NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 30, 2013
Print ISSN 1222-4227; Online ISSN 2067-5720

INTERRELATIONSHIP OF SOME AGRONOMIC TRAITS WITH GRAIN YIELD IN WINTER BREAD WHEAT AND THEIR ALTERATION BY CLIMATOLOGIC EFFECTS

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ABSTRACT

This research was conducted to investigate the relationships of some agronomic traits with grain yield in bread wheat and determine the changes in these relationships depending on climate conditions. Twenty four winter wheat varieties were used in this study. Eight agronomic traits were measured along with grain yield. Correlation and path analyses were used to investigate the relationships among the traits of interest. Multidimensional Scaling (MDS) was applied for characterization of cultivars based on observed characters. Results of the statistical analysis showed that grain rate per spike and grain number per spike could be used for selection of genotypes for high yielding. It seems that the effect of days to heading on grain yield varied depending on climatologic factors. Earliness emerges as a highly important trait and it should be taken into consideration when choosing appropriate cultivars for trans-regions such as Çanakkale. Multi-Dimensional Scaling may be used as an effective method for characterization of the cultivars and provide useful information for agronomists in recommending the best varieties to producers.

Key words: *Triticum aestivum,* correlations with grain yield, multi-dimensional scaling.

INTRODUCTION

Yield is a complicated character, controlled by multi-genes and environmental effects. Many agronomic traits affect grain yield in bread wheat. Determining such traits and their interactions with grain yield could provide effective selection tools in wheat variety improvement. Nevertheless, the relations desired to exist between agronomic traits and yield show significant variations in different years and/or locations due to environmental effects, thereby complicating the selection process in breeding studies.

Çanakkale, located as a trans-region between the Aegian and Marmara regions, has typical Mediterranean climate characteristics, in which most of the precipitation falls during autumn and winter. Serious water deficits may occur in spring, causing drought stress during anthesis. This means significant decreases in grain yield (Edmeades et al., 1989). Prevailing winds and Çanakkale Strait (Dardanelles) play an important role in climatologic structure of the region. Long term records indicate significant deviations from the average in many years in terms of precipitation and temperature. Thus, determination of wheat varieties with high adaptation capacity to different aerial conditions is highly important for Çanakkale region.

Some statistical tools, such as correlation and path analysis, are used in breeding programs for an effective selection. Path coefficients show the alternate and non-directional effects in correlation values; for this, path analysis is more useful than correlation (Dewey and Lu, 1959). However, one problem in path analysis is multi-collinearity, i.e., high correlation among independent variables. Hair et al. (1995) postulated that multi-collinearity would not pose a problem when variance inflation factor (VIF) value was below 10 or tolerance value was above 0.1 in a data set. Correlation and path coefficients have been widely used in scientific research in most cultivated plants (Puri et al., 1982; Kang et al., 1983; Milligan

Received 11 April 2012; accepted 22 January 2013. First online: 30 January 2013. DII 2067-5720 RAR-181

et al., 1990; Williams et al., 1990; Board et al., 1997; Moghaddam et al., 1998; Samonte et al., 1998). Kumar and Hunshal (1998) observed that characters such as harvest index, total dry matter, fertile tillers, number of grains per spike, and grain weight per spike had important effects on grain yield in durum wheat. Khan et al. (2003) reported that number of tillers per plant and spike length were important traits for grain yield in bread wheat. Mohammed et al. (2006) reported negative correlations of grain yield with days to heading, days to maturity, plant height; while positive correlations with biological yield, and harvest index. Subhani and Chowdry (2000) examined the relations among some plant traits under normal and drought stressed conditions and found that environmental factors affected the correlation and path coefficients among those traits.

Another statistical method, multi-dimensional scaling (MDS) has frequently been used in different disciplines such as social sciences and psychometry (Kruskal and Wish, 1978), market analysis (Groenen and Franses, 2000), and chemistry (Agrofiotis et al., 2001). This analysis makes possible to visualize the relations of cases on one or multiple diagrams. In plant sciences, MDS analysis has been utilized to observe genetic relationships and display the results of molecular marker analysis in different plant species (Curley and Junk, 2004; Martos et al., 2005). MDS may be effectively used for variety characterization using agro-morphological plant traits.

