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Heritability of Morphological Traits in Bread Wheat Advanced Lines Under Irrigated and Non-Irrigated Conditions

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Abstract: Current research was conducted with aim to identify the characters of utmost importance in irrigated and non-irrigated conditions that may be used as selection criteria in a wheat breeding program. The experimental material consisted of 13 wheat genotypes including 11 bread wheat advanced lines from two different sources, 1 synthetic hexaploid and its durum parent. Stress was imposed by withholding irrigation at three different growth stages of plant i.e. tillering, anthesis and grain filling. Experiment was carried out in a randomized complete block in a split-plot arrangement. Water regimes (irrigated and non-irrigated) were allocated to the main plots and genotypes to the sub-plots. Morphological traits were recorded including days to heading, flowering, anthesis, physiological maturity, grain-filling period, flag leaf area, plant height, biomass, number of spikes, number of spikelets per spike, spike length, number of grains, grain yield, harvest index and 1000-grain weight. According to obtained results heritability among the traits under irrigated and non-irrigated conditions was estimated. Spike length exhibited highest heritability value of 0.89, 0.84 and 0.87 under irrigated, tillering and grain filling stress whereas grain yield had highest heritability value of 0.76 under anthesis stress. These traits therefore deserve more attention in future breeding programs for evolving better wheat for stress environments.

Key words: Heritability, irrigated, morphological traits, non-irrigated, wheat

INTRODUCTION

Wheat is the largest grain crop in the world. It provides food to 36% of the global population, and contributes 20% of food calories. With progressive global climatic change and increasing shortage of water resources and worsening eco-environment, wheat production is influenced greatly (Singh and Chaudhary, 2006). Yield and its component traits are controlled by polygenes, whose expression is greatly affected by environments (Ahmed *et al*., 2007). Since yield is a complex trait and is strongly influenced by the environment, severe losses can be caused by drought, a stress common in most arid and semi arid areas. Accordingly, drought tolerance is one of the main components of yield stability and its improvement is a major challenge to geneticists and breeders (Eid, 2009).

Heritability, a measure of the phenotypic variance attributable to genetic causes, has predictive function of breeding crops (Songsri *et al*., 2008). It provides an estimate of the genetic advance a breeder can expect from selection applied to a population under certain environment. The higher the heritability estimates, the simpler are the selection procedures (Khan *et al*., 2008). High genetic advance coupled with high heritability estimates offers the most effective selection criteria for selection (Larik *et al*., 2000). The magnitude of genetic inheritance and expected genetic advance are important for the prediction of response to selection in diverse environments and provide the basis for planning and evaluating breeding programs (Ahmad *et al*., 2006, 2007). High heritability alone is not enough to make sufficient improvement through selection generally in advance generations unless accompanied by substantial amount of genetic advance (Bhargava *et al*., 2003). The utility of heritability therefore increases when it is used to calculate genetic advance, which indicates the degree of gain in a character obtained under a particular selection pressure. Thus, genetic advance is yet another important selection parameter that aids breeder in a selection program (Shukla *et al*., 2004). Phenotypic and genotypic variance, heritability and genetic advance have been used to assess the magnitude of variance in wheat breeding material (Bhutta, 2006). The main aim was to identify the traits which can be used as selection markers under irrigated and non-irrigated conditions.

MATERIALS AND METHODS

All the genotypes were grown in the screen house of Genetics department, University of Karachi. Data was recorded for the year 2006-2007. Experiment was carried out in a randomized complete block in a split plot arrangement. Water regimes (irrigated and non-irrigated)

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were allocated to the main plots and genotypes to the sub-plots. The experiments were conducted using earthen/ceramics pots (40cm×40cm) filled with sandy loam soil and manure. Germplasm comprised of eleven advanced wheat lines, one synthetic hexaploid and their durum parent which were provided by CIMMYT, Mexico and NARC, Islamabad, Pakistan. Water stress imposed by withholding irrigation, were as follows: Control plants were watered regularly and never allowed to dry out whereas tillering stress was imposed at 38 days after sowing and continued till 47 days after sowing or completion of tillering. Stress was also imposed before anthesis began in each genotype (avoiding spikes with any sheded pollens), with subsequent irrigations at intervals of fifteen days till harvesting and was named as anthesis stress. Grain-filling stress was imposed after anthesis and continued till harvesting. Plants were watered at fifteen days intervals during this period.

