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Genetic Association of Canopy Temperature and Early Ground Cover with Yield and Its Component in Wheat under Water Deficit Condition

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Abstract: In order to identify the traits suitable to be used in a breeding program for the effective selection of high yielding and drought tolerant varieties of wheat, the prevalence of variability, inheritance pattern and associations of certain physiological and morphological traits were investigated among ten varieties. The varieties were grown in a randomized complete block design with five repeats. Analysis of variance, GCV, PCV, heritability, correlation and path analysis among various morphological and physiological traits was done. Least PCV and GCV canopy temperature difference, days to heading and days to maturity suggested as genetically predominant, necessitate further exploitation in wheat breeding program. High heritability values were obtained for days to heading, plant height, days to maturity and canopy temperature, confirming the existence of additive gene action. The results of correlation analysis showed that early ground cover and cooler canopies possessed significant positive correlation with grain yield. Path analysis influenced that canopy temperature, days to maturity, tillers per plant and plant height had positive direct effect on the grain yield. Thus, canopy temperature may be secondary, while days to maturity and plant height may be primary selection criterion of drought tolerant genotypes with higher yield in breeding program.

Key words: Canopy temperature, Drought, Early ground cover, Wheat.

INTRODUCTION

Wheat is an important staple food crop, ranking second after maize. It is an outstanding crop in term of cultivated area and food source. The progenitor of wheat, emmer wheat has been cultivated about 10,000 years ago in Fertile Crescent “Center of origin” (Willcox, 2005). Among all cultivated wheat species, *Triticum aestivum* is the most promising and major specie being grown on huge acreage in most of the countries, including Pakistan. Because of its hardy and competating nature, hexaploid wheat is extensively cultivated under diversified environments in the world.

Water deficit conditions have adverse effects on wheat growth and productivity in term of grain yield through morphological, physiological, biochemical and molecular features. Plant breeders mainly emphasize on the yield losses, hence they focus on the yield performance under water deficit condition. As the yield is a quantitative trait, much influenced by the environmental factors (i.e., biotic and abiotic factors) as well as other un-noticed factors. Fleury and Jafferies (2010) evidenced that breeding for improved crop performance under water deficit conditions has largely relied on morphological phenotyping. Improvement in yield performance only through morphological traits is difficult, while morpho-physiological traits based breeding strategies are very rarely practiced in breeding programs. Integrative breeding approach has merit over the empirical breeding solely on the basis of yield and yield related traits (Naeem *et al*., 2015). Recent studies implicit that physiological traits-based selection has potential to improve genetic yield gain in wheat (Reynolds, 2014). The physiological basis for drought tolerance is still poorly implicit. Early ground cover and canopy temperature are the reliable physiological markers (Balota *et al*., 2008; Naeem *et al*., 2015), which have potential to improve the crop performance under water deficit conditions. Physiological traits are easy, rapid and efficient way for selection of desirable genotypes. However, the selection of the desirable genotypes for the development of drought tolerant variety requires a better understanding of yield contributing traits, i.e., days taken for heading, days taken for maturity, grains per spike, plant height, number of tillers plant, grain weight and grain yield along with physiological traits, i.e., early ground cover and canopy temperature.

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Brancourt-Hulmel *et al.* (2003) reported that the best approach for crop improvement in term of yield under drought environment is to investigate the possible physiological and yield contributing traits and also exploration of their genetic variation. The prevalence of genetic variability for physiological and morphological traits among the studied genotypes suggests a prospect for the improvement of crop yield and drought tolerance. Precise estimates of genetic variability components (GCV, PCV and H^2) for physiological and morphological traits of interest assist plant breeders to identify drought tolerant genotypes. Grain yield is a quantitative trait, which involving interaction of different characters, is called yield contributing traits. Inter-relationship among yield contributing traits are quantified through correlation analysis. Phenotypic and genotypic correlations within varieties indicated the extent to which various physio-morphic traits are related with grain yield. The prevalence of correlation between different physiological and morphological traits with grain yield under drought stress is of great importance for many plant breeders. These factors also influenced the grain yield directly and indirectly. Path analysis describes whether the influence of these factors directly affects grain yield or takes some other indirect way for ultimate effect. The development of drought tolerant genotypes thus necessitates a comprehensive study of correlated response of different physiological and morphological traits.