The objectives of this study were to: (i) evaluate associations of grain yield with some plant traits, (ii) determine direct and indirect effects of climate on agronomic traits affecting grain yield, and (iii) characterize the cultivars by MDS.

MATERIAL AND METHODS

Bread wheat cultivars were kindly provided by Field Crops Central Research Institute and the Agricultural Research Institutes of Aegian, Anatolian, Thrace, Blacksea, and Sakarya. Twenty four winter bread wheat cultivars (Alpu 2001, Bezostaja 1, Demir 2000, Dropia, Flamura-85, Gelibolu, Golia, Harmankaya, Kate A1, Murat1, Nina, Pehlivan, Prostor, Sakin, Sana, Saraybosna, Sagittario, Sönmez, Tahirova, Tekirdağ, Tina, Uzunyayla, Yantar, Yıldız), possessing different kernel and plant characteristics, were used in this study.

Field experiments were conducted at Dardanos Research and Application Center of Çanakkale Onsekiz Mart University. Trials were arranged in a randomised complete block design with three replicates. Plot size was 5 m^2 and planting was made using a plot seed drill with a plant density of 550 plants $(m^2)^{-1}$. Planting was made on 06.12.2005 and 05.12.2006 in the first and second growing seasons, respectively. The plots were fertilized with urea in tillering stage to supply 120 kg ha^{-1} nitrogen. Climatologic data for the area are given in table 1.

Table 1. Temperature and rainfall values for Çanakkale in the experimental seasons

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Temperature (°C)												
05-06	14.9	10.5	9.1	3.1	5.6	8.7	13.2	17.7	22.2	24.8	26.4	21.3
06-07	16.2	10.4	7.5	9.4	5.6	10.0	12.8	18.8	24.6	27.0	26.4	21.0
Long term	15.8	11.8	8.3	6.1	6.6	8.0	12.3	17.3	21.9	24.6	24.4	15.8
Rainfall (mm)												
05-06	46.8	218.8	62.9	53.2	84.7	124.0	43.8*	16.7	23.0	8.2	1.2	70.6
06-07	38.0	33.9	25.6	30.2	48.4	151.3	18.1	44.7	35.2	0.0	0.1	5.8
Long term	47.0	86.5	108.9	98.7	71.1	65.0	42.8	29.7	23.7	11.3	7.4	23.4

* Actual rainfall was 3.8 mm. The plots were given 40 mm water due to severe drought conditions.

The agronomic characters measured were plant height (PH), spike weight (SW), spike length (SL), spikelet number spike^{-1} (SNS), grain number spike^{-1} (GNS), grain weight spike^{-1} (GWS), days to heading (DH), test weight (TW), thousand grain weight (TGW) and grain yield (GY). Grain rate per spike (GRS) was computed as grain weight per spike/spike weight to reduce Variance Inflation Factor values of the traits in path model. Spike traits were observed on 10 spikes for each replicate. Days to heading was recorded when at least 50% of the plants in a plot headed.

The variance analysis was made as randomised complete block design model with Proc GLM procedure of SAS (SAS Inst., 1999). Correlation coefficients (Wright, 1921) and path coefficients (Dewey and Lu, 1959) were computed with Proc CORR and Proc REG procedures of SAS, respectively. Tolerance and Variance Inflation Factor (VIF) values were computed as described by Hair et al. (1999) by means of SPSS 9.0 package program. Multidimensional Scaling (MDS) analysis was performed in Classical Multidimensional (CMDS) model for all observed traits in SAS. Metric distance matrix of correlation for genotypes was generated with $d_{ij} = [2(1-r_{ij})]^{(1/2)}$ formula (Mardia et al., 1979). Graphs were generated by Proc GPLOT procedure in SAS.

RESULTS AND DISCUSSION

Results of variance analysis showed that genotype, year and genotype x year terms were significant for most of the observed traits. Year was the most important variation source for the traits except GNS and PH (Table 2). Grain yield had the largest variation, as indicated by coefficient of variation values (data not shown).