Climatic conditions: Weather data were recorded regularly during growing seasons. During Nov 2006-April, 2007 mean temperature was 18.0-30.50ºC with humidity 54.45% throughout the growing season. Moveable plastic sheet cover was used for protecting the plants from rain. Total rainfall recorded during the growing season was provided by Pakistan Meteorological Department, Karachi, Pakistan.

Morphological data: Data were recorded for days to heading, flowering, anthesis, maturity, grain filling period, flag leaf area, plant height, biomass, spike numbers, spikelet numbers, spike length, number of grains per spike, grain yield, harvest index and 1000-grain weight at different timing of growth stages under different water stress levels.

Statistical analysis: Broad sense heritability (h^2_B) (Falconer and Mackay 1996), genetic advance under selection (GA) (Allard, 1960) were estimated by partitioning the variance in plant traits into between accessions and within accessions components and applying these in the following function.

$$h^2_B = Vg / Vp$$

where,

- *Vg* genetic variance = (variance between-accessions-variance within accessions)/*n*
- *Vp* phenotypic variance = [(variance between-accessions-variance within accessions)/*n*] + variance within-accessions
- *n* number of replications per treatment

$$\text{Genetic Advance (GA)} = K \times (Vp)^{0.5} \times h^2_B$$

where,

K = selection intensity at 5% (2.06)
Vp = phenotypic variance
h^2_B = heritability (broad sense)

$$\text{Phenotypic Coefficient of Variation (PCV)} = \frac{\text{Phenotypic Variance } (Vp)}{\text{Mean value of the trait}} \times 100$$

$$\text{Genotypic Coefficient of Variation (GCV)} = \frac{\text{Genotypic Variance } (Vg)}{\text{Mean value of the trait}} \times 100$$

RESULTS AND DISCUSSION

Analysis of variance of some morphological traits in thirteen bread wheat advanced lines used in this study is presented in Table 1. Broad sense heritability, Genetic Advance under selection (GA), Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) are shown in Table 2.

The efficiency of selection from a population for a particular trait depends largely upon the genetic and non-genetic factors affecting the expression of phenotypic differences among genotypes in the population. Heritability, thus, is a significant parameter for the selection of an efficient population improvement method. Single plant selection in the earlier generations may be much effective for a character that is highly heritable as compared to that character which is less heritable. Further more, environment may also interact with the genotypic constitution to influence heritability (Riaz, 2003).

In irrigated condition, high heritability was estimated for days to heading (0.95) and the expected genetic gain upon selecting the best 5% for days to heading was 52.33. Moderate (Fida *et al*., 2001) and high (Asif *et al*., 2004; Mohsin *et al*., 2009) values for heritability related to time to heading were obtained in the studies that were conducted previously. These findings suggest that selection can be practiced for this character in subsequent generations. Days to heading showed high heritability (0.97) coupled with high genetic advance of 59.58 under tillering stress. Genotypic and phenotypic coefficients of variation were nearly equal. This indicated that all the variation present in the genotypes for days to heading may be genetic in nature. These results are in accordance with the earlier findings (Mahmood and Chowdhry, 1999; Riaz, 2003). However high heritability accompanied by low genetic advance for days to heading under drought stress has been recorded by Eid (2009).

High heritability (broad sense) estimates 0.95 with genetic advance of 52.35 were obtained for days to flowering under control condition. High heritability with low genetic advance for days to flowering has been achieved by Mohsin *et al*. (2009). Genotypic and

Table 1: Mean squares for some morphological traits of bread wheat advanced lines under irrigated and non-irrigated conditions

