http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (2): 313-317, 2000

Path Coefficient Analysis for Water Use Efficiency, Evapo-transpiration Efficiency and Some Yield Related Traits in Wheat

Muhammad Aslam Chowdhry, Mohsin Ali, Ghulam Mahboob Subhani[1] and Ihsan Khaliq
Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan
[1]Wheat Research Institute, AARI, Faisalabad, Pakistan

Abstract: Correlation and path-coefficient were computed on 10 bread wheat genotypes for plant height, flag leaf area, grains per spike, 100-grain weight, total dry matter of above ground material, total water used, evapo-transpiration efficiency, harvest index, water use efficiency and grain yield per plant. Highly significant differences were observed among the varieties/advanced lines for all the traits except water use efficiency, which was only significant. Grain yield was positively and significantly correlated with total dry matter, evapo-transpiration efficiency, harvest index and water use efficiency but non-significantly with plant height, flag leaf area, grains per spike, 100-grain weight and total water used. Maximum and positive direct effect (1.2956) was produced by water use efficiency and followed by total dry matter (1.286). While minimum negative direct effect was produced by 100-grain weight (-0.7902). Plant height, flag leaf area, 100-grain weight, total water used, evapo-transpiration efficiency and water use efficiency produced maximum positive indirect effects of 0.5313, 0.3390, 0.6495, 0.6985, 0.7382 and 0.4079 on grain yield through total dry matter, respectively. The traits having positive direct effects on grain yield, considered to be a suitable selection criteria for evolving high yielding genotypes. While in case of negative direct effects on grain yield, indirect selection criteria could be practiced through traits with positive indirect effects.

Key words: Path-coefficient, water use efficiency, wheat

Introduction

Water stress is the most important limitation to wheat *(Triticum aestivum* L. emend. Fion and Paol) productivity in semi-arid regions of the world. Therefore, the development of wheat cultivars that use available water more efficiently and that are able to tolerate drought is a major goal for increasing productivity in drought prone environments. Water use efficiency is considered an important component of adaptation to drought. Considerable research has been done with bread wheat to characterise and evaluate different traits affecting grain yield in drought environments. Plant height, grains per spike and 1000-grain weight *are* positively correlated with grain yield (Akhtar *et al*., 1992; Kumar *et al*., 1986a; Sheoran *et al*., 1986; Yadav and Mishra, 1992). Grain yield was significantly and positively correlated with harvest index (Al-Saheal and Gamil, 1982; Adnan *et al*., 1994). Several studies have shown that grain yield was positively and significantly correlated with biological yield and harvest index (Atale and Zope, 1988; Srivastava *et al*., 1988; Sharma and Rao, 1989). Grain yield and harvest index increased with increase in evapo-transpiration up to certain level and increase in evapo-transpiration decreased water-use-efficiency but increased the harvest index (Aggarwal *et al*., 1986). Singh (1987) observed that water use efficiency decreased with increase in irrigation. Similarly Kumar *et al*. (1986b) found that irrigation increased evapo-transpiration and decreased water use efficiency. While Ehdaie and Waines (1993) recorded a negative correlation was observed between evapo-transpiration and harvest index, whereas there was a positive correlation with plant height. Siddique *et al*. (1990) reported that improved water use efficiency in modern wheat cultivars was associated with higher harvest index.

Materials and Methods

Ten bread wheat varieties/advanced lines were grown in pots under a well-watered treatment during 1998. They included 4 International Maize and Wheat Improvement Centre (CIMMYT) derived varieties grown in Pakistan namely Pak, 81, Kohinoor 83, Faisalabad 85, Pasban 90 and six Pakistani genotypes, viz. LU26S, Inqlab 91, 5039, 4770, 4072 and 4943. Five seeds for each variety were planted in a plastic pot containing a polythene bag filled with 10 kg of sandy loam soil with water holding capacity of 21 percent by weight. Pots were arranged in a completely randomized design with 3 replications in a green house at the University of Agriculture, Faisalabad. Each replication contained one pot of each variety. Each pot was brought to water holding capacity by adding 2100 ml of half-strength Hoagland's solution to the soil on 7 November 1998 when seeds were planted in each pot. Throughout the study, the pots were irrigated with the same solution. Pots were weighed every 3-4 days and the amount of solution equal to the loss in weight was added. Fifteen days after sowing, 4 seedlings were removed from each pot keeping the most vigorous one. At this time, 250 g of medium-sized pebbles were added to the top of each pot to reduce surface evaporation. Plants were irrigated as described until the physiological maturity of the plants. Varieties received different amount of water due to genotypic differences in maturity. Plants were harvested after maturity. Shoots were removed from soil surface. The pots were weighed and the total amount of water used was calculated as the difference between final and initial weight and the amount of water supplied to each pot. Thus, the total water used included both transpired and evaporated water.

