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Genetic Control of Some Physiological Attributes in Wheat under Drought Stress Conditions

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Abstract: Investigation of inheritance, mode of gene action and determination of effective breeding strategy for improvement of physiological and morph-physiological traits specifically in drought stress conditions is very important. Therefore, this study was conducted using two drought susceptible and tolerant wheat cultivars. Cultivars Sakha8 (tolerant) and Pishtaz (susceptible) as parents along with F_1, F_2, BC_1 and BC_2 generations were sown in a randomized complete block design with three replications in drought stress conditions. Results of analysis of variance indicated significant difference between generations for all the traits. Degree of dominance revealed over-dominance for all the traits. Fitting simple additive-dominance model designated that the model accounted for genetic changes of harvest index and biological yield. Additive-dominance model was not able to account for changes of traits relative flag leaf water content and mean of grain filling rate. It was revealed that m-d-h-i-j model for relative flag leaf water content and m-d-h-i model for mean of grain filling rate are the best models. Estimation of heritability and mode of gene action indicated that selection for improvement of traits studied in stress condition and specifically in early generations have medium genetic gain. Therefore, it is concluded from the present study that can propose use of traits mean of grain filling rate and harvest index as indirect selection criteria for improvement plant grain yield in drought stress condition.

Key words: Bread wheat, generation mean analysis, drought tolerance, heritability, genetic improvement, gene action

INTRODUCTION

Drought usually is the most important abiotic stress that affects crop production. Hence, selection for drought resistance and production of tolerant cultivars with high yield potential is the main objective of breeding programs. Many researchers (Passioura, 1996; Quarrie *et al.*, 1999; Richards, 1996) believed that tolerance to drought stress must be done via genetic improvement of physiological traits. Harvest index and biological yield introduced as the most important traits in this connection (Quarrie *et al.*, 1999). In small-grained cereals increase in harvest index may causes yield improvement, without increase in plant water use (Quarrie *et al.*, 1999; Richards, 1996). On the other hand, breeding for biological yield improve plant water use efficiency (Quarrie *et al.*, 1999). Therefore, selection criteria must be improving these traits. Relative leaf water content and mean of grain filling rate are the proper criteria for this aim (Golparvar, 2003; Dhanda and Sethi, 1996; Slafer and Araus, 1998). Indirect selection in early generation through traits correlated with seed yield is one of the most important strategies in plant breeding. Knowledge about inheritance and genetic control of different traits is prominence for plant breeders. Alteration in environment parameters cause change genetic architect of traits (Amawate and Behl, 1995; Chowdhry *et al.*, 1999; Redhu, 1988; Srivastava *et al.*, 1981; Walia *et al.*, 1995). Genotype environment interaction is the main reason for these changes, especially accured in stress conditions (Sharma *et al.*, 2002). Generation mean analysis is quantitative genetics method be able to estimate additive, dominance and epistatic effects (Kearsy and Pooni, 1998; Mather and Jinks, 1982). Yadav and Narsinghani (1999) studied bread wheat crosses in drought stress conditions and reported

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additive effects in genetic control of yield components. Transgressive segregation is very efficient for these traits. Results of this study also showed that complementary epistasis have important role in control of plant and spike seed yield. Bhutta and Mishra (1995) and Collaku (1994) emphasized on over-dominance and non-additive gene effects for yield and it's components in bread wheat cultivars under drought and non-drought environments. Dhanda and Sethi (1996, 1998) reported additive gene effects and high narrow-sense heritability for harvest index, biological yield and relative flag leaf water content in drought stress condition that indicates possibility of genetic improvement of traits mentioned. Sharma *et al.* (2002) found additive gene actions and high narrow-sense heritability for seed yield in drought stress conditions. Srivastava *et al.* (1981), Amawate and Behl (1995) and Walia *et al.* (1995) reported additive×additive interaction in genetic control of traits seed weight, plant height and seed yield. The aims of this study were genetic assessment of traits harvest index, biological yield, relative flag leaf water content, mean of grain filling rate and determination of the effective breeding strategy for genetic improvement of these traits in drought stress conditions.

MATERIALS AND METHODS

Generations P_1, P_2, F_1, F_2, BC_1 and BC_2 were obtained from cross between Sakha8 (drought tolerance) and Pishtaz (drought susceptible) cultivars. Six generations were grown in randomized complete block design. Homogenous generations (P_1, P_2 and F_1) were grown in two rows and heterogeneous generations (BC_1, BC_2 and F_2) in four, four and six rows, respectively. Intra and inter row distance of 5 and 20 cm were applied in this study. 300 kg ha^{-1} of ammonium phosphate fertilizer before planting and 300 kg ha^{-1} nitrogen half before and half after planting were used. Irrigation was achieved in order to seed germination. Seeds did not receive another water via irrigation but used from humidity stored in soil and precipitation (163 mm). Relative flag leaf water content was measured using method proposed by Schonfeld *et al.* (1988):

$$RLWC = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Saturated weight} - \text{dry weight}}$$

Mean of grain filling rate and harvest index were estimated using below formulas (Chowdhry *et al.*, 1999; Lazar *et al.*, 1995):

$$GFR = \frac{\text{Seed yield}}{\text{Grain filling duration}}$$

$$H.I = \frac{\text{Seed yield}}{\text{Biological yield}}$$

Biological yield was considered as shoot dry weight