Table 2. Mean squares for the observed traits

Source	DF	PH	SL	SNS	GRS	GNS	DH	TW	TGW	GY
Replicate	2	485.3**	0.94	3.90	0.007	7.51	15.76*	6.20*	23.6*	6247
Year (Y)	1	119.7	92.64**	91.52**	0.025*	0.32	556.17**	1952.2**	6120.5**	2009046**
Genotype (G)	23	585.3**	4.18**	4.31**	0.013**	139.3**	68.01**	16.81**	64.0**	17082**
GxY	23	67.1*	0.90*	4.08**	0.009*	94.10**	24.06**	4.46**	14.8**	7432**
Error	94	37.4	0.53	1.73	0.005	40.89	3.96	1.41	5.3	2061

Note: *, **, statistically significant at $p<0.05$, $p<0.01$, respectively.

Correlation analysis showed that GY was significantly correlated with GRS and GNS in the first season; and with GNS and DH in the second season. Correlation coefficients between GY and some traits (e.g., SNS, HD, TGW) showed significant changes across the years. In this study, we were interested especially in the correlations of grain yield with the other traits. Dönmez et al. (2001) revealed that reduced plant height in new wheat genotypes was correlated with higher grain yield. Our results also indicated a negative correlation between the plant height and grain yield; so, shorter genotypes have an advantage in grain yield over tall ones. GRS, one of the most important traits, is correlated with GY positively, but it was significant only in the first year. Many researchers reported GWS as the most closely related variable with grain yield and it was used in selecting for high yielding wheat varieties (Kumbhar et al., 1983). For both years, correlation analysis showed that GNS was highly and positively related to GY, as reported by earlier studies (Dönmez et al., 2001; Okuyama et al., 2004). DH had a strong negative correlation with grain yield in the second year. This result was in agreement with the findings of Ayçiçek and Yıldırım (2006). There was no significant correlation between grain yield and other traits such as TW and TGW in any years. Besides being non-significant, it seemed that TGW had a variable correlation (-0.18 vs. 0.34) with grain yield in different years (Table 3).

Tolerance and VIF values ranged between 0.207-0.629 and 1.591-4.842 for the first year, 0.348-0.778 and 1.286-2.871 for the second year, respectively. This finding indicated that multi-collinearity was not a problem for this data set in path model. Path analysis may provide useful information about some plant traits affecting grain yield, especially informative under unfavourable conditions, by estimating their actual contribution. Results of path analysis suggested that changes in total correlations between the agronomic traits and grain yield were not only caused by the direct effects of those traits, but also by their indirect effects via some other traits (Table 3). Regarding the total correlations and direct effects of observed traits, it seemed that positive direct effects of PH, SL, SNS, and GNS were highly affected by indirect effect of DH in the first year. This case also existed in the second year, but not as strongly as it was in the first year. There were highly positive direct effects of GRS and GNS on grain yield, in the first and second years, respectively. In consideration of correlations among these two traits with grain yield, slight indirect effects via other traits seemed to exist. There were highly negative direct effects of DH on grain yield in both years. Dissecting the total correlation between DH and GY, first year data suggest indirect effects of DH via some other traits, while a negative direct effect of this trait is prominent in the second year. Negative direct effect of TW was masked by indirect effects of some other traits in the second year. As a result, the total correlation value was positive. Total correlation values between TGW and GY were in the same direction with the direct effect of TGW, in both years.

Table 3. Direct (bold) and indirect effects of agronomic traits on grain yield and their correlation

Year	Trait	PH	SL	SNS	GRS	GNS	DH	TW	TGW
2006	PH	**0.029**	0.022	0.011	-0.004	0.002	0.015	0.003	0.009
2007		**-0.200**	-0.094	-0.007	0.029	0.040	-0.021	-0.079	-0.076
2006	SL	0.058	**0.077**	0.052	-0.007	0.020	0.049	-0.011	0.001
2007		0.138	**0.294**	0.125	-0.123	0.041	0.068	-0.030	0.001
2006	SNS	0.126	0.217	**0.323**	0.047	0.158	0.236	-0.116	-0.088
2007		-0.012	-0.142	**-0.334**	-0.030	-0.074	-0.127	0.116	0.130
2006	GRS	-0.089	-0.062	0.094	**0.648**	0.481	0.110	-0.057	-0.090
2007		-0.030	-0.090	0.019	**0.214**	0.019	-0.072	0.037	0.061
2006	GNS	0.014	0.051	0.095	0.144	**0.194**	0.086	-0.004	-0.068
2007		-0.105	0.074	0.117	0.048	**0.530**	0.006	-0.058	-0.147
2006	DH	-0.246	-0.295	-0.339	-0.078	-0.206	**-0.464**	0.129	0.063
2007		-0.052	-0.116	-0.191	0.168	-0.005	**-0.502**	0.278	0.199
2006	TW	0.014	-0.018	-0.044	-0.011	-0.002	-0.034	**0.124**	0.028
2007		-0.066	0.017	0.058	-0.029	0.019	0.093	**-0.169**	-0.088
2006	TGW	-0.010	0.000	0.009	0.005	0.012	0.005	-0.008	**-0.034**
2007		0.097	0.001	-0.100	0.073	-0.071	-0.102	0.135	**0.257**
Total Correlation with Grain Yield									
2006		-0.10	-0.01	0.20	0.74**	0.66**	0.00	0.06	-0.18
2007		-0.23	-0.06	-0.31	0.35	0.50*	-0.66**	0.23	0.34

