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# Genetic diversity for grain size and its association with yield components in bread wheat

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**Key words:** Biplot analysis, Correlation, Grain yield, Grain shape, Morphlogical traits, Vector length.

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## Abstract

Food security for increasing population demands high grain yield potential. Development of high yielding cultivars along with bold grain size is major confront for researchers. The shape, size and density of grain are vital constituents for governing high yield, market value as well as good milling. Present study was designed to evaluate of 50 genotypes from CIMMYT (34 ESWYT) for high yield and grain characteristics was performed following RCBD. From biplot analysis,genotypesAK41 and AK50 were selected as high yielding lines with good grain size. Significant positive correlation of grain size was observed with grain yield, days to an thesis, days to maturity, spikelet's/spike, plant height and flag leaf area. Whereas grain size showed non-significant association with grain weight/spike, thousand grain weight, number of grains/spike, productive tillers $m^{-1}$ and spike length. Grain yield showed significant positive correlation with grain weight/spike, spike length, thousand grain weight, number of grains per spike, productive tillers $m^{-1}$ and spikelet's per spike and non-significant association with days to maturity. The results reported in this study could play crucial role in the development of plant material with desirable grain size and high yield.

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## Introduction

Wheat crop is principle element of food, feed and have important role in industries as a raw material (Capron *et al.*, 2012). Wheat is staple food all over the globe and supply about 22% of total protein and 20% calories in human diet (Kumar *et al.*, 2011). Based on the unique protein properties, wheat flour is central part in different baking products and diversified food and non-food usage (Shewry, 2009; Hurkman, 2013). Wheat is leading food commodity in the trade markets around the globe and also the important crop product for human consumption (Curtis and Halford, 2014). Wheat yield rose sharply after Second World War and it almost got doubled (from 3.5 tons $ha^{-1}$ in 1961 to 7.7 tons $ha^{-1}$) in 1984. However afterwards it started levelling off and in the last quarter of the century it showed a slight decrease (7.6 tons $ha^{-1}$) (Food and Agriculture Organization, 2013). It demands sudden shift of the breeders towards more productive breeding programs with altered traits preference.

Grain size is a key determinant of grain yield in wheat and has vital importance in breeding programs and used as a standard during selection. Grain shape is not given due importance as selection criteria but milling performance of wheat grain is mainly influenced by grain shape i.e. grain density, size and consistency (Gegas *et al.*, 2010). Kernel weight, spikelet's per spike and number of productive tillers are considered pivotal constituents of grain yield in wheat. These grain yield determining components are further influenced by plant height, days to anthesis and grain weight. Grain shape and grain size has also a key role in deterring grain yield. All the grain yield determining traits are polygenic in nature (Dhungana *et al.*, 2007; Gegas *et al.*, 2010). Grain size could be improved by increasing the grain filling period or extended photosynthetic period of wheat crop (Zhao *et al.*, 2015).

Grain size and grain number are directly or indirectly influenced by different genetic physiological and ecological factors i.e. grain mass, rate of grain filling, grain protein contents, plant biomass, number & weight of endosperm cells, desiccation tolerance, elevated temperature at grain filling, carpel mass at anthesis, mass of adventitious roots, growth rate, lodging resistance, flower volume, seed rate and fertilizers use (nitrogen). Positive association of grain size was observed with grain filling rate, carpel mass at anthesis, seed viability and seedling survival while its negative association was reported with lodging resistance, high temperature at grain filling and number of grains (Coventry *et al.*, 2003).

Grain yield in turn is determined by different morpho-physiological traitsi.e. Ear size, grain size, grain number, stomatal conductance, lodging resistance, organized nutrient transport system and distance between peduncle and leaves (Reynolds *et al.*, 1996).As yield is a complex trait governed by several genes and largely affected by different morphological and agronomical traits thus direct evaluation based on grain yield may not be very fruitful. Yield could be improved through analysis of different traits which have strong association with grain yield (Ali *et al.*, 2008). Asgrain yield and grain quality are primarily determined by grain size. So, the objective of current study was to evaluate morphological bases of different parameters which systematically influence grain size and grain yield in order to break the stagnant grain yield barrier.

## Materials and methods

*Experimental conditions*

The study was carried out in the field of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan (located at 30° N/S and 70° E/W, 574 ft. above the sea level). Soil on the site was alluvial deposits mixed with loess, physically 42% sand, 34% silt, and 23% clay.

