Journal of Agriculture and Sustainability
ISSN 2201-4357
Volume 3, Number 2, 2013, 122-131

Correlation, Path Analysis and Stepwise Regression in Durum Wheat (Triticum Durum Desf.) under Rainfed Conditions

HANNACHI Abderrahmane[1], FELLAHI Zine El Abidine[1], BOUZERZOUR Hamenna[2] and BOUTEKRABT Ammar[3]

[1]National Institute of Agricultural Research (INRAA), Setif Agricultural Research Unit, 19000 (Algeria)
[2]Faculty of Life and Natural Sciences, Ecology and Plant Biology Department, University Ferhat Abbas Setif 1, 19000 (Algeria)
[3]Faculty of Agro-veterinary and Biological Sciences, Agronomy Department, University Saad Dahlab Blida, 09000 (Algeria)

Corresponding author: HANNACHI Abderrahmane, National Institute of Agricultural Research (INRAA), Setif Agricultural Research Unit, 19000 (Algeria).

The present study was carried at the Field Crop Institute-Agricultural Experimental Station of Setif (Algeria) during 2011/12 crop season. Correlation, Path analysis and stepwise regression were executed to investigate the relationships between grain yield and other important yield components in durum wheat (*Triticum durum* Desf.). The experimental material consisted of fifteen hybrids produced using a half diallel fashion in 2010/11 season and theirs six parents. Differences among all the traits were statistically significant. Grain yield per plant was significantly and positively correlated with above ground biomass, straw yield, number of spikes per plant and number of grains per spike. Results of stepwise regression and path analysis revealed that both above ground biomass and harvest index can be a criterion to select high-yielding genotypes in breeding durum wheat programs.
Key words: durum wheat, correlation, path analysis, stepwise regression, grain yield.

Introduction

Durum wheat is one of the most extensively cultivated crops under dryland conditions in the Mediterranean environments (Araus *et al.*, 2002). It is an important source of human nutrition and serves as the raw material of numerous foods such as couscous (North Africa), pasta (Europe) and bulgur (Middle Eastern) in the alimentation of world population. The need and importance of wheat is increasing day by day due to increase in human population. Drought is one of the most important factors which strongly affect the production of wheat in the world and Algeria. Developing plants with suitable advantages under water stress conditions is a basic challenge for wheat improvement programs (Moayedi *et al.*, 2010). Yield of wheat is complex quantitative character that results to the actions and interactions of various component traits (Singh and Diwivedi, 2002). Correlation and path coefficient analysis could be used as an important tool to bring information about appropriate cause and effects relationship between yield and some yield components (Khan *et al.*, 2003). Selections based on simple correlation coefficients without regarding to interactions among yield and yield components may mislead the breeders to reach their main breeding purposes (Garcı´a del Moral *et al.*, 2003). Some researchers reported a positive and significant correlation between plant height and yield (Anwar *et al.*, 2009; Akram *et al.*, 2008); however, Tas and Çelik (2011) in their study reported a negative and no significant correlation between them. In many studies, it has been reported that grain number per spike has a positive effect on yield (Dogan, 2009; Aycicek and Yildirim, 2006). Above ground biomass has been found to have a positive effect on yield (Leilah and Al-Khateeb, 2005). Khan *et al*. (2003) showed significant and positive correlation between grain yield and number of tillers per plant. Correlations themselves express only the degree of traits interrelationships, while path analysis developed by Wright (1921) and applied by Dewey and Lu (1959), is used to separate the correlation coefficients to their direct and indirect effects through other traits. Path analysis procedure was used by number of researchers in wheat. It can provide useful information about affectability form of traits to each other and relationships between them. Mollasadeghi *et al.* (2011) indicated that number of grain per spike, grain weight, 1000 kernel weight and biological yield had the most direct and positive effect on grain yield. In additional, stepwise regression is a method that is used to estimate the value of a quantitative variable regarding its relation with one or some other quantitative variables. This relation is such that it is possible to predict other changes using one variable. Many investigators have used this technique on wheat such as Mohamed (1999), Pržulj and Momcilovic (2011), Soleymanifard *et al.* (2012).

The present study was conducted to establish the inter-relationship and direct and indirect effects of various wheat components among themselves and with yield under rainfed conditions.