Sources of Variation	d.f	days to flowering	d.f	physiological maturity	flag leaf area	plant height	number of spikes	spike length	number of spikelets $spike^{-1}$	number of grains	grain yield	Harvest index	1000-grain weight
Treatments (T)	1	13.65	3	95.31	1081.57	3476.60	36.90***	52.14	134.86	63277.72**	108.94***	17785.55***	7150.37***
Error (a)	1	12.52	3	16.45	160.64	490.96	1.35	16.68	14.48	2611.17	3.59	281.21	310.86
Genotypes (G)	12	2633.46***	12	4998.55***	989.94***	318.63	5.93***	107.09***	120.72**	8253.82***	5.21***	1355.50***	489.36***
G ´ T	12	43.16	36	138.747	171.89	258.95	2.54***	10.84	16.48	4304.75**	4.26***	363.85	135.31
Error (b)	24	62.66	48	87.197	127.66	385.38	1.30	9.66	21.47	1561.16	1.71	374.40	139.63

* and ** significant at 5% and 1% level of probability, respectively

Table 2: Estimates of broad sense heritability, genetic advance, phenotypic and genotypic coefficients of variation for agronomic traits in bread wheat advanced lines under irrigated and non-irrigated conditions

Agronomic traits	Treatments	h^2	GA	PCV (%)	GCV (%)
Days to heading	Control	0.95	52.33	35.84	35.04
	Tillering	0.97	59.58	39.98	39.48
Days to flowering	Control	0.95	52.35	34.66	33.94
	Tillering	0.97	58.84	38.22	37.75
Days to anthesis	Control	0.95	49.27	31.29	30.65
	Tillering	0.97	53.82	33.41	32.97
	Anthesis	0.97	63.61	39.29	38.82
Physiological maturity	Control	0.95	55.01	27.35	26.72
	Tillering	0.96	47.42	23.33	22.92
	Anthesis	0.97	58.30	28.49	28.08
	Grain filling	0.98	54.56	26.70	26.45
Grain filling period	Control	0.77	15.94	44.95	39.65
	Tillering	0.77	19.06	52.89	46.49
	Anthesis	0.72	15.81	49.98	42.68
	Grain filling	0.79	14.41	43.15	38.35
Flag leaf area	Control	0.83	22.61	61.31	56.16
	Tillering	0.86	33.00	108.24	100.63
	Anthesis	0.65	17.59	65.65	53.03
	Grain filling	0.81	24.22	80.20	72.54
Plant height	Control	0.65	16.14	16.72	13.55
	Tillering	0.55	14.91	21.23	15.86
	Anthesis	0.28	8.96	23.97	12.86
	Grain filling	0.49	13.08	20.34	14.24
Number of spikes	Control	0.74	3.20	92.31	79.55
	Tillering	0.55	0.88	58.96	43.90
	Anthesis	0.76	2.25	97.44	85.19
	Grain filling	0.57	0.90	60.08	45.55
Spike length	Control	0.89	6.82	36.82	34.83
	Tillering	0.84	6.13	38.42	35.38
	Anthesis	0.53	5.90	55.30	40.57
	Grain filling	0.87	7.79	48.19	45.12
Number of spikelets	Control	0.78	7.03	28.81	25.54
	Tillering	0.74	7.76	37.14	31.98
	Anthesis	0.62	6.42	35.28	27.99
	Grain filling	0.75	8.41	41.02	35.60
Biomass	Control	0.78	10.25	104.99	93.17
	Tillering	0.40	1.27	49.18	31.42
	Anthesis	0.67	5.99	108.92	89.70
	Grain filling	0.66	43.43	65.96	53.90
Number of grains	Control	0.78	134.14	114.11	101.41
	Tillering	0.58	27.28	65.41	49.85
	Anthesis	0.72	83.94	132.72	112.69
	Grain filling	0.69	43.41	88.24	73.63
Grain yield	Control	0.73	3.86	106.68	91.56
	Tillering	0.52	0.77	67.40	48.99
	Anthesis	0.76	2.47	163.00	142.47
	Grain filling	0.49	0.54	77.91	54.61
1000-grain weight	Control	0.58	12.47	30.05	23.06
	Tillering	0.70	19.93	35.37	42.27
	Anthesis	0.64	14.24	49.48	52.98
	Grain filling	0.68	17.39	56.37	46.74
Harvest index	Control	0.55	25.75	54.64	40.69
	Tillering	0.54	23.84	60.79	44.67
	Anthesis	0.60	23.38	82.39	63.89
	Grain filling	0.79	23.29	73.14	65.05

Abbreviation: h^2 = heritability; GA = Genetic Advance; PCV = Phenotypic Coefficient of Variation; GCV = Genotypic Coefficient of Variation phenotypic coefficients of variation were closer indicating that variation present in the genotypes could be because of genetic influence. A similar result was found under tillering stress (Table 2).