Individual analysis of variance (Steel and Torrie, 1980) was conducted for each character. The traits measured were plant height, flag leaf area, grains per spike, 100-grain weight, total dry matter of above ground material, total water used, evapotranspiration efficiency, harvest index, water use efficiency and grain yield per plant. Water use efficiency is defined as the ratio of grain yield to total water used. Total water used includes both transpiration and soil evaporation (evapo-transpiration) water. The two primary components of water use efficiency are evapotranspiration efficiency and harvest index, which are defined as follows:

Evapo-transpiration efficiency = Total dry matter/Total water used
Harvest index = Grain yield/Total dry matter

Thus, Water use efficiency can be expressed as:

Water use efficiency = Evapo-transpiration × efficiency Harvest index
= (Total dry matter /Total water used) (Grain yield/ Total dry matter)
= Grain yield/Total water used

Genetic and phenotypic correlations were worked out according to the method given by Falconer (1981). The direct and indirect effects of each trait were assessed by path analysis according to the method described by Dewey and Lu (1959).

Results and Discussion

Analysis of variance showed highly significant differences among varieties/advanced lines for all the traits except water use efficiency, which were only significant (Table 1).

Variety means ranged from 62.59 to 75.07 cm for plant height and from 10.47 to 17.61 g for total dry matter (Table 2). Varieties Pak.81 and Kohinoor 83 (International Maize and Wheat Improvement Centre-derived varieties) showed the highest values while genotypes 4770 and 5039 showed lowest means for plant height and total dry matter, respectively. In general International Maize and Wheat Improvement Centre-derived varieties were intermediate for both traits. In case of flag leaf area mean values ranged from 14.06 to 25.63 cm^2 for Kohinoor 83 and genotype 4943, respectively (Table 2). Highest number of grains was produced by the genotype 4770 closely followed by 4943. Lowest number of grains was produced by LU26S. In case of 100-grain weight variety LU26S and 4770 gave the maximum weight of 4.68 and 4.51 g, respectively. It is obvious from Table 2 that 4943 has the highest values of 6.93 kg, 2.096 g/kg and 8.36 g for total water used, water use efficiency and grain yield, respectively. It means genotype 4943 used maximum water and better water use efficiency ultimately gave the highest yield. But Pasban 90 and LU26S used less water and did not use the water efficiently thus giving low yield. Maximum evapo-transpiration efficiency was noted for 4770. It was followed by 4943 and Faisalabad 85. The highest value of harvest index was recorded by variety Pak.81 followed by genotype 4072. The genotype 4770 showed the minimum value for harvest index.

The genotypic and phenotypic correlations coefficients are presented in Table 3. The correlations between plant height and flag leaf area, 100-grain weight, total dry matter, total water used, evapo-transpiration efficiency, harvest index and grain yield were found to be positive but non-significant at genotypic and phenotypic levels (Akhtar *et al*., 1992). The association between plant height and grains per spike was recorded to be negative. Hence, the lesser the plant height the more the number of grains, it produces. Similarly this trait was negatively and non-significantly correlated with water use efficiency.