Materials and methods

Six durum wheat genotypes (*Triticum durum* Desf.) *viz.*, Waha, Zenati Bouteille/Flamengo, $Mexicali_{75}$, Ofanto, Gaviota durum, and Guemgoum Rkhem were crossed in a diallel mating system without reciprocals according to Griffing (1956), to produce 15 hybrids F_1 during the 2010/2011 crop season. The F_1's and their six parents were grown in the field at the Agricultural Experimental Station (AES) of Setif (Algeria) in the 2011/2012 growing season. Seeds of 15 F_1 along with their self-pollinated parents were sown in a single row, 2.5 m long, per replicate in a randomized complete block design with three replications. Rows were 30 cm apart and seeds were spaced 15 cm on the row. Mineral fertilization and chemical weed control were applied as per the AES recommendations. The following traits were measured: plant height (PH); spikes number per plant (SN); number of grains per spike (NGS); thousand-kernel weight (TKW), harvest index (HI); straw yield, (SY); above ground biomass (BIO) and grain yield (GY). Data, recorded on 05 random plants per replicate, were subjected to analysis of variance (ANOVA) according to Steel and Torrie (1980). Correlation coefficients between each pairs of the traits were computed according to Snedecor and Cochran (1981). In path analysis, grain yield used as dependent variable, and the other studied traits were use as predictor variables. The stepwise regression analysis was also carried out for the data obtained to test the significance of the independent variables affecting the grain yield.

All statistical analyses were down using LazStats software.

Results and Discussion

Analysis of variance

Mean squares due to genotypes were significant for all traits understudy except for above ground biomass, spikes number per plant and grain yield (Table 2) as revealed by ANOVA. This provides evidence for sufficient genetic variability.

Simple correlation analysis

Correlations coefficients between studied traits are presented in Table 3. Grain yield showed positive and significant correlation with above ground biomass (r = 0.81**), straw yield (r = 0.47*), number of spikes per plant (r = 0.88**) and number of grains per spike (r = 0.51*). Our findings were in accordance with the results of Ali and Shakor (2012) and Khan *et al*. (1999), who reported significant and positive correlations between grain yield, biomass yield and straw yield respectively. Previous authors reported similar results between grain yield, spikes number and number of grains per spike (Sharma and Rao, 1989; Singh and Sharma, 1994; Subhani and Khaliq, 1994; Khan *et al*., 1999; Mohammad *et al*., 2002; Aycicek and Yildirim, 2006). On the other hand, harvest index showed negative and significant correlation with plant height (r = - 0.76**), straw yield (r = - 0.63**) and thousand-kernel weight (r = - 0.66**). However, it registered positive and significant correlation with number of grains per spike (r = 0.73**). Other researchers such as Mollasadeghi and Shahryari (2011) reported a negative correlation between harvest index and plant height. The other positive and significant correlations were showed between PH/BIO, PH/SY, PH/TKW, BIO/SY, BIO/SN, SY/SN and SY/TKW (Table 3).

Path analysis

Path coefficient technique was performed to divide the correlation coefficients between grain yield and yield related traits into direct and indirect effects via alternative characters or pathways. Table 4 exhibited that above ground biomass and harvest index exerted positive direct effect on grain yield (1.365*** and 0.235*, respectively), whereas straw yield had a negative direct effect on grain yield (-0.713***). The highest indirect effects on grain yield were observed with straw yield (1.220), spikes number per plant (1.128), plant height (0.647), and thousand-kernel weight (0.463) through above ground biomass and with harvest index via straw yield (0.453). However, plant height, spikes number per plant, number of grains per spike and thousand-kernel weight exerted insignificant effects on grain yield. Similar results were reported by Singh and Diwivedi, (2002) and Leilah and Al-Khateeb (2005) who revealed that biological yield per plant and harvest index had positive and high direct effect on grain yield. Conversely, Baranwal *et al.* (2012) revealed that sheath length followed by grains per spike, spike length and 1000-grain weight exhibited the maximum positive direct effect.