Under non-stressed, tillering and anthesis stress, heritability estimate and genetic advance were high for days to anthesis (0.95, 0.97 and 0.97). Almost similar values of phenotypic and genotypic coefficients of variability reflects greater role of genetic factors than environmental in the expression of character, which provide ample chances for selection of desirable traits. High heritability estimates with high genetic advance were observed for physiological maturity under non-stressed (0.95), tillering (0.96), anthesis (0.97) and grain filling stress (0.98). It suggests that selection for this parameter could be effectively done. However, one has to plan cautiously as drastic curtailment in growth period may provide an escape from drought injury but can also adversely affect the yield through reduced accumulation of total dry matter (Ahmed *et al*., 2007). Heritability value of 0.77 was obtained for grain filling period with genetic advance of 15.94 in irrigated condition. Similar pattern has been obtained under tillering, anthesis and grain filling stress.

Heritability estimate obtained for flag leaf area during current work was high under non-stressed condition (0.83), tillering (0.86) and grain filling stress (0.81) with a low genetic advance whereas moderate heritability with low genetic advance under anthesis stress (0.65) has been noticed. Flag leaf area plays a vital role in proper grain filling and development. High value of heritability (Khan *et al*., 2003) and moderately high heritability has also been reported (Kashif and Khaliq, 2004). It is suggested that effective and proper selection is possible for this trait. The broad sense heritability for plant height in the wheat population under irrigated condition gave a value of 0.65. The expected genetic gain upon selecting the tallest 5% of the wheat lines would be 16.14 of the general wheat population mean. The present results are in accordance with those previously reported by Jedynski (2001); Kashif and Khaliq (2004) in wheat for this character. Low (Aycicek and Yildirim, 2006; Mohsin *et al*., 2009; Yagdi and Sozen, 2009; Aydin *et al*., 2010), moderate (Ehdaie and Waines, 1989; Abdel-Hady, 2006) and mostly high values of heritability has been obtained for the plant height in the studies that have been previously conducted (Dhonde *et al*., 2000; Fida *et al*., 2001). This trait provides an ample scope for genetic improvement. It means that breeders should pay more attention to select the genotypes with lodging resistance for the locations in which trials were conducted (Aydin *et al*., 2010). At tillering stress plant height reduced with a moderate heritability (0.55) coupled with low genetic advance of 14.91. Under anthesis stress a low value of heritability (0.28) was obtained for plant height and the value of genetic advance was 8.96. The heritability for plant height in the wheat population gave a value of 0.49 and the expected genetic gain upon selecting the tallest 5% of the wheat lines was 13.08 of the population mean. Under tillering stress plant height showed moderate heritability however low value of heritability was obtained under anthesis stress. It is suggested that careful selection is needed in case of plant height under water stress. Current results are in agreement with the finding of Eid (2009). It indicates slow progress through selection for this trait.

Under irrigated condition estimation of the broad sense heritability for the number of spikes gave a value of 0.74, which was considered a moderately high estimate. The expected genetic gain upon selecting the 5% of the wheat lines for this character was 3.20 of the population mean. Heritability reduces to a value of 0.55 for number of spikes in tillering stress with a low genetic advance of 0.88. At anthesis water stress number of spikes showed a high value of heritability (0.76) along with 2.25 of genetic advance. Whereas a moderate value of 0.57 with a genetic advance of 0.90 has been observed at grain filling stress. Moderate heritability was accompanied by high genetic advance for number of spikes for control, but it had a low value under drought condition (Eid, 2009).