The objectives of the present study were: (i) to investigate the prevalence of variability and inheritance pattern among studied traits, (ii) to collect information on association of physiological and morphological traits and (iii) to evaluate the feasibility of employing primary and secondary selection traits to identify drought tolerant genotypes.

MATERIALS AND METHODS

Ten wheat varieties, viz. Yecora, Chakwal-86, GA-2002, Inqlab-91, Parwaz-94, Sehar-06, Shafaq-06, Faisalabad-08, Lasani-08 and AARI-11, were sown in randomized complete block design with five repeats under water deficit condition. The material was planted on 17th November 2012, in Faisalabad. Pre-sowing soaking irrigation was applied and sowing was done in well prepared moist soil with hand drill. The plot size was 4 m × 1.8 m with 30cm row-to-row distance. Seed was used @ 120 kg/ha for each experimental plot. After germination, thinning was done to maintain 7.5 cm distance, accommodating 320 plants per plot. Weeds were controlled manually by hoeing. NPK fertilizer was applied 110-110-75 kg/ha. Full dose of phosphorus and potash was applied at sowing along with half of nitrogen, while the rest of the nitrogen was applied at tillering with first irrigation.

Morphological traits: Data on the following morphological traits were recorded, i.e., days to heading (50%), days to maturity (90%), plant height (cm), No. of tillers per plant, No. of grains per spike, 1000 grain weight (g) and yield per plot (g).

Early ground cover: Observations for early ground cover were recorded by naked eye during 10th week after sowing on scale (1-10). One mentioning minimum area cover, i.e., 10% inter row area covered and 10 complete ground cover, when the leaves of the plants completely covered area between two rows. These observations were recorded on alternate days during the week and an average of 3 readings was calculated for use in further analysis.

Canopy temperature (°C) A separate set of experimental material was planted on the same date, following same procedure as mentioned above. The plot size was 2.5 m × 0.6 m having 2 rows. This set was normally irrigated. The data was recorded in the first week of February. Six readings were recorded and an average of these readings was used for further analysis. Data was recorded with LT.300 6th Sense Infrared Thermometer (IRT), during sunny days with least wind speed at noon time during 11 a.m. to 1 p.m. when the dew dried off from the plant canopy.

Statistical analysis: Analysis of variance (ANOVA) was performed by following the procedure of Steel and Torrie (1980). Phenotypic coefficient of variability (PCV) and genotypic coefficient variability (GCV) were calculated, using the technique developed by Johnson *et al.* (1955). The estimation of broad sense heritability (H^2bs) was calculated by adopting the formula developed by Allard (1960). Genotypic and phenotypic correlation coefficient was calculated, following Al-Jibouri *et al.* (1958) and significant test for genotypic correlation was applied by the formula of Robertson (1959). Path coefficient analysis was carried out, using the approach of Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance: Analysis of variance revealed the existence of significant genotypic differences for all traits, including physiological traits, i.e., early ground cover and canopy temperature, and morphological traits, viz. days to heading, days to maturity, grain per spike, plant height, number of tillers, grain weight and grain yield (Table 1). This indicated that a sustainable genetic variability existed in the studied material for the above mentioned traits, which can be exploited in future breeding program.

Genetic variability and heritability estimates: High phenotypic coefficient of variability was observed for all studied traits compared to the genotypic coefficient of variability. This suggested the obvious influence of environmental factors on the expression of all studied traits. These observations are in agreement with the findings of Sedeek *et al.*, 2009 and Soleymanifard *et al.*, 2012. The genotypic coefficient of variability among the studied traits, ranged from 0.719 to 167158.900. The phenotypic coefficient of variability among studied traits ranged from 1.181 to

295351.400. A high level of genotypic and phenotypic coefficient of variability was shown by the grain yield and tillers per plant. These results suggested that these traits play an important role in genetic variation. These findings corroborated the observations of Khan *et al.*, 2007 and Mirza *et al.*, 2011. Canopy temperature, days to heading and days to maturity demonstrated the least differences between genotypic and phenotypic coefficient of variability. Sedeek *et al.*, 2009, also observed similar findings. This suggested that most fraction of phenotypic coefficient of variability mostly contributed by genetic components and least influenced by environmental factors. These traits might be genetically predominant, having ability for further improvement, employing further exploitation in wheat breeding program.