The plant material was sown by drill sowing. Experimental plot comprised of two rows of 2.5 m and row to row distance was maintained at 9 inches. The plant material comprised of 50 wheat genotypes (Nursery-34ESWYT from CIMMYT) including one local check variety (Millat-11) (Table 1). Plots were arranged under Randomized Complete Block Design with three replications. Fertilizer i.e. DAP (18:46%, N and $P_2O_5$ respectively) was applied at the rate of 75 kg/acre along with Urea (46% N) at the rate of 50 kg/acre were applied in a single dose at sowing. Bacteral Super 60% (18.7% bromochozanailoctanate, 18.1 % heptanovate ester, 40% M.C.P.L ethyl hexayl ester and 23% other chemicals w/w) and Axial (5.05 % Petokessdan and 94.95% other chemicals) were sprayed following manufacturer's instruction (Bayer and Syngenta respectively) to control the weeds. After germination, gravity based three irrigations were applied at Zadok 20 (tillering), 40 (booting) and 65 (grain filling).

*Measurement of morphological parameters*

Data was recorded on different morpho-physiological traits i.e. Flag leaf area (measured by multiplying the Length× Width ×0.72) from 10 plants of each genotype. Days to anthesis and maturity were recorded by following the Zadoks scale (Zadoks *et al.*, 1974). The spikes per plant (fertile tillers) and number of spikelet's per spike were counted for each genotype. Data on plant height (cm) andear length (cm)was also computed for ten plants per entry. Grain length (mm) and grain width (mm) was computed for ten grains per entry with an electronic caliper (6 inch/150 mm Digital Calipers, China). Grain size (GZ) was calculated from these measurements. Data of 1000 grain weight (using tele counter machine and compax, RS 232 (electric balance)), number of grains spike$^{-1}$, grain weight per spike (g), and grain yield (g) were also recorded.

*Statistical analysis*

The data were subjected to analysis of variance (Steel *et al.*, 1997) and mean data were analyzed for biplot analysis using biplot function option in Gen Stat v10 (Yan, 2001). Check genotype were represented in green circle, genotypes were represented by serial number instead of AK1-AK50 for easy graphical representation on biplot. Mean data of grain size were used to plot graph for identification of best performing genotypes. Simple correlation was computed between grain size contributing traits and yield components using GenStat v 10.

**Results and discussion**

ANOVA revealed that morphological parameters i.e. days to anthesis, productive tillers m$^{-1}$, grain weight/spike, thousand grain weight exhibited highly significant differences ($p < 0.01$) among genotypes.

Further grain size, plant height, days to maturity, flag leaf area, spike length and non-significant results for number of grains per spike, spikelet's per spike showed significant ($p < 0.05$) differences among genotypes (Table 2).

**Table 1.** List of genotypes, their origin and pedigrees.

| Sr. No. | Genotype Name | Origin of genotypes | Pedigree Parentage of the Genotypes |
|---|---|---|---|
| 1. | AK1 | Pakistan | Millat-11 |
| 2. | AK2 | MXI11-12\M34ESWYT\231 | PBW343 |
| 3. | AK3 | MXI11-12\M34ESWYT\232 | PRL/2*PASTOR |
| 4. | AK4 | MXI11-12\M34ESWYT\233 | AK1MUNAL #1 |
| 5. | AK5 | MXI11-12\M34ESWYT\234 | SUPER 152 |
| 6. | AK6 | MXI11-12\M34ESWYT\204 | SITE/MO//PASTOR/3/TILHI/4/WAXWING/KIRITATI |
| 7. | AK7 | MXI11-12\M34ESWYT\206 | ATTILA*2/PBW65*2//KACHU |
| 8. | AK8 | MXI11-12\M34ESWYT\208 | REEDLING #1 |
| 9. | AK9 | MXI11-12\M34ESWYT\213 | KACHU #1/4/CROC_1/AE.SQUARROSA (205)//BORL95/3/2*MILAN/5/KACHU |
| 10. | AK10 | MXI11-12\M34ESWYT\218 | SAUAL/3/ACHTAR*3//KANZ/KS85-8-4/4/SAUAL |
| 11. | AK11 | MXI11-12\M34ESWYT\222 | BECARD/KACHU |
| 12. | AK12 | MXI11-12\M34ESWYT\224 | ALTAR84/AE.SQUARROSA(221)//3*BORL95/3/URES/JUN//KAUZ/4/WBLL1/5/MUTUS |
| 13. | AK13 | MXI11-12\M34ESWYT\228 | NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KACHU/6/KACHU |
| 14. | AK14 | MXI11-12\M34ESWYT\4 | CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92/4/MUNAL #1 |
| 15. | AK15 | MXI11-12\M34ESWYT\9 | KACHU//WBLL1*2/BRAMBLING |
| 16. | AK16 | MXI11-12\M34ESWYT\11 | KACHU/KIRITATI |
| 17. | AK17 | MXI11-12\M34ESWYT\13 | KACHU #1//WBLL1*2/KUKUNA |
| 18. | AK18 | MXI11-12\M34ESWYT\16 | KIRITATI/WBLL1//FRANCOLIN #1 |
| 19. | AK19 | MXI11-12\M34ESWYT\19 | SUP152/BAJ #1 |