A non-significant and negative correlation was observed between flag leaf area and grains per spike, 100-grain weight and harvest index. Flag leaf area was positively and non-significantly associated with total dry matter, total water used, evapo-transpiration efficiency, water use efficiency and grain yield. Flag leaf area is an essential component for better plant growth and productivity as it determines the photosynthetic capacity of plant which ultimately influences final productivity the grain yield (Akhtar *et al*., 1992). The correlation between grains per spike and 100-grain weight was found to be negative and non-significant. This confirms that more grains per spike lower the 100-grain weight probably due to reduction in the size of grains due to assimilation of available photosynthates to larger number of grains. There was a positive and non-significant association between grains per spike and total dry matter, total water used and grain yield, While positive and significant correlation was observed between grains per spike and water use efficiency (Atale and Zope, 1988; Yadav and Mishra, 1992).

There was a positive and significant correlation between 100-grain weight and total dry matter. Whereas 100-grain weight was positively and non-significantly associated with total water used, evapo-transpiration efficiency, harvest index, water use efficiency and grain yield. Total dry matter was positively and significantly correlated with total water used. This is due to more green surface area associated with higher biomass. Similarly positive and significant correlation was observed between total dry matter and evapo-transpiration efficiency. Henca higher evapo-transpiration efficiency results in the production of more biomass (Ehdaie and Waines, 1993). Total dry matter and water use efficiency, harvest index were positively and non-significantly correlated. Total dry matter includes straw yield and grain yield while water use efficiency is grain yield obtained per unit of water consumed. Hence efficient water users produce more grain yield which augments the total dry matter (Ehdaie and Waines, 1993). The association between total dry matter and grain yield was recorded as positive and significant (Atale and Zope, 1988; Srivastava *et al*. 1988; Sharma and Rao, 1989). Higher total dry matter contributed to grain yield positively and vice versa. Correlations between total water used and evapo-transpiration efficiency, harvest index, water use efficiency, grain yield were positive and non-significant. A negative and non-significant correlation was observed between evapotranspiration efficiency and harvest index. It means that an increase in evapo-transpiration efficiency will decrease harvest index and vice versa. These results confirm the earlier findings of Ehdaie and Waines (1993) but are in contradiction with those of Aggarwal *et al*. (1986) who observed increase in harvest index with increase in evapo-transpiration efficiency. Evapo-transpiration efficiency and water use efficiency was positively correlated which indicates that plants which transpire more water are more efficient users of water (Aggarwal *et al*., 1986; Kumar *et al*., 1986a; Ehdaie and Waines, 1993). Evapo-transpiration efficiency and grain yield were positively and significantly correlated. Hence it is apparent that evapotranspiration efficiency could be used as selection criterion for improved grain yield (Aggarwal *et al*., 1986; Ehdaie and Waines, 1993).

A review of Table 3 reveals that a positive correlation was observed between harvest index and water use efficiency. Harvest index and grain yield were found to be positively and significantly associated with each other (Al-Saheal and Gamil, 1982; Sharma and Rao, 1989; Adnan *et al*., 1994). Higher the harvest index, the higher will be the grain yield and vice versa. High harvest index would be desirable for better conversion of biomass into grain (Ehdaie and Waines, 1993). There was a positive and significant correlation between water use efficiency and grain yield. Hence this desirable positive association is of prime importance in drought tolerance breeding programme (Ehdaie and Waines, 1993).

The direct and indirect effects of various traits are presented in Table 4. Plant height and grain yield was recorded to be positively correlated. The direct effects of plant height on grain yield were also positive. Kumar *et al*. (1986a) confirms these findings. The major indirect positive contributors to grain yield were total dry matter (0.5313), grains per spike (0.3798) and total water used (0.1179). The traits with negative indirect contribution to grain yield were through flag leaf area (-0.1737), 100-grain weight (-0,2181), evapo-transpiration efficiency (-0.3130), harvest index (-0.0775) and water use efficiency (-0.2581).