Table 1: Mean square values of variance due to studied varieties of nine morpho-physiological traits.

Source	Early ground cover	Canopy temperature	Days to heading	Days to maturity	No of Grains per Spike	No of Tillers per plant	Plant height	1000 grain weight	Yield per plant
Genotypes	0.037*	0.009**	4.942**	8.123**	0.006**	5.925**	8.545**	0.006**	0.002**
GCV	8.240	0.719	16.156	3.744	39.173	677.410	59.392	13.110	167158.900
PCV	23.407	1.180	17.11	4.804	39.311	941.270	68.285	26.364	295351.400
h^2_{bs}	0.354	0.609	0.944	0.778	0.493	0.719	0.869	0.497	0.566

GCV= Genotypic coefficient of variation, PCV=Phenotypic coefficient of variation, h^2_{bs} = Broad sense heritability, *Significant, **Highly significant, ns = non-significant

Heritability estimates the extent of inheritance of traits, which would be transmitted to next generation. Plant breeders predict the genetic architecture of a line/variety into the succeeding generations. High heritability estimates point out the possibility of improvement in days to heading (94%), plant height (87%), days to maturity (78%), tillers per plant (72%) and canopy temperature (61%). Ijaz *et al.* (2014) reported high heritability for different yield parameters. These higher magnitudes revealed that a greater proportion of the entire variance was because of genotypic variance and the presence of predominant additive gene action. Hence, the selection of superior traits with higher heritability can be focused in early segregating populations for crop improvement (Ahmed *et al.*, 2007). Nakhaei *et al.* (2014) reported that the selection efficiency depends on the extent of heritability. The medium to lower broad sense heritability showed by early ground cover (35%), grain per spike (49%), grain weight (50%) and yield (57%). Araus *et al.* (2000) reported that grain yield is a quantitative trait, influenced by the number of environmental factors and, hence, employing low heritability estimates. Low broad sense heritability estimates indicated the low genetic potential for these traits among the studied genotypes. These results suggested that the selection should be delayed to late filial generations (F_5-F_6) on the basis of these traits.

Genotypic and phenotypic correlation: Genotypic correlation coefficient revealed that early ground cover (EGC) had highly significant positive association with the number of tillers and grain yield (Table 2). Similar results were revealed by phenotypic correlation coefficient. This suggested that the enrichment of tillering capacity may be attributed to early ground cover, which, ultimately, had the positive impact on grain yield. Chhibber and Jain (2014) and Suleiman *et al*. (2014) observed similar findings that tillering is closely associated to early ground cover, which further enhanced the photosynthetic activity, carbohydrate formation and finally the grain yield. Meanwhile, canopy temperature and grain weight exhibited a highly significant negative association, which revealed that early ground cover may be attribution of a decrease in canopy temperature. As early ground cover increased the number of tillers (which starts the intra-plant competition), it is strong enough to limit the availability of resources for the proper grain filling ultimately grain weight is decreased.

Canopy temperature revealed the highly significant negative genotypic correlation with grain yield, suggesting that the plants with hot canopies corresponded to low yielders. This idea is supported by Ata *et al*. (2014), who stated that the plant with cooler canopies ultimately revealed higher yields. It also demonstrated highly significant positive correlations with days to heading, days to maturity and grains per spike. These results gave a clue that the plants with hot canopies tend early days to heading and days to maturity as confirmed by earlier findings of Araus *et al.*, 2008, Balota *et al.*, 2008. Similar findings were revealed by phenotypic correlations that canopy temperature had significant negative correlation with yield, while significant positive correlations with early days to heading and days to maturity. Days to heading showed a highly significant positive genotypic and phenotypic correlation with days to maturity, grain per spike and plant height, whereas, highly significant to significant negative correlation with grain weight. Days to maturity depicted highly significant positive genotypic correlation with grains per spike and plant height, while a negative correlation with grain weight and yield. This suggested that early days to maturity improved the grains per spike, but due to short period of time grains were not completely filled and thus looked like shriveled grains, which ultimately corresponded to low grain weight and yield. Similarly, it showed highly significant positive phenotypic correlation with grains per spike. The grain per spike exhibited a significant negative genotypic and phenotypic association with grain weight. Tillers per plant had a highly significant positive genotypic and phenotypic correlation with plant height and yield, whereas a negative correlation with the grain weight due to an intra plant competition. Singh *et al*. (2010), Baloch *et al*. (2013) and Suleiman *et al*. (2014) also observed that grain yield was positively correlated with productive tillers. Plant height exhibited a positive genotypic correlation with grain weight and yield. Chowdhry *et al*. (2000); Chowdhry *et al.* (2002) and Kashif and Khaliq (2003) found similar results, i.e. single plant yield showed significant positive relationship with the height of plant, number of tillers produced by the single plant and weight of 1000 grains. This may be due to equal portioning of dry matter between grain yield and plant height. Similar results were observed by Ata *et al*., 2014, however, a contradiction shown by earlier studies of Suleiman *et al*., 2014. Grain weight showed a negative genotypic association with plant yield. Similar results were reported by earlier studies of Singh *et al*. (2010). Meanwhile, contradictory results were reported by Subhani and Chowdhry (2000), showing under drought stress conditions, the grain yield was positive and significantly correlated with 1000-grain weight.