| | | | |
|---|---|---|---|
| 20. | AK20 | MXI11-12\M34ESWYT\21 | SUP152//WBLL1*2/BRAMBLING |
| 21. | AK21 | MXI11-12\M34ESWYT\23 | SUP152/BECARD |
| 22. | AK22 | MXI11-12\M34ESWYT\31 | BAJ #1/3/KIRITATI//ATTILA*2/PASTOR |
| 23. | AK23 | MXI11-12\M34ESWYT\36 | WBLL4/KUKUNA//WBLL1/3/WBLL1*2/BRAMBLING |
| 24. | AK241 | MXI11-12\M34ESWYT\40 | ITP40/AKURI |
| 25. | AK25 | MXI11-12\M34ESWYT\57 | KIRITATI/WBLL1//MESIA/3/KIRITATI/WBLL1 |
| 26. | AK26 | MXI11-12\M34ESWYT\58 | KIRITATI/WBLL1//2*BLOUK #1 |
| 27. | AK27 | MXI11-12\M34ESWYT\67 | FRNCLN*2/TECUE #1 |
| 28. | AK28 | MXI11-12\M34ESWYT\76 | SUP152/AKURI//SUP152 |
| 29. | AK29 | MXI11-12\M34ESWYT\81 | MUTUS*2/TECUE #1 |
| 30. | AK30 | MXI11-12\M34ESWYT\84 | WBLL1*2/VIVITSI//AKURI/3/WBLL1*2/BRAMBLING |
| 31. | AK31 | MXI11-12\M34ESWYT\89 | MUTUS*2/AKURI |
| 32. | AK32 | MXI11-12\M34ESWYT\98 | BAJ #1*2/WHEAR |
| 33. | AK33 | MXI11-12\M34ESWYT\106 | TACUPETO F2001*2/KIRITATI//VILLA JUAREZ F2009 |
| 34. | AK34 | MXI11-12\M34ESWYT\109 | KACHU/KINDE |
| 35. | AK35 | MXI11-12\M34ESWYT\111 | PBW343*2/KUKUNA/3/PASTOR//CHIL/PRL/4/GRACK |
| 36. | AK36 | MXI11-12\M34ESWYT\130 | VILLA JUAREZ F2009/CHYAK |
| 37. | AK37 | MXI11-12\M34ESWYT\131 | WBLL1*2/BRAMBLING//QUAIU |
| 38. | AK38 | MXI11-12\M34ESWYT\135 | BECARD/QUAIU #1 |
| 39. | AK39 | MXI11-12\M34ESWYT\138 | BECARD/QUAIU #1 |
| 40. | AK40 | MXI11-12\M34ESWYT\146 | BECARD/FRNCLN |
| 41. | AK41 | MXI11-12\M34ESWYT\159 | WBLL1*2/BRAMBLING//CHYAK |
| 42. | AK42 | MXI11-12\M34ESWYT\160 | BECARD//ND643/2*WBLL1 |
| 43. | AK43 | MXI11-12\M34ESWYT\165 | ATTILA/3*BCN*2//BAV92/3/KIRITATI/WBLL1/4/DANPHE |
| 44. | AK44 | MXI11-12\M34ESWYT\172 | FRET2*2/BRAMBLING//BECARD/3/WBLL1*2/BRAMBLING |
| 45. | AK45 | MXI11-12\M34ESWYT\173 | KAUZ*2/MNV//KAUZ/3/MILAN/4/BAV92/5/AKURI/6/MUTUS |
| 46. | AK46 | MXI11-12\M34ESWYT\174 | KACHU/BECARD//WBLL1*2/BRAMBLING |
| 47. | AK47 | MXI11-12\M34ESWYT\175 | KAUZ/PASTOR//PBW343/3/KIRITATI/4/FRNCLN |
| 48. | AK48 | MXI11-12\M34ESWYT\180 | SUP152*2/TECUE #1 |
| 49. | AK49 | MXI11-12\M34ESWYT\188 | FRANCOLIN #1/AKURI #1//FRNCLN |
| 50. | AK50 | MXI11-12\M34ESWYT\195 | ND643/2*TRCH//MUTUS/3/SUP152 |