Note: *, **, statistically significant at P<0.05, P<0.01, respectively.

These results suggested that environmental factors played a major role on the correlation of grain yield with DH, and TW. Due to severe drought stress prior to anthesis in the first year, the trial was irrigated. In the second year, winter season received a limited amount of precipitation. There was also a drought period negatively affecting the plant development during booting. Nevertheless, no irrigation was applied in this year, and these factors resulted in significant reductions in GRS and GY. When winter wheat cultivars were grown under hot and dry conditions, kernel weight was reduced more than kernel number per spike (Al-Khatib and Paulsen, 1990). In our study, GRS (0.74 to 0.35) was more affected than GNS (0.66 to 0.50) under unfavourable conditions (second year), as understood from total correlation and direct effect values of GRS on GY (Table 3). The effects of these traits together with DH play an important role in the occurrence of total correlations between the grain yield and the other observed traits. Earliness was reported as a significant trait for high yielding (Cox et al., 1988). Our findings also pointed out early genotypes had an advantage in that they may get a better use of spring rainfall than late ones do; thus, their heading and grain filling occur in less stressed conditions than others.

Climate is one of the most important environmental factors causing variation for many plant traits, as well as for grain yield across years. In the present study, the existing variation within observed traits could be explained by climatologic effects, especially precipitation. In the first year of the study, total rainfall was 753.9 mm (with +40 mm irrigation) as opposed to 431.3 mm in the second year. Mean temperature of the second year (15.8 °C) was higher than that of the first year (14.7 °C). With higher temperature and lower rainfall, the second year was more stressful than the first year. Prevalence of such unfavourable conditions in the second year caused significant changes in the effects of yield-related traits on grain yield.

On a MDS graph, it is possible to characterize the genotypes in a certain section by calculating the average value of the investigated traits for that particular section (Table 4). Also, correlation values among investigated traits and grain yield allow characterizing genotypes on MDS graphs.

Table 4. Means of investigated characters in dimension sections of MDS graphs

Traits	Year 1				Year 2				Year 1	Year 2
	Sec1	Sec2	Sec3	Sec4	Sec1	Sec2	Sec3	Sec4	Mean	Mean
PH (cm)	85.9	71.9	92.0	73.5	86.4	77.3	93.9	73.5	80.9	82.8
SL (cm)	8.1	7.4	8.5	7.1	9.8	9.5	9.7	8.7	7.8	9.4
SNS (number)	17.4	16.5	17.0	15.5	18.2	18.1	18.4	18.3	16.7	18.2
GRS (ratio)	0.75	0.74	0.69	0.64	0.68	0.70	0.70	0.66	0.71	0.68
GNS (number)	41.8	43.4	38.6	28.5	44.1	39.6	35.5	37.9	39.2	39.3
DH (day)	155.7	153.7	156.8	150.3	148.1	149.8	151.4	152.8	154.4	150.5
TW (g)	82.7	84.1	84.4	82.9	77.3	74.8	77.3	75.9	83.7	76.3
TGW (g)	43.6	42.8	45.9	47.0	31.5	32.4	33.4	28.9	44.6	31.5
GY (kg ha^{-1})	4488	4312	3277	2857	2724	2861	2061	2122	3804	2442