Path coefficient analysis: A path coefficient analysis demonstrated that canopy temperature (0.141), days to maturity (0.646), tillers per plant (0.291) and plant height (0.259) had a positive, direct effect on grain yield (Table 3). This revealed that the highest positive, direct effect was shown by days to maturity and plant height on grain yield. This suggested that the slight enhancement in one of the above traits may directly enhance the crop yield.

Table 2: Phenotypic and genotypic correlation of ten wheat genotypes for physiological and morphological traits.

	Early ground cover	Canopy temperature	Days to heading	Days to maturity	Grain per spike	Tillers	Plant height	Grain weight	Yield per plant
Early ground cover	–	–0.849**	–0.225ns	–0.223 ns	0.064 ns	0.730**	0.129 ns	–0.774**	0.756**
Canopy temperature	–0.441*	–	0.715**	0.727**	0.945**	–0.273 ns	0.103 ns	–0.065 ns	–0.545**
Days to heading	–0.115 ns	0.531**	–	0.925**	0.914**	0.126 ns	0.609**	–0.472**	–0.206 ns
Days to maturity	–0.011 ns	0.435*	0.785**	–	0.984**	0.153 ns	0.801 ns	–0.279 ns	0.089 ns
No. of grains per spike	–0.215 ns	0.286 ns	0.642**	0.625**	–	–0.034 ns	0.323 ns	–0.741**	–0.078 ns
No. of tillers per plant	0.423**	–0.302 ns	–0.378*	–0.111 ns	–0.403*	–	0.504**	–0.157 ns	0.538**
Plant height	0.019 ns	0.002 ns	–0.177 ns	0.098 ns	–0.050 ns	0.410*	–	0.026 ns	0.289 ns
1000 grain weight	–0.159 ns	0.076 ns	0.109 ns	0.241 ns	0.079 ns	–0.038 ns	0.077 ns	–	–0.016 ns
Yield per plant	0.571**	–0.425 ns	0.583**	0.604**	0.313 ns	0.509 ns	0.100 ns	0.071 ns	–

Values presented above diagonal is genotypic correlations and below diagonal is phenotypic correlations, *= Significant, ** = Highly significant, ns = non-significant (at $P < 0.05$).

Table 3: Direct and indirect effects of physiological and morphological traits on yield per plant.

	Early ground cover	Canopy temperature	Days to heading	Days to maturity	Grain per Spike	Tillers	Plant height	Grain weight
Early ground cover	–0.017	–0.120	0.296	–0.144	–0.016	0.213	0.066	0.478
Canopy temperature	0.014	0.141	–0.942	0.469	–0.241	–0.079	0.053	0.040
Days to heading	0.003	0.101	–1.318	0.598	–0.234	0.036	0.313	0.292
Days to maturity	0.003	0.102	–1.220	0.646	–0.251	0.044	0.412	0.173
No. of grains per spike	–0.001	0.133	–1.204	0.635	–0.256	–0.010	0.166	0.458
No. of tillers per plant	–0.012	–0.039	–0.165	0.097	0.008	0.291	0.013	0.097
Plant height	–0.002	0.014	–0.803	0.517	–0.082	0.146	0.259	–0.015
1000 grain weight	0.013	–0.009	0.622	–0.180	0.189	–0.045	0.514	–0.818

The highest positive indirect effect towards the grain yield was shown by early ground cover via canopy temperature (0.015), canopy temperature via grain per spike (0.134), days to heading via grain weight (0.622), followed by early ground cover (0.296), days to maturity via grain per spike (0.636) and days to heading (0.598), grain per spike via grain weight (0.190), tillers per plant via early grain cover (0.213), followed by the plant height (0.147), the plant height via days to maturity (0.412) and days to heading (0.314), tillers per plant via early grain cover (0.213), followed by plant height (0.147) and grain weight via early grain cover (0.479) and grain per spike (0.458).