A higher value of heritability (0.89) for spike length was obtained in non-stressed condition with low genetic advance. Phenotypic and genotypic coefficient of variation was very close. Higher broad sense heritability for spike length was obtained in irrigated condition. The results are in agreement with Kashif and Khaliq (2004). However contradicted with findings of Nabi *et al*. (1998) and Jedynski (2001) who reported very low heritability estimates for spike length. Moderate heritability with low genetic advance has been reported for spike length by Safeer-ul-Hassan *et al*. (2004). They suggested that making effective selection for appropriate parent is very important in case of moderately high heritability and low genetic advance. These results are also supported by Gupta and Ahmed (1982) and Abid and Shahid (1993). The broad sense heritability for spike length was high (0.84) with low genetic advance under tillering water stress. The difference between phenotypic and genotypic coefficient of variation was minimum. Moderate heritability estimates indicates moderate inheritance of the character. Spike length showed moderate heritability (0.53) along with low genetic advance under anthesis water stress. Higher phenotypic coefficient of variability compared to genotypic is indicative of more environmental influence. High heritability (0.87) was obtained for spike length and low genetic advance under grain filling stress. The difference between phenotypic and genotypic coefficient of variation was minimum.

High heritability for spike length was also indicated by Mahmood and Chowdhry (2000). However, Rajper *et al*. (1990) found a low estimate for spike length. Moderate heritability values recorded could be an indicative of improvement in spike length. Attention, therefore, may be focused on this important trait while synthesizing genotypes for stress stricken areas (Ahmed *et al*., 2007).

Number of spikelets per spike showed high heritability estimates (0.78) along with genetic advance of 7.03 of wheat population in irrigated condition. The difference between phenotypic and genotypic coefficient of variation was minimum. Moderately high heritability has been reported for spikelets per spike (Kashif and Khaliq, 2004). At tillering stress, heritability for number of spikelets gave an estimate of 0.74, which could be considered as moderately high. The expected genetic gain upon selecting the best 5% of the wheat lines for number of spikelets was 7.76 of the wheat population mean. Estimation of the broad sense heritability for this trait gave a value of 0.62, which was moderate estimate along with genetic advance of 6.42 of population mean under anthesis stress. Like control heritability estimated was 0.75 for number of spikelets per spike under grain filling stress. The expected genetic gain was 8.41 of the population mean. The difference between phenotypic and genotypic coefficient of variation was not very large. These results are in conformity with those of Mahmood and Chowdhry (2000) and Riaz (2003) who reported high heritability estimates for spikelets per spike. High broad sense heritability (0.78) for biomass per plant has been obtained with low genetic advance in the irrigated condition. The difference between phenotypic and genotypic coefficient of variation was not very large. The value of the heritability and genetic advance obtained for biomass was low (0.40) under tillering stress. Phenotypic and genotypic coefficient of variation was almost similar. It provided little chance for its further improvement. Biomass per plant showed a moderate heritability (0.67 and 0.66) estimate along with genetic advance of 5.99 and 43.43 under anthesis and grain filling stress. Phenotypic and genotypic coefficient of variation was almost similar.

Number of grains showed high heritability (0.78) estimates with a high genetic advance under irrigated condition. High heritability has been achieved for the grain number per spike (Aycicek and Yildirim, 2006; Memon *et al*., 2007). Although low values have been obtained for the grain number per spike in some studies that were conducted previously (Fida *et al*., 2001). Uddin *et al*. (1997) obtained moderate and Singh *et al*. (1999) got high heritability in the studies they conducted. Moderate to high heritability estimates with high genetic advance has been reported for number of grains per spike (Ahmed *et al*., 2007). Effective selection for this trait could be practiced for improvement. Moderate heritability (0.58) along with high genetic advance for number of grains was noted at tillering water stress. Higher genetic advance indicates that this can be effectively used for selection of better genotypes. Number of grains showed a high heritability (0.72 and 0.69) along with high genetic advance under anthesis and grain filling stress. Phenotypic coefficient of variation was higher than the genotypic component. High estimates of heritability for grains per spike have been reported by Lu *et al*. (1991) and Riaz (2003).