Similar results were also reported by Salman *et al.*, (2014) who also observed highly significant variation for flag leaf area, chlorophyll contents, number of tillers, plant height, spike length, days to heading, days to maturity, 1000 grain weight and grain yield and concluded that simple selection could play a significant role for improvements of the said trait and grain yield.

**Table 2.** Mean square values for yield related and grain associated parameters of 50 wheat accession estimated under normal condition.

| S.O.V | DF | DTA | DTM | PH | FLA | NOG | SPS | EL | PT | GWS | GS | TGW | GY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blocks | 1 | 96.04 | 12.25 | 18.92 | 23.48 | 282.24 | 19.36 | 0.13 | 1730.56 | 2190.24 | 1.90 | 2190.2 | 274.23 |
| Genotype | 49 | 81.7** | 8.91* | 19.01* | 34.11* | 105.69$^{ns}$ | 11.61** | 1.93* | 234.55** | 588.52** | 6.10* | 588.52** | 4558.01** |
| Error | 49 | 42.7 | 4.98 | 8.58 | 20.67 | 73.85 | 3.19 | 1.01 | 91.91 | 87.09 | 3.80 | 87.09 | 2505.58 |

Whereas DTA = Days to anthesis, DTM = Days to maturity, PH = Plant height (cm), FLA = Flag leaf area ($cm^2$), NOG = No. of grains/spike, SPS = Spikelet's /spike, EL = Ear length (cm), PT = Productive tillers, GWS = Grain weight/spike (g), GS = Grain size, TGW = Thousand grain weight (g), GY = Grain yield (g) and ** = highly significant at $p<0.01$, SOV= source of variation, DF= Degree of Freedom.

*Biplot analysis*

Biplot is an extended form of scatter plot which make use of points and vectors for representation of the structures. In biplot, relative location of points is important. Points that lies close together have similar scores and vice versa.

In case of vectors both the length and direction of the vector is important (Yan, 2001). In our study,biplot analysis revealed that genotypes AK38, AK40, AK41 and AK50 had maximum OP vector for grain yield per plot as well as for spikelet's per spike hence these genotypes have highest grain yield and spikelet's per spike. While highest grains per spike was observed in genotypes AK41 and AK49 as these showed longest OP vector for grains per spike (Fig. 1).

**Table 3.** Correlation coefficients among various morphological traits of wheat genotypes in normal condition.

| Traits | Gain yield (g) | Thousand grain Weight (g) | No of grains/spike | Single head Weight (g) | Productive Tillers ($m^1$) | Days to Maturity (days) | Plant Height (cm) | Ear length (cm) | Days to Anthesis | Grain Size ($mm^2$) | Flag Leaf Area ($cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Spikelet's/spike | 0.28* | 0.30* | 0.37** | 0.33** | $0.25^{ns}$ | $0.23^{ns}$ | 0.37** | 0.41** | 0.33** | 0.38** | 0.32* |
| Grain yield(g) | | 0.36** | 0.29* | 0.36** | 0.27* | $0.23^{ns}$ | 0.47** | 0.39** | 0.38** | 0.28* | 0.39** |
| Thousands Grain weight (g) | | | 0.66** | $0.23^{ns}$ | 0.34** | 0.36** | 0.30* | 0.29* | 0.29* | $0.17^{ns}$ | 0.35** |
| No of grains/spike | | | | 0.33** | 0.31* | $0.27^{ns}$ | $0.25^{ns}$ | 0.55** | $0.19^{ns}$ | $0.13^{ns}$ | 0.33** |
| Single head Weight (g) | | | | | 0.36** | 0.28* | $0.00^{ns}$ | 0.37** | 0.50** | $0.01^{ns}$ | 0.37** |
| Productive Tillers($m^1$) | | | | | | 0.36** | 0.08** | $0.14^{ns}$ | 0.37** | $0.06^{ns}$ | $0.01^{ns}$ |
| Days to maturity (days) | | | | | | | $0.04^{ns}$ | $0.19^{ns}$ | 0.30* | 0.31* | 0.33** |
| Plant height (cm) | | | | | | | | 0.34** | 0.31* | 0.43** | 0.36** |
| Ear length (cm) | | | | | | | | | $0.16^{ns}$ | $0.11^{ns}$ | 0.31* |
| Days to Anthesis (days) | | | | | | | | | | 0.28* | 0.28* |
| Grain size ($mm^2$) | | | | | | | | | | | 2.98* |