CONCLUSION

In this study, the analysis of variance of all traits was found to be highly significant. The interpretation of results suggested that the traits, like, days to heading, plant height, days to maturity, number of tillers and canopy temperature, showed least differences between genotypic and phenotypic coefficient of variation leading to high heritability 94%, 87%, 78%, 72% and 61%, respectively. Least differences among genotypic and phenotypic coefficient of variability, corresponding to high heritability, was examined by earlier studies. Higher magnitude of these traits suggested that a greater proportion of the entire variance was because of genotypic variance. Correlation studies revealed that early ground cover and tillers per plant had a highly significant positive correlation with grain yield. As tillering is closely associated with early ground cover, it enhanced the photosynthetic activity, carbohydrate formation and ultimately improves the grain yield. Canopy temperature showed a significant negative correlation with grain yield, suggesting that a high canopy temperature corresponded to lower yielding genotypes and vice versa. Path analysis demonstrated that canopy temperature, days to maturity, tillers per plant and plant height had a positive, direct effect on the grain yield, whereas, most of the traits had indirect effect on grain yield via early ground cover. This suggested that a slight increment in one of the above traits may directly enhance the crop yield. Hence, it may be concluded that the canopy temperature may be as secondary, while days to maturity and plant height may be primary selection criterion of drought tolerant genotypes with higher yield in breeding program.

REFERENCES

Ahmed, N., M.A. Chowdhry, I. Khaliq and M. Maekaw, 2007. The inheritance of yield and yield components of five wheat hybrid populations under drought conditions. Indones. J. Agric. Sci., 8: 53-59.

Al-Jibouri, H., P.A. Miller and H.F. Robinson, 1958. Genotypic and environmental variances and co-variances in upland cotton crosses of inter-specific origin. Argon. J., 50:633-635.

Allard, R.W., 1960. Principles of plant breeding. Jhon Wiley and Sons, Inc., USA, pages 96.

Araus, J.L., J. Bort, J. Casadesús, M. Nachit, D. Villegas, N. Aparicio and C. Royo, 2000. Some remarks on ecophysiological traits for breeding. In: Royo, C., M. Nachit, N. Di Fonzo, J.L. Araus, (ed.). Durum wheat improvement in the Mediterranean region: New challenges, pp. 57-62.

Araus, J.L., G.A. Slafer, C. Royo and M.D. Serret, 2008. Breeding for yield potential and stress adaptation in cereals. Crit. Rev. Plant Sci., 27: 377-412.

Ata, A., B. Yousaf, A.S. Khan, G.M. Subhani, H.M. Asadullah and A. Yousaf, 2014. Correlation and path coefficient analysis for important plant attributes of spring wheat under normal and drought stress conditions. J. Biol. Agric. Healthc., 4: 1-7.

Baloch, M.J., E. Baloch, W.A. Jatoi and N.F. Veesar, 2013. Correlations and heritability estimates of yield and yield attributing traits in wheat (*Triticum aestivum* L.). Pak. J. Agric., 29: 96-105.

Balota, M., W.A. Payne, S.R. Evett and T.R. Peters, 2008. Morphological and physiological traits associated with canopy temperature depression in three closely related wheat lines. Crop Sci., 48: 1897-1910.

Brancourt-Hulmel, M., G. Doussinault, C. Lecomte, P. Berard, B Le Buanec and M. Trottet, 2003. Genetic improvement of agronomic traits of winter wheat cultivars released in France from 1946 to 1992. Crop Sci., 43: 37-45.

Chhibber, S. and D. Jain, 2014. Inter-correlation studies among yield and its contributing traits in bread wheat genotypes grown in Haryana, India (*Triticum aestivum* L.). Int. J. Curr. Res. Rev. 5: 12-18.