Stepwise regression

Stepwise regression is a semi-automated process of building a model by successively adding or removing variables based solely on the t-statistics of their estimated coefficients. In order to remove effect of non-effective characteristics in regression model on grain yield, stepwise regression was used. Results of stepwise regression (Table 5) showed that the biological yield and harvest index with R square of 98.3%, had justified the maximum of yield changes. Therefore the following equation can be obtained:

$$GY = -26.575 + 0.756^{***} HI + 0.351^{***} BIO$$

With GY: Grain yield, HI: Harvest index and BIO: Above ground biomass.

Existence of significant R square in a successful regression equation indicates the effectiveness of these traits to increase grain yield. Leilah and Al-Khateeb (2005), Ahmadizadeh *et al.* (2011) and Zarei *et al.* (2011) reported importance of Harvest index and above ground biomass to grain yield. However, obtained results were in the opposite of those of Soleymanifard *et al.* (2012), who found that 75% of variation in grain yield is explained by spikes/m^2, 1000 grain weight and Plant height traits. With respect to the positive and significant regression coefficients of biological yield and harvest index, it could be stated that increasing the amount of these traits will cause an increase in the yield. Thus, in this study, two traits, biological yield and harvest index had the most effect on the grain performance in semi arid conditions.

Conclusion

The multiple statistical procedures which have been used in this study showed that above ground biomass and harvest index were the most important yield variables to be considered under drought condition. This was clear with all used statistical procedures (Table 6). Hence, we concluded that above ground biomass and harvest index are good measurement for predicting grain yield. However, we suggest that breeders do not generally select for specific traits to improve yield under drought principally because drought is unpredictable from year to year. These make breeding for drought resistance particularly slow and difficult.

References

[1]. Ahmadizadeh, M., Nori, A., Shahbazi, H. and Aharizad, S. 2011. Correlated response of morpho-physiological traits of grain yield in durum wheat under normal irrigation and drought stress conditions in greenhouse. African Journal of Biotechnology, 10 (85): 19771 - 19779.

[2]. Akram, Z., Ajmal, S. and Munir, M. 2008. Estimation of correlation coefficient among some yield parameters of wheat under rainfed conditions Pakistan J. Bot., 40 (4): 1777 - 1781.

[3]. Ali, I. H. and Shakor, E. F. 2012. Heritability, variability, genetic correlation and path analysis for quantitative traits in durum and bread wheat under dry farming conditions. Mesoptamia J. of Agri., 40 (4): 27 - 39.

[4]. Anwar, J., Ali, M.A., Hussain, M., Sabir, W., Khan, M.A., Zulkiffal, M., Abdullah, M. 2009. Assessment of yield criteria in bread wheat through correlation and path analysis. J. Anim. Plant. Sci., 19 (4): 185 - 188.

[5]. Araus, J.L., Slafer, M.P., Reynolds, M.P. and Royo, C. 2002. Plant breeding and drought in C3 cereals: what should we breed for? Ann Bot 89: 925 - 940.

[6]. Aycicek, M. and Yildirim, T. 2006. Path coefficient analysis of yield and yield components in bread wheat (*Triticum aestivum* L) genotypes. Pak. J. Bot., 38: 417 - 424.

[7]. Baranwal, D. K. Mishra, V. K. Vishwakarma, M.K. Yadav, P.S. and Arun, B. 2012. Studies on genetic variability, correlation and path analysis for yield and yield contributing traits in wheat (*T. aestivum* L. em Thell.). Plant Archives, 12 (1): 99 - 104.

[8]. Dewey DR, Lu KH (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. Agro. J., 9: 515 - 518.

[9]. Dogan, R. 2009. The correlation and path coefficient analysis for yield and some yield components of durum wheat (*Triticum turgidum* var. *durum* L.) in West Anatolia conditions. Pak. J. Bot., 41(3): 1081 - 1089.

[10]. Farshadfar E. (2004). Multivariate principles and procedures of statistics. Taghbostan Pub. Kermanshah, Iran. 734 p.

[11]. Garcia Del Moral, L.F., Y. Rharrabti, D. Villegas and C. Royo. 2003. Evaluation of grain yield and its components in durum wheat under Mediterranean conditions. Agron. J., 95: 266 - 274.

[12]. Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing system. Aus. J. Bio. Sci., 9: 463 - 493.