Whereas, genotype AK30 and AK10 exhibited maximum OP vector for days to anthesis. Genotypes AK48, AK49 and AK50 showed longest OP vector for days to maturity (Fig. 2). AK25 and AK30 genotypes exhibited longest OP vector for single head weight while genotype AK41, AK48 and AK50 showed maximum OP vector for thousand grain weight, single head weight and grain yield (Fig. 3).

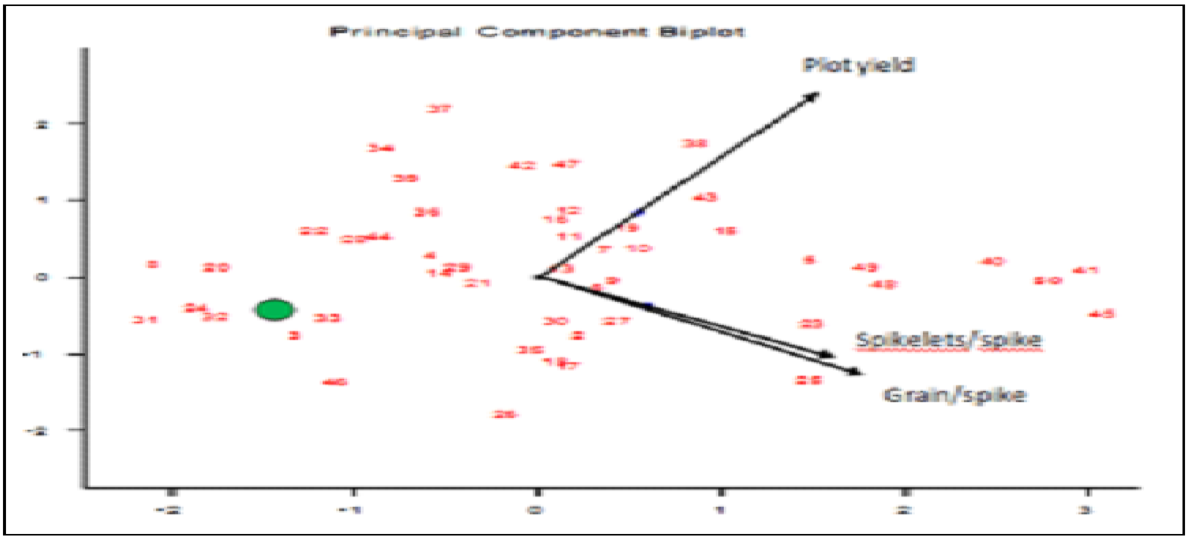


**Fig. 1.** Biplot analysis showing genetic diversity among genotypes for spikelets / spike and grains per spike and their association with grain yield (g).

Genotypes AK15, AK37 and AK41 displayed maximum OP vector for flag leaf area. On the other hand, AK27 as well as AK1 (Local check) exhibit longest positive OP vector for grain size (Fig. 4).

Genotype AK43 and AK45 displayed maximum OP vector for plant height. While, genotypes AK25, AK49 and AK50 showed maximum OP vector for ear length (Fig. 5). AK1 (Local check) had the longest negative OP vector for grain yield, spikelet's per spike, number of grains per spike, days to maturity, days to anthesis, thousand grain weight, single head weight, Flag leaf area, ear length and plant height indicating that check has lowest values for these traits.