The genotypic correlation between flag leaf area and grain yield was recorded to be positive, although the direct effect of

Table 1: Analysis of variance for plant height, flag leaf area, grains per spike, 100-grain weight, total dry matter, total water used, evapo-transpiration efficiency, harvest index, water use efficiency and grain yield of single plant of wheat varieties grown in pot experiment

Source	df	Mean squares									
		Plant Height	Flag leaf area	Grains per Spike	100-grain weight	Total dry matter	Total water used	Evapo-transpiration efficiency	Harvest index	Water use efficiency	Grain yield
Varieties	9	52.26**	6.38**	188.15**	0.85**	17.97**	2.63**	0.413**	0.043**	0.32**	3.78**
Error	20	5.092	0.368	19.188	0.030	0.899	0.083	0.011	0.038	0.038	0.275

***Significant at $p<0.05$ and 0.01, respectively

Table 2: Mean values of plant height, flag leaf area, grains per pike, 100-grain weight, total dry matter, total water used, evapo-transpiration efficiency, harvest index, water use efficiency and grain yield of single plant of wheat varieties grown in cot experiment

Varieties/ advance lines	Plant Height (cm)	Flag leaf area (cm^2)	Grains per spike	100-grain weight (G)	Total dry matter (a)	Total water used (Kg)	Evapo-transpiration efficiency (g/Kg)	Harvest index	Water use eficiency (g/kg)	Grain yield (g)
Pak 81	75.07a	22.49c	57.99b	3.51e	12.11ef	5.30c	1.95b	0.832a	1.783ab	7.59abc
Incilab 91	73.58ab	17.98e	51.33bcd	3.03e	11.43f	4.79de	1.85bc	0.627def	1.539bc	5.92de
4072	70.70bc	20.33d	55.22bc	3.68cd	16.60ab	6.61a	1.67c	0.820ab	1.770bc	6.70cd
Faisalabad 85	67.51cd	23.76b	52.92bcd	3.47d	13.93cd	5.87b	2.14a	0.711bcd	1.932ab	5.99de
4943	66.20de	25.63a	66.24a	3.89bc	13.22de	6.93a	2.23a	0.753abc	2.096a	8.36a
Pasban 90	65.83de	14.50fg	47.33cd	3.82bc	11.72ef	4.03f	1.45d	0.586efg	1.074d	5.53e
Kohinoor 83	65.70de	14.06g	46.41d	4.02b	17.61a	5.20cd	1.73c	0.689cde	1.428c	7.20bc
LU26S	64.81de	15.48f	45.09d	4.68a	11.20f	4.60e	1.14e	0.572efg	1.389cd	5.15e
5039	63.85de	15.04fg	46.41d	3.58cd	10.47f	4.71de	1.46d	0.517fg	1.444bc	5.79de
4770	62.59de	25.25a	66.33a	4.51a	15.37bc	6.07b	2.26a	0.484g	2.012a	8.07ab

Within columns means followed by the same letter are not significantly different at p = 0.05 probability level using LSD test

Table 3: Estimates of genotypic and phenotypic correlations among plant height, flag leaf area, grains per spike, efficiency, harvest index, water use efficiency and grain yield of single plant of wheat varieties grown 100-grain weight, total dry matter, total water used, evapo-transpiration in pot experiment

Traits		Flag leaf area	Grains per spike	100-grain weight	Total dry matter	Total water used	Evapo-transpiration efficiency	Harves index	Water use eficiency	Grain yield
Plant height	r_g	0.303	-0.500	0.276	0.413	0.365	0.422	0.286	-0.199	0.450
	r_p	0.298	-0.450	0.216	0.358	0.358	0.417	0.320	-0.181	0.367
Flag leaf area	r_g		-0.031	-0.281	0.264	0.122	0.137	-0.246	0.215	0.435
	r_p		-0.033	-0.275	0.219	0.105	0.121	-0.225	0.201	0.418
Grains per spike	r_g			-0.367	0.312	0.113	-0.124	-0.232	0.547*	0.617
	r_p			-0.342	0.309	0.101	-0.110	-0.224	0.535*	0.608
100-grain weight	r_g				0.505*	0.297	0.154	0.404	0.241	0.611
	r_p				0.497*	0.217	0.146	0.243	0.237	0.462
Total dry matter	r_g					0.543*	0.574*	0.203	0.317	0.795*
	r_p					0.503*	0.562*	-0.240	0.301	0.698*
Total water used	r_g						0.436	0.492	0.214	0.619
	r_p						0.428	0.481	0.204	0.599
Evapo-transpiration	r_g							-0.396	0.275	0.688*
efficiency	r_p							-0.355	0.257	0.654*
Harvest index	r_g								0.187	0.814*
	r_p								0.171	0.633*
Water use efficiency	r_g									0.697*
	r_p									0.644*