[13]. Khan, A.S., Ashfaq, M. and Asad, M.A. 2003. A correlation and path coefficient analysis for some yield components in bread wheat. Asian J. of Plant Sci., 2 (8): 582 - 584.

[14]. Khan, H.A., Shaik, M. and Mohammad, S. 1999. Character association and path coefficient analysis of grain yield and yield components in wheat. Crop Research, Hisar, 17 (2): 229 - 233.

[15]. Leilah A.A. and Al-Khateeb S. A., (2005). Statistical analysis of wheat yield under drought conditions, Journal of Arid Environments, 61 (3): 483 - 496.

[16]. Moayedi, A.A., Boyce, A.N. and Barakbah, S.S. 2010. The performance of durum and bread wheat genotypes associated with yield and yield component under different water deficit conditions. Aust. J. Basic Appl. Sci., 4(1): 106 - 113.

[17]. Mohamed, N.A., 1999. Some statistical procedures for evaluation of the relative contribution for yield components in wheat. Zagazig Journal of Agricultural Research, 26 (2): 281 - 290.

[18]. Mohammad, S., Fida, M. and Mohammad, T. 2002. Path coefficient analysis in wheat. Sarhad Journal of Agriculture, 18 (4): 383 - 388.

[19]. Mollasadeghi, V., Imani, A.A., Shahryari, R. and Khayatnezhad, M. 2011. Classifying bread wheat genotypes by multivariable statistical analysis to achieve high yield under after anthesis drought. Middle-East J. Scientific Res., 7 (2): 217 - 220.

[20]. Mollasadeghi, V., Shahryari, R. 2011. Important morphological markers for improvement of yield in bread wheat. Advances Environ. Biol., 5 (3): 538 - 542

[21]. Pržulj, N. and Momcilovic, V. 2011. Characterization of vegetative and grain filling periods of winter wheat by stepwise regression procedure. I. Vegetative period. GENETIKA, 43 (2): 349 - 359.

[22]. Sharma, S.C. and Rao, S.R.G. 1989. Genetic variability, association among metric traits and path coefficient analysis in Triticale. Ann Agric Res. 10 (2): 145 - 152.

[23]. Singh, I. and Sharma, S.K. 1994. Interrelationship of harvest index and other traits in wheat. Hayrana Agricultural University Journal of Research. 24(1): 33 - 38.

[24]. Singh, S.P. and Diwivedi, V.K. 2002. Character association and path analysis in wheat *(Triticum aestivum* L.) Agric. Sci. Digest, 22 (4): 255 - 257.

[25]. Snedecor, G.W. and Cochran, W. G. 1981. Statistical Methods, Iowa State University, Ames, Iowa, USA, 7th edition.

[26]. Soleymanifard, A., Naseri, R. and Meysam, M. 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 (3): 479 - 485.

[27]. Steel, R. G. D. and Torrie, J. 1980. Principles and Procedures of Statistics, A Biometric Approach. McGraw-Hill Book Company, NY. 633p.

[28]. Subhani GM, Khaliq I. 1994. Path coefficient analysis in wheat. Pakistan J Scie Indu Res. 37 (11): 474 - 476.

[29]. Tas, B and Çelik, N. 2011. Determination of seed yield and some yield components through path and correlation analyses in many six-rowed barley (*Hordeum vulgare* conv. *hexastichon).* African Journal of Agricultural Research, 6 (21): 4902 - 4905

[30]. Wright, S. 1921. Correlation and causation. J. agric. Res., 20, 557-585. *In* Paroda and Joshi (1970): correlations, path-coefficients and the implication of discriminant function for selection in wheat (Triticum aestivum). Heredity 25, 383–392

[31]. Zarei, L., Cheghamirza, K. and Farshadfar, E. 2011. Interrelationships of some agronomic characters of durum wheat under supplementary irrigation at grain filling stage conditions. Researches of the first international conference. (Babylon and Razi Universities) 2011, 9. 211-215.

Table 1: Origin and pedigree of durum wheat cultivars used as parental genotypes for the diallel cross.