For MDS characterization, graphs could be divided into two main regions for each dimension (positive and negative regions of dimensions) which are section 1-2 and section 3-4 for dimension 1, section 1-3 and section 2-4 for dimension 2 (Figure 1a, 1b). In both years, dimension 1 classified the genotypes in accordance with the traits that significantly correlated with grain yield, whereas dimension 2 did it with respect to the other traits. Considering the total correlation and mean values for the observed traits, it seemed that genotypes with high yield, GRS and GNS grouped in positive section of dimension 1 (i.e., sections 1 and 2) in the first year (Figure 1a). Cultivars located in the positive region of dimension 1 were the ones having higher grain yields than the yearly average of all genotypes. In the graphs the central point of the horizontal plane represents the yearly average of the genotypes. Cultivars such as Pehlivan (G13), Kate A1 (G11), and Nina (G3) located very far away from the central point, so they had the highest grain yield in the first year (Figure 1a). Similarly, Tina (G2), Tekirdağ (G21), Gelibolu (G8) and Nina (G3) were the cultivars with the highest grain yield in the second year (Figure 1b). The graphs may provide information about other traits as well. It appears that late (G22, G12, G1) and early (G2, G3, G8, G21) cultivars were clearly separated into the negative and positive regions of dimension 1 in figure 1b. The second year MDS diagram (Figure 1b) looks more dispersed on vertical plane in comparison with the first year's diagram (Figure 1a). This is due to the fact that days to heading correlated negatively with most of the observed traits for this year (data not shown), and this caused the second dimension to explain some more variation as compared to the first year's diagram.