*Significant at 0.05 level of probability

Table 4: Direct and indirect effects of plant height, flag leaf area, grains per spike, 100-grain weight, total dry matter, total water used, evapo-transpiration efficiency, harvest index, water use efficiency and grain yield of single plant of wheat genotypes grown in pot experiment

	Plant Height	Flag leaf area	Grain per spike	100-grain weight	Total dry matter	Total water used	Evapo-transpiration efficiency	Harvest index	Water use efficiency	Grain yield
Plant height	(0.4614)	-0.1737	0.3798	-0.2181	0.5313	0.1179	-0.3130	-0.0775	-0.2581	0.450
Flag leaf area	0.1400	(-0.5724)	0.0236	0.2223	0.3390	0.0394	-0.1016	0.0668	0.2782	0.4351
Grain per spike	-0.2305	0.0177	(-0.7604)	0.2900	0.4008	0.0365	0.0918	0.0629	0.7083	0.6172
100-grain weight	0.1273	0.1610	0.2791	(-0.7902)	0.6495	0.0961	-0.1146	-0.1094	0.3126	0.6114
Total dry matter	0.1907	-0.1509	-0.2370	-0.3991	(1.2856)	0.1755	-0.4263	-0.557	0.411	0.7947
Total water used	0.1684	-0.0698	-0.0859	-0.2350	0.6985	(0.3231)	-0.3240	-0.1333	0.2776	0.6197
Evapo-transpiration efficiency	0.1945	-0.0784	0.0941	-0.1219	0.7382	0.141	(-0.7425)	0.1073	0.3556	0.6879
Harvest index	0.1320	0.1410	0.1763	-0.3189	0.2607	0.1589	0.2938	(-0.2711)	0.2418	0.8143
Water use efficiency	-0.0919	-0.1229	-0.4157	-0.1907	0.4079	0.0692	-0.2038	-0.0506	(1.2956)	0.6971

flag leaf area on grain yield was negative. The positive indirect effects were noted through total dry matter (0.3390), water use efficiency (0.2782), 100-grain weight (0.2223), plant height (0.140), harvest index (0.0668) and grains/spike (0.0236). Evapotranspiration efficiency contributed negative indirect effect on grain yield through flag leaf area (-0.1016). Due to the negative direct effect and positive correlation between flag leaf area and grain yield, the indirect selection can be made for high yielding wheat genotypes through most of the traits having positive indirect effects.

The correlation between grains per spike and grain yield was found to be positive, whereas the direct effect of grains per spike was recorded to be negative (Kumar *et al.,* 1986a). Only plant height had negative indirect effect on grain yield with grains per spike. Water use efficiency and total dry matter contributed the maximum positive indirect effects 0.7083 and 0.4008, respectively. Due to the negative direct effect of grains per spike on grain yield, indirect selection should be made *via* traits having positive indirect effects.

The genotypic correlation between 100-grain weight and grain yield was also positive. Although negative direct effects (-0.7902) be produced by 100-grain weight (Kumar *et al.*,1986a). Maximum positive indirect effect was contributed by total dry matter followed by water use efficiency.

The positive and significant correlation was found between total dry matter and grain yield. Positive direct effect was also recorded by total dry matter on grain yield (Atale and Zope, 1988; Srivastava *et al.,* 1988). Water use efficiency had maximum indirect effect followed by plant height. Most of the traits have negative indirect effect on grain yield. Due to positive direct effect of total dry matter on grain yield and positive and significant correlation between these two traits, it Was considered suitable selection criterion for evolving high yielding wheat varieties.

The correlation between total water used and grain yield was found to be positive. This trait had also a positive direct effect on grain yield. Maximum indirect effect was produced by total dry matter and followed by water use efficiency. Most of the traits have negative indirect effects. The association between evapotranspiration efficiency and grain yield was noted to be positive and significant but direct effect of evapo-transpiration efficiency was negative on grain yield. Positive indirect effects, ie 0.7382, 0.3556, 0.1945, 0.141, 0.1073 and 0.0941 were contributed by total dry matter, water use efficiency, plant height, total water used, harvest index and grains per spike, respectively. Therefore, indirect selection could be practiced to evolve high yielding wheat genotypes through those traits having positive indirect effects.