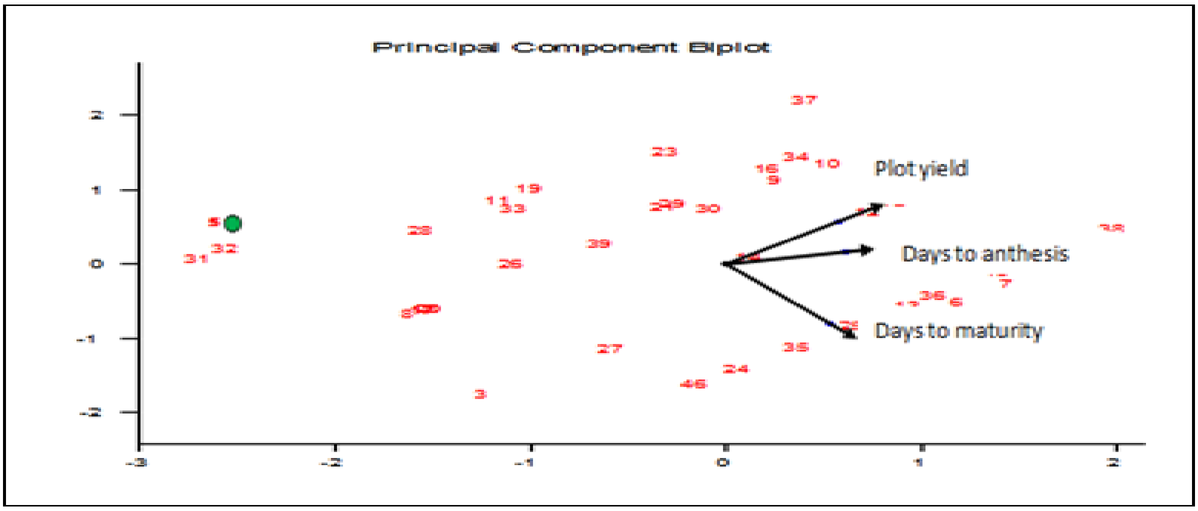


**Fig. 2.** Biplot analysis showing genetic diversity among genotypes for days to anthesis and days to maturity and their association with grain yield (g).

The results of Alam *et al*., (2017) are in line with our study who studied yield stability of promising genotypes using biplot analysis through days to heading, days to maturity, grains per spike, and 1000-grains weight.

*Genotypic performance and correlation of traits*

Highest grain size was recorded in genotype AK29 (24 $mm^2$) whereas lowest GZ was observed in genotype AK41 (15.25 $mm^2$) in comparison with check. About twenty one genotypes exhibited higher grain size as copmpred to Local check (18.1 $mm^2$) as provided in Figure 1. Highest grain yield per plot was observed in genotype AK41 (304.55 g) while lowest grain yield was recorded in genotype AK32 (109.75g) as compared to Millat-11 as given in Figure 2.

About forty seven genotypes diplayed higher grain yield than Millat-11 (133.8 g). Huge variation exist in mean performance of genotypes.