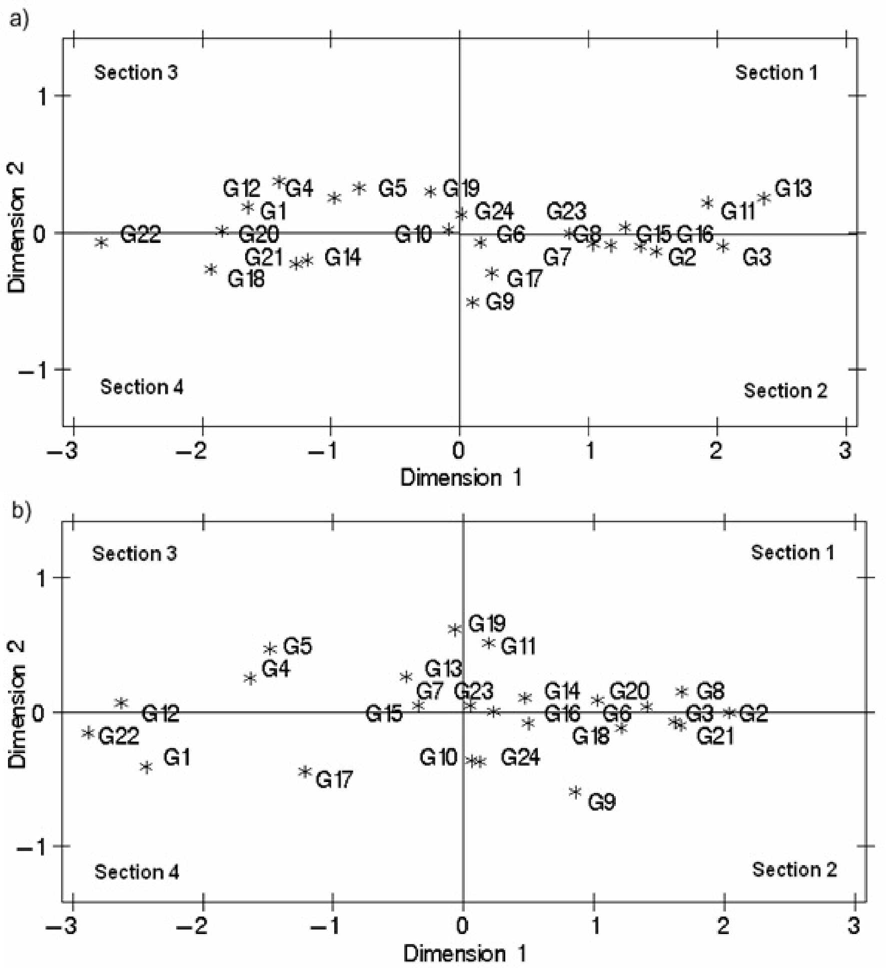

Figure 1. Distribution of the genotypes in the first (a) and second (b) year based on MDS analysis
Genotypes: G1: Alpu 2001, G2: Tina, G3: Nina, G4: Bezostaja, G5: Demir 2000, G6: Dropia, G7: Flamura 85, G8: Gelibolu, G9: Golia, G10: Harmankaya, G11: KateA1, G12: Murat1, G13: Pehlivan, G14: Prostor, G15: Sakin, G16: Sana, G17: Saraybosna, G18: Sagittario, G19: Sönmez, G20: Tahirova, G21: Tekirdağ, G22: Uzunyayla, G23: Yantar, G24: Yıldız 98.

We discussed the graphs and attempted to characterize the genotypes only for grain yield and its correlated components. In the present study, genotypes were not discussed in terms of dimension 2, which explains the variation pertaining to the traits that were not correlated with grain yield. To characterize the genotypes for a certain trait other than grain yield and/or traits closely correlated with it (i.e., GRS, GNS), the correlation coefficients (data not shown) between that particular trait and its related traits must be taken into consideration. When classifying the genotypes, their location on the graph and proximity to the reference lines are important. A genotype may not possess the specialties of the graphical section it was in when it is closely located to the reference line. In MDS diagram, two neighbour points indicate high similarity between them, whereas two distant points indicate dissimilarity or no correlation (Franco et al., 2003). Thus, we could say that neighbour genotypes on MDS diagram had similar performances with respect to the observed traits. The effect of genotype x year interaction resulted in variation in the genotype means across the years, as well as changes in the correlation and path coefficients among the traits. This, in turn, brings about a diverse distribution of the genotypes in figures 1a and 1b.

CONCLUSION

Useful statistical procedures such as correlation, path analysis and multi-dimensional techniques could be used to better interpret complex inter-relationships among plant traits and yield. Correlation or path analysis alone is generally not informative enough to define the relations between yield and other traits. Results of our study suggested that grain rate spike^{-1} and grain number spike^{-1} were highly correlated with grain yield. Days to heading was another trait showing correlation with yield, at least in one year. It is possible to argue that early flowering genotypes could perform better in drought years like the second season of this study, while late cultivars would have disadvantages. Therefore, earliness should be a character deemed when choosing a suitable variety for Çanakkale or similar regions.

REFERENCES

Agrafiotis, D.K., Rassokhin, D.N., Lobanov, V.S., 2001. *Multidimensional scaling and visualization of large molecular similarity tables, Journal of Computational Chemistry.* 22 (5): 488-500. doi: 10.1002/1096-987X(20010415)22:5<488::AID-JCC1020>3.0.CO;2-4.

Al-Khatib, K., Paulsen, G.M., 1990. *Photosynthesis and productivity during high temperature stress of wheat genotypes from major world regions*. Crop Sci., 30: 1127-1132.

Ayçiçek, M., Yıldırım, T., 2006. *Path Coefficient Analysis of Yield and Yield Components in Bread Wheat (Triticum aestivum L.) Genotypes*, Pak. J. Of Botany, 38 (2): 417-424.

Board, J.E., Kang, M.S. and. Harville, B.G., 1997. *Path analyses identify indirect selection criteria for yield of late-planted soybean*. Crop Sci., 37: 879-884.

Cox, T.S., Shroyer, J.P., Ben-Hui, L., Sears, R.G., Martin, T.J., 1988. *Genetic improvement in agronomic traits of hard red winter wheat cultivars from 1919 to 1987.* Crop Sci., 28: 756-760.

Curley, J., Jung, G., 2004. *RAPD based genetic relationships in Kentucky Bluegrass.: Comparison of Cultivars, Interspecific Hybrids and Plant Introductions.* Crop Sci., 44:1299-1306.

Dewey, D.R., Lu, K.H.A, 1959. *Correlation and path-coefficient analysis of components of crested wheatgrass seed production.* Agronomy Journal, Madison, 51 (8): 515-518.

Dönmez, E., Sears, R.G., Shroyer, J.P., Paulsen, G.M., 2001. *Genetic Gain in Yield Attributes of Winter Wheat in the Great Plains.* Crop Sci., 41:1412-1419.