High heritability (0.73) with low genetic advance was observed for grain yield under non-stressed condition. Grain yield is the prime objective of plant breeders. High estimates of variation, heritability and genetic advance for this trait would be helpful for the breeders to select for the best combinations and to reach at the desirable level of yield potential (Firouzian, 2003). The heritability value alone provides no indication of the genetic progress that would result in selecting the best individual, but heritability estimates along with the genetic advance is considered more useful (Ajmal *et al*., 2009). Moderate broad sense heritability (0.52) with low genetic advance has been noted for grain yield under tillering stress. Phenotypic coefficient of variation was higher than genotypic coefficient of variation under stress condition. Grain yield showed a high heritability (0.76) along with low genetic advance under anthesis stress. The difference between phenotypic and genotypic coefficient of variation was large which indicated more influence of environment under water deficit. High heritability estimates and genetic advance with high magnitude indicated that effective selection for this trait is possible (Ahmed *et al*., 2007). High heritability for grain yield per plant has also been reported earlier (Camargo and Oliveira, 1983; Mahmood and Chowdhry, 1999). Low heritability with low genetic advance for the grain yield has been found under grain filling stress. Phenotypic coefficient of variation was higher than genotypic. Grain yield was affected by environmental factors more than by the genetic improvement for this character.

Moderate broad sense heritability (0.58) for 1000-grain weight with low genetic advance was observed in irrigated condition. Moderate broad sense heritability for 1000-grain weight was observed in irrigated condition. The values of the heritability obtained for 1000-grain weight were low that matches with the values obtained by Al-Marakby *et al*. (1994). However, there are other studies, in which moderate (Chaturvedi and Gupta, 1995) and high (Fida *et al.*, 2001) values for the heritability regarding the 1000-grain weight have been obtained. High heritability for this trait under tillering stress indicated that 1000-grain weight was affected by genetic factors less than the environmental ones. These results are supported from the earlier studies (Reddi *et al*., 1969;

Ahmed *et al*., 2007). High heritability reflected that effective selection for this character is possible and drought stages may be evolved possessing higher 1000-grain weight along with resistance against drought. High heritability (0.64 and 0.68) estimates with low genetic advance has been noticed under anthesis and grain filling stress. The difference between phenotypic and genotypic coefficient of variation was low. High heritability (0.70) with low genetic advance for this trait under tillering stress indicated that 1000-grain weight was affected by genetic factors less than the environmental ones. The difference between phenotypic and genotypic coefficient of variation was minimum. These findings are in line with the results of Li and Yang (1985); Xu (1988) and Riaz (2003) who observed high heritability estimates for 1000-grain weight.

Moderate heritability (0.55) with low genetic advance was observed for harvest index in non-stressed condition. The difference between phenotypic and genotypic coefficient of variation was not very large indicative of more genetic effects. These results are partially in agreement with the finding of Ahmed *et al*. (2003). Moderate heritability (0.54) with low genetic advance was observed for harvest index under tillering water stress. Phenotypic coefficient of variation was higher than genotypic coefficient of variation. Harvest index showed a high heritability (0.60 and 0.79) coupled with low genetic advance at anthesis and grain filling water stress. Phenotypic coefficient of variation was higher than genotypic variation. A careful selection is needed in case of harvest index.

CONCLUSION

High heritability and moderately high genetic advance were shown by different traits, especially heading, flowering, anthesis, physiological maturity, grain filling period, flag leaf area, plant height, number of spikes, spike length, number of spikelets, biomass, number of grains and grain yield under irrigated condition. However under water stress conditions, days to heading, flowering, anthesis, physiological maturity, grain filling period, flag leaf area, spike numbers, spike length, grains number, grain yield and 1000-grain weight showed high heritability. Moderate heritability was found in plant height under tillering and grain filling stress. Biomass also showed moderate heritability under anthesis and grain filling stress. However low heritability for grain yield under tillering and grain filling stress has been observed. It indicates that these bread wheat advanced lines are stable and performed better under irrigated and non-irrigated conditions. Further research is required to investigate the water relations of the genotypes under water deficit to obtain deeper and better understanding of the performance of the genotypes. These traits therefore also deserve better attention in future breeding programs for evolving better wheat for stress environments.

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