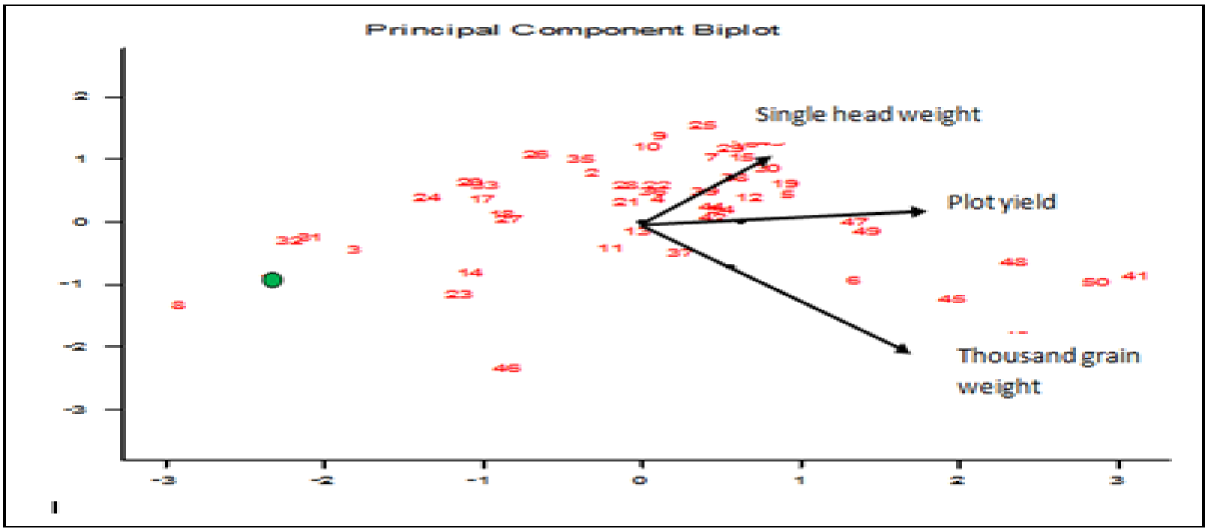


**Fig. 3.** Biplot analysis showing genetic diversity among genotypes for single head weight (g) and thousand grain weight (g) and their association with grain yield (g).

Grain size showed positive association with days to anthesis, days to maturity, grain yield, flag leaf area and spikelet's per spike. Coventry *et al*., (2003) also reported positive association of grain size with grain yield, days to anthesis, days to maturity, spikelet's per spike and flag leaf area (Table 3). Positive association was also reported among thousand grain weight and grain size (Gegas *et al.*, 2010). Positive correlation was also observed among 1000 grain weight, number of grains per spike and grain yield as was also reported by Shahid *et al.*, (2002), Aycicek *et al.*, (2006) and Khan *et al.*, (2012). Positive correlation of grain yield was also observed with spikelet's per spike and flag leaf area (Depauw *et al.*, 1998; Chowdhry *et al.*, 2000; Tamman *et al.*, 2000).

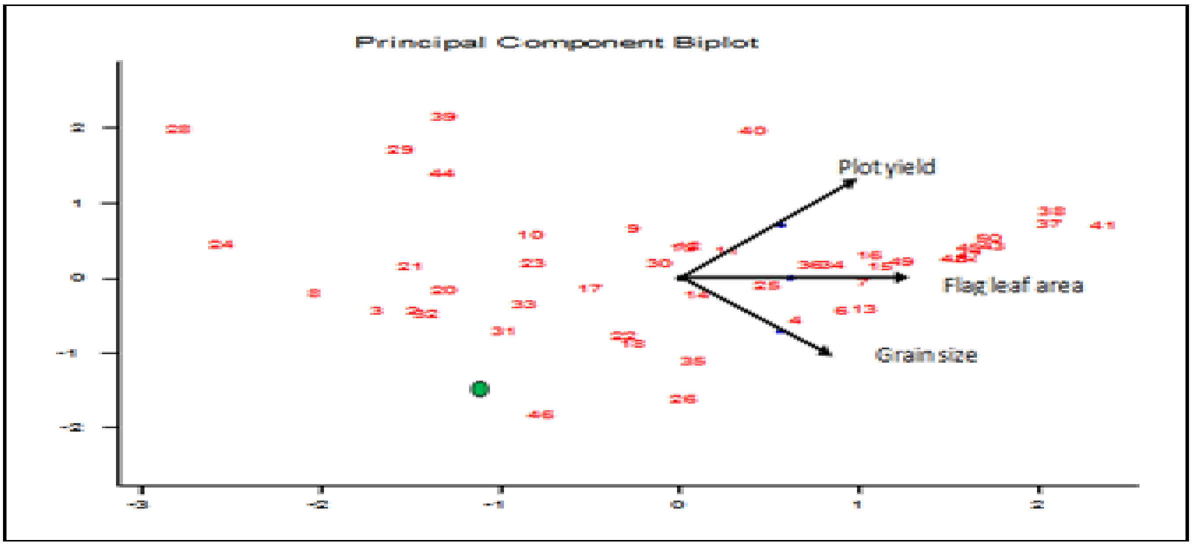


**Fig. 4.** Biplot analysis showing genetic diversity among genotypes for flag leaf area ($cm^2$) and grain size and their association with grain yield (g).

Flag leaf area had positive correlation with plant height, grain size, spikelet's per spike, days to anthesis and days to maturity. Whereas it had positive association with number of grains per spike, single head weight, 1000 grain weight and grain yield. While it had positive and significant correlation with grain size, days to heading and days to maturity (Coventry *et al.*, 2003).

