The group of location G_3(RARI Bahawalpur//E311A_E2) w. r. t. seed yield, provided by Biplot analysis is exactly same as: Invd_2(RARI Bahawalpur//E311A) suggested in Pattern Analysis given in Table 3.4 and about remaining groups both methods do not agree with each others.

Now in Fig. 3.5, it can be observed that SHM-927//SNF8 and T-40318//SNF11 are best cultivars w. r. t. seed yield during autumn at locations: NARC//E111A_E1 and ORI Faisalabad//E611A_E4 respectively. So the suggestion made regarding SHM-927//SNF8 in Biplot Analysis validates the conclusion drawn in previous section 3.2. But on the other hand SMH-916//SNF3, SMH-1028//SNF4, SMH-917//SNF6 SMH907//SNF7 Hysun-33//SNF9 and SunStar-333//SNF12 lie very close to the origin because of low values for IPCA1 and IPCA2 and so all these can be declared as low yielding cultivars during autumn at tested locations. It can also be seen that genotypes SMH-934//SNF10, SMH-821//SNF13 and SMH-945//SNF14 have negative values for IPCA1 and lie at left side of Biplot so these cultivars can be concluded as unstable at all tested locations with below average seed yield.

REFERENCES

1. NARC, "Annual Report of oil Seed development program", *PARC*, Islamabad (2010)
2. "Economic Survey of Pakistan", *Economics Division*, Islamabad (2013)
3. Faostat,*http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor* (2013)
4. Adugna, W. and Labschagne, M. T., "Parametric and nonparametric measures of phenotypic stability in linseed", *Euphytica*, **129:** 211–218(2003)
5. Solomon, K. F., Smit, H. A., Malan, E. and Du Toit, W. J., "Parametric model based assessment of genotype × environment interactions for grain yield in durum wheat under irrigation", *International Journal of Plant Production*, **2** (1): (2008)
6. Dalma, C., Iván, M., Alejandro del, P., Ricardo, M. and Mario, M., "Adaptability and Genotype x Environment Interaction of Spring Wheat Cultivars in Chile using Regression Analysis, AMMI, and SREG", *Chilean J. Agric. Res*., **72**(2): (2012)
7. Reza, M., Abdolvahab, A., Reza, H. and Armion. M., "Interpreting genotype environment interactions for durum wheat grain yields using nonparametric methods", *Euphytica*, **157**:239–251 (2007)
8. Aldenderfer, Mark, S. and Roger, K. B., "Cluster Analysis", *Thousand Osks.*, CA: Sage (1984)
9. Everit, B. S., "Cluster analysis", *London Edward Arnold*. **3**rd Edition (1993)
10. Gabriel, K.R., "The biplot graphic display of matrices with application to pricipal component analysis", *Biometrika*, **58:** 453 (1971)
11. Yan, W. and Kang, M.S., "GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticists, and Agronomists". *CRC Press*. Boca Raton, FL (2003)
12. McDermott, B. and Ric Coe, "Statistical Services", *Centre, University of Reading, UK and World Agroforestry Centre.*, Kenya (2012)
13. Watson, S. L., DeLacy, I.H., Podlich, D.W. and Basford, K.E., "The GEBEI Analysis Package", *Department of Agriculture*, University of Queensland. Brisbane (1981)
14. IRRISTAT Ver. 4.0, "International Rice Research institute (IRRI), *Biometrics Unit*. Philippine.
15. Gauch, H. G. and Zobel, R. W., "AMMI analysis of yield traits in Genotypes by environment interaction.(Kang, M.S. and H. G. Gauch eds)", *CRC Press, Boca Raton FL.*, 85-122 (1996)