Cultivar	Origin	Pedigree
1. Waha	Icarda	Plc/Ruff//Gta's/3/Rolette CM.17904
2. Zb/Fg	Cimmyt	Zb/Fg's//Lk/3/Ko120/4/Ward
3. Mexicali75	Cimmyt	Gdo.vz 469/3/Jo's//61.130/ Lds/4/Stk. CM .470
4. Ofanto	Italy	Adamelo /Appulo
5. Gaviota durum enano/	Cimmyt	Crane/4/PolonicumPI185309//Triticum glutinosum 2*Tehuacan60/3/Grulla
6. Guemgoum Rkhem	Algeria	local land race

Table 2: Results of analysis of variance (ANOVA) for studied traits

Source of variation	Mean squares								
	DF	PH	BIO	SY	SN	NGS	TKW	HI	GY
Blocks	2	278.26	3232.0	460.6	47.3	95.18	143.45	19.66	485.59
Genotypes	20	373.32**	1034.0	338.0*	28.0	335.14**	49.26*	81.01**	138.04
Error	40	43.67	603.28	113.0	20.61	85.03	24.82	11.67	89.88

PH: Plant height, BIO: above ground biomass, SY: straw yield, SN: spikes number per plant, NGS: number of grains per spike, TKW: thousand-kernel weight, HI: harvest index and GY: grain yield. * and **: significant at 5% and 1%, respectively.

Table 3: Correlation coefficients between 8 traits.

	PH	BIO	SY	SN	NGS	TKW	HI	GY
PH	1.000	0.474*	0.728 **	0.061	-0.587 **	0.833**	-0.765 **	0.014
BIO		1.000	0.892**	0.826**	0.092	0.339	-0.253	0.817**
SY			1.000	0.588**	-0.231	0.569**	-0.635**	0.478*
SN				1.000	0.389	-0.114	0.149	0.886**
NGS					1.000	-0.623**	0.739**	0.518*
TKW						1.000	-0.667**	-0.059
HI							1.000	0.336
GY								1.000

PH: Plant height, BIO: above ground biomass, SY: straw yield, SN: spikes number per plant, NGS: number of grains per spike, TKW: thousand-kernel weight, HI: harvest index, GY: grain yield. * and **: significant at 5% and 1%, respectively.

Table 4: Partitioning of correlation coefficient analysis direct (diagonal) and indirect effects for mean yield

	PH	BIO	SY	SN	NGS	TKW	HI
PH	**0.061**^{ns}	0.647	-0.519	0.007	-0.046	0.043	-1.180
BIO	0.029	**1.365*** **	-0.636	0.094	0.007	0.018	-0.060
SY	0.044	1.220	**-0.713*** **	0.067	-0.018	0.030	-0.149
SN	0.004	1.128	-0.419	**0.114**^{ns}	0.030	-0.006	0.035
NGS	-0.036	0.126	0.165	0.044	**0.078**^{ns}	-0.032	0.174
TKW	0.051	0.463	-0.406	-0.013	-0.049	**0.052**^{ns}	-0.157
HI	-0.047	-0.345	0.453	0.017	0.058	-0.035	**0.235***

PH: Plant height, BIO: above ground biomass, SY: straw yield, SN: spikes number per plant, NGS: number of grains per spike, TKW: thousand-kernel weight, HI: harvest index and GY: grain yield. ns, * and ***: not significant and significant effects at 5% and 0.1% levels, respectively.

Table 5: Regression coefficient, standard error, *t*-value and probability of the accepted variables by the stepwise procedure to predict grain yield.

Variable	B	SE	t	Prob.>t	VIF
HI	0.756	0.041	18.284	0.000***	1.068
BIO	0.351	0.012	30.379	0.000***	1.068

B: Regression coefficient, SE: Standard error, t: Student *t*-value and Sig: Probability, HI: Harvest index, BIO: Above ground biomass. R^2 = 0.983, Adj R^2 = 0.981 and Constant = -26.575.

Table 6: Durum wheat characteristics identified as crucial in wheat grain yield with each one of the used statistical techniques.

Trait	Simple correlation	Path analysis	Stepwise regression
PH			
BIO	♦	♦	♦
SY	♦	♦	
SN	♦		
NGS	♦		
TKW			
HI		♦	♦

PH: Plant height, BIO: above ground biomass, SY: straw yield, SN: spikes number per plant, NGS: number of grains per spike, TKW: thousand-kernel weight, HI: harvest index.