There was a positive and significant relationship between harvest index and grain yield but direct effect of harvest index on grain yield was found to be negative. Maximum indirect effect was produced through evapo-transpiration efficiency and followed by total dry matter. The correlation was found to be positive and significant between water use efficiency and grain yield. The positive direct effect was also found for water use efficiency, maximum positive indirect effect was noted for total dry matter and followed by total water used. The water use efficiency has a positive direct effect on grain yield and a significant correlation existed between these two traits.

It is concluded that dwarf and semi dwarf varieties are more efficient users of available water than tall ones. It is also concluded that those genotypes, which use more water, give greater harvest index value and produce more grain yields. These important points should be given due consideration while selection is made for drought resistance where efficient use of limited available water is a prerequisite. Due to the positive direct effect of total dry matter on grain yield and positive and significant correlation between these

two traits, it was considered suitable selection criterion for evolving high yielding wheat varieties.

References

Adnan, M., M.A. Chowdhry and T. Mahmood, 1994. Association of flag leaf area and spike characteristics with grain yield in *Aestivum* spp. Pak. J. Agric. Sci., 31: 51-53.

Aggarwal, P.K., A.K. Singh, G.S. Chaturvedi and S.K. Sinha, 1986. Performance of wheat and triticale cultivars in a variable soil-water environment II. Evapotranspiration, water use efficiency, harvest index and grain yield. Field Crops Res., 13: 301-315.

Akhtar, M., K. Alam and M.A. Chowdhry, 1992. Genotypic and phenotypic correlation studies of yield and other morphological characters in *Triticum aestivum* L. J. Agric. Res., 30: 301-305.

Al-Saheal, Y.A. and K.H. Gamil, 1982. Induced mutation of Saudi Arabian local variety of bread wheat. I. Yield and yield components. Wheat Inform. Ser., 54: 20-26.

Atale, S.B. and W.N. Zope, 1988. Evaluation of yield components under low fertility rainfed and high fertility irrigated conditions in aestivum wheat. Ann. Plant Physiol., 2: 22-29.

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

Ehdaie, B. and J.G. Waines, 1993. Variation in water-use efficiency and its components in wheat: I. Well-watered pot experiment. Crop Sci., 33: 294-299.

Falconer, D.S., 1981. Introduction to Quantitative Genetics. 2nd Edn., John Wiley and Sons, Inc., New York, USA.

Kumar, D., S.C. Sharma and S.C. Gupta, 1986a. Correlation and path studies in wheat under normal and saline conditions. Wheat Inform. Serv., 61: 64-67.

Kumar, A., S.D. Dhiman and S.K. Yadav, 1986b. Studies on evapo-transpiration, water use efficiency and moisture extraction pattern by wheat genotypes in irrigated and unirrigated conditions. Indian J. Agron., 31: 11-15.

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

Sheoran, I.S., O.P. Luthra and M.S. Kuhad, 1986. Association of physiological and biochemical characters with the yield of rainfed wheat. Indian J. Agric. Sci., 56: 71-74.

Siddique, K.H.M., D. Tennant, M.W. Perry and R.K. Belford, 1990. Water use and water use efficiency of old and modern wheat cultivars in a Mediterranean-type environment. Aust. J. Agric. Res., 41: 431-447.

Singh, B.N., 1987. Yield and water-use efficiency of bread-wheat under varying levels of irrigation and nitrogen in humid subtropical hills of Meghalaya. Indian J. Agric. Sci., 57: 245-250.

Srivastava, R.B., V.P. Singh and D. Singh, 1988. Component characters of grain yield and harvest index in wheat. Indian J. Agric. Res., 22: 65-74.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometral Approach. McGraw-Hill Book Company, New York.

Yadav, R.K. and R.K. Mishra, 1992. Variability and correlation in F_2 population of wheat. Crop Res., 5: 298-301