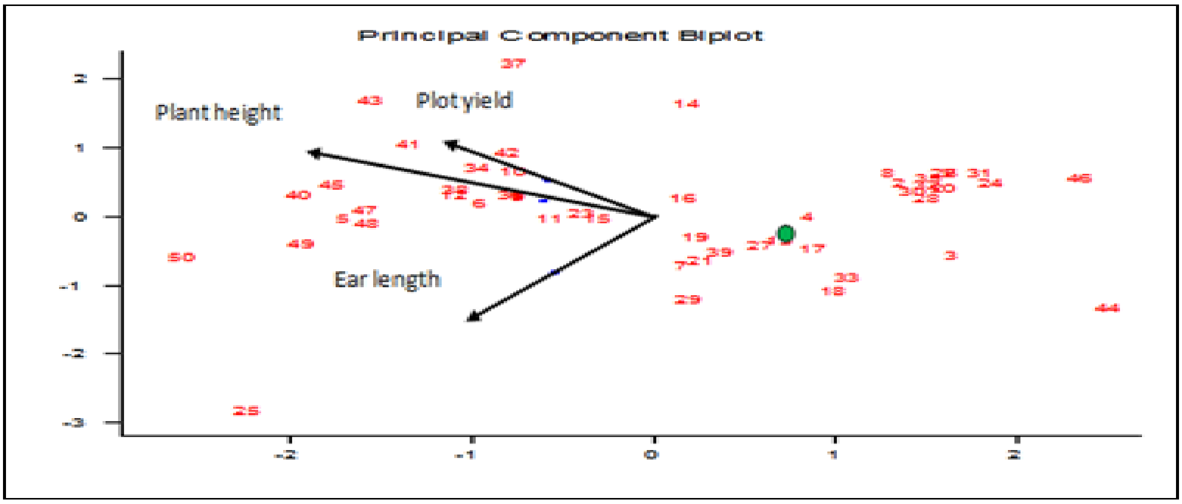


**Fig. 5.** Biplot analysis showing genetic diversity among genotypes for plant height (cm) and ear length (cm) and their association with grain yield (g).

Plant height association with productive tillers $m^{-1}$, spikelets per spike, grain yield and 1000 grain weight were positive as well as significant. Plant height association with grain size was significant but negative (Coventry *et al.*, 2003) but present study results exhibited this association as positive (Table 3).

Positive and significant correlation was exhibited among 1000 grain weight, days to maturity, days to anthesis, ear length, plant height with grain yield but positive correlation of 1000 grain weight was exhibited with flag leaf area (Laghari *et al*., 2010; Ajmal *et al*., 2010; Mohammadi *et al*., 2014). Positive association was observed among days to anthesis and thousand grain weight, plant height, ear length, flag leaf area and grain yield (Leilah and Al-Khateeb, 2005; Kandic *et al*.,2009; Dogan, 2009). Days to maturity showed positive association with thousand grain weight. Opposite results of correlation of days to maturity with thousand grain weight were observed by Reynolds *et al*., (2014). Productive tillers showed positive correlation with thousand grain weight (Ashfaq *et al*., 2014). Its association with single head weight and thousand grain weight was also positive. Ear length correlation with grain yield was positive (Akram *et al*., 2008; Khan *et al*., 2010). Correlation between ear length and thousand grain weight was positive. Ear length showed positive association with grain weight per spike (Singh *et al*., 2001).Spikelet's per spike have positive correlation with grain yield (Bhutta and Chowdhry, 1984; Saleem, 2006) and grain size (Coventry *et al*., 2003). Grains per spike showed positive association with grain weight per spike, thousand grain weight and grain yield (Singh and Diwivedi, 2002; Khokhar *et al*., 2010; Khan *et al*., 2010). Whereas as grain yield showed positive association with grain weight per spike (Munir *et al*., 2007).

**Conclusion**

Grain yield and quality are controlled by grain size.Genetic as well as environmental factors intimately influence on grain yield. Grain size of different wheat varieties was assessed and its association with different morpho-physiological traits was worked out. Results from ANOVA revealed that all the genotypes were highly significantly different form one another and also explained high variability of genotypes for all morphological trait.Biplot analysis indicated that genotypes AK41, AK49 and A50 showed good performance in reference to grain yield, grain size and their contributing traits. Further strong correlation of grain size was observed with days to anthesis, days to maturity, grain yield, flag leaf area, spikelet's per spikewhich explicated that bold grain size directly associated with high grain yield production. Thus, current screening genotypes will play an important role in wheat breeding programmesas a selection criterion. Significant knowledge about grain size facilitates the production of high yielding genotypes in order to meet the current demands of increasing population.

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