Edmeades, G.O., J. Bolanos, H.R. Lafitte, S. Rajaram, W. Pfeiffer, and R.A. Fisher. 1989. *Traditional approaches to breeding for drought resistance in cereals.*: 27-52. *In:* F.W.G. Baker (ed.) Drought resistance in cereals. ICSU Press and CAB Int., Wall-ingford, UK.

Franco, J., Crossa, J., Taba, S., Shands, H., 2003. *A Multivariate Method for Classifying Cultivars and Studying Group x Environment x trait Interaction.* Crop Sci., 43-1249:1258.

Groenen, P., Franses, P.H., 2000. *Visualizing time-varying correlations across stock markets.* Journal of Empirical Finance, 7: 155-172.

Hair, J.R., Anderson, R.E., Tatham, R.L., Black, W.C., 1995. *Multivariate Data Analysis with Readings.* Prentice Hall, Englewood, NJ.

Kang, M.S., Miller, J.D., Tai, P.Y.P., 1983. *Genetic and phenotypic path analyses and heritability in sugarcane.* Crop Sci., 23: 643-647.

Khan, A.S., Ashfag, M., Azeem, M., 2003. *A Correlation and Path Coefficient Analysis for Some Yield Components in Bread Wheat.* Asian Journal of Plant Science, 2(8): 582-584.

Kruskal, J.B., Wish, M., 1978. *Multidimensional scaling* (Sage Publications).

Kumar, B.N.A., Hunshal, C.S., 1998. *Correlation and path coefficient analysis in durum wheats (Triticum durum Desf.) under different planting dates.* Crop-Research-Hisar., 16(3): 358-361.

Kumbhar, M.B., Larik., A.S., Hafiz, H. M., Rind, M.J., 1983. *Interrelationship of polygenic traits affecting grain yield in Triticum aestivum* L. Wheat Information Service, 57: 42-45.

Mardia, K.V., Kent, J.T., Bibby, J.M., 1979. *Multivariate analysi*s. Academic Press, London.

Martos, V., Royo, C., Rharrabti, Y., Garcia del Moral, L.F., 2005. *Using AFLPs to determine phylogenetic relationships and erosion in durum wheat cultivars released in Italy and Spain throughout the 20th century.* Field Crop Research, 91: 107-116. http://dx.doi.org/ 10.1016/ j.fcr.2004.06.003

Milligan, S.B., Gravois, K.A., Bischoff, K.P., Martin, F.A., 1990. *Crop effects on genetic relationships among sugarcane traits.* Crop Sci., 30: 927-931.

Moghaddam, M., Ehdaie, B., Waines, J.G., 1998. *Genetic variation for interrelationships among agronomic traits in landraces of bread wheat from southwestern Iran.* J. Genet. Breed, 52: 73-81.

Mohammad, T, Haider, S., Amin, M., Khan, M.I., Zamir, R., 2006. *Path Coefficient and Correlation* *studies yield and yield associated traits in candidate bread wheat (Triticum aestivum L.) lines.* Suraneree J. Sci. Technol., 13(2): 175-180.

Okuyama, L.A., Federizzi, L.C., Neto, J.F.B., 2004. *Correlation and path analysis of yield and its components and plant traits in wheat.* Ciencia Rural, 34 (6): 1701-1708. http://dx.doi.org/10.1590/S0103-84782004000600006.

Puri, Y., P. Qualset, C.O., Williams, W.A., 1982. *Evaluation of yield components as selection criteria in barley breeding.* Crop Sci., 22: 927-931.

Samonte, S.O.P.B., Wilson, L.T., McClung, A.M., 1998. *Path analyses of yield and yield-related traits of fifteen diverse rice genotypes.* Crop Sci., 38: 1130-1136.

SAS 1999. *SAS V8 User Manual*. SAS Institute, Cary NC.

Subhani, G.M., Chowdry, M. A., 2000. *Correlation and Path Coefficient Analysis in Bread Wheat under Drought Stress and Normal Conditions.* Pakistan Journal of Biological Sciences, 3(1): 72-77.

Williams, W.A., Jones, M.B., Demment, M.W., 1990. *A concise table for path analysis statistics.* Agron. J., 82: 1022-1024.

Wright, S., 1921. *Correlation and causation.* J. Agric. Res., 1(20): 557-585.