Chowdhry, M.A., M. Ali, G.M. Subhani and I. Khaliq, 2000. Path coefficient analysis for water use efficiency, evapo-transpiration efficiency and some yield related traits in wheat. Pak. J. Biol. Sci., 3: 313-317.

Chowdhry, M.A., A. Ambreen and I. Khaliq, 2002. Genetic control of some polygenic traits in *Aestivum* species. Asian J. Plant Sci., 1: 235–37.

Dewey, D.R. and K.H. Lu, 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. Argon. J., 51: 515-518.

Fleury, D. and S. Jefferies, 2010. Genetic and genomic tools to improve drought tolerance in wheat. J. Exp. Bot., 61: 3211-3222.

Ijaz, F., I. Khaliq and M.T. Shahzad, 2015. Estimation of heritability for some yield contributing traits in f2 populations of bread wheat (*Triticum aestivum*L.). J. Agric. Res., 53(2): 157-164.

Johnson, H.W., H.F. Robinson and R.E. Comstock, 1955. Estimation of genetic and environmental variability in soybean. Argon. J., 47: 314-318.

Kashif, M. and I. Khaliq, 2003. Mechanism of genetic control of some quantitative traits in bread wheat. Pak. J. Biol. Sci., 6: 1586-1590.

Khan, M.A., M.Y. Mirza, M. Akmal, N. Ali and I. Khan, 2007. Genetic parameters and their implications for yield improvement in sesame. Sarhad J. Agric., 23: 623-627.

Mirza, M.Y., M.A. Khan, M. Akmal, A.S. Mohmand, M.S. Nawaz, N. Nawaz and N. Ullah, 2011. Estimation of genetic parameters to formulate selection strategy for increased yield in linseed. Pak. J. Agric. Res., 24:19-24.

Naeem, M.K., M. Ahmad, M. Kamran, M.K.N. Shah and M.S. Iqbal, 2015. Physiological responses of wheat (*Triticum aestivum* L.) to drought stress. Int. J. Plant Soil Sci., 6: 1-9.

Nakhaei, M., A. Baghizadeh, G. Mohammadi-Nejad and P. Golkar, 2014. Genetic analysis of salt tolerance in safflower (*Carthamus tinctorius* L.). Annu. Res. Rev. Biol., 4: 337-346.

Reynolds, M., S. Nagarajan, M.A. Razzaque, O.A.A. Ageeb, 2014. Heat tolerance. In: M.P.. Reynolds, J.I. Ortiz-Monasterio and A. McNab (eds.) Application of physiology in wheat breeding. CIMMYT, Mexico, 124-135.

Robertson, A., 1959. The sampling of variance of the genetic correlation coefficients. Biometrics, 15: 469-485.

Sedeek, S.E.M., S.A.A. Hammoud, M.H. Ammar and T.F. Metwally, 2009. Genetic variability, heritability, genetic advance and cluster analysis for some physiological traits and grain yield and its components in rice (*Oryza sativa* L.). J. Agric. Res., 35: 858-878.

Singh, S., A.K. Gupta, S.K. Gupta and N. Kaur, 2010. Effect of sowing time on protein quality and starch pasting characteristics in wheat (*Triticum aestivum* L.) genotypes grown under irrigated and rain-fed conditions. Food Chem., 122: 559-565.

Soleymanifard, A., R. Naseri and M. Meysam, 2012. The study genetic variation and factor analysis for agronomic traits of Durum wheat genotypes using cluster analysis and path analysis under drought stress condition in western of Iran. Intl. Res. J. Appl. Basic Sci.,3: 479-485.

Steel. R.G.D. and J.H. Torrie, 1980. Principles and procedures of statistics. McGraw-Hill Book Co. Inc., New York, Pages 99.

Subhani, G.M. and M.A. Chowdhry, 2000. Correlation and path coefficient analysis in bread wheat under drought stress and normal conditions. Pak. J. Biol. Sci., 3: 72-77.

Suleiman, A.A., J.F. Nganya and M.A. Ashraf, 2014. Correlation and path analysis of yield and yield components in some cultivars of wheat (*Triticum aestivum* L.) in Khartoum State, Sudan. J. Forest Prod. Ind., 3, 221-228.

Willcox, G., 2005. The distribution, natural habitats and availability of wild cereals in relation to their domestication in the Near East: multiple events, multiple centers. Veget. Hist. Archaeobot., 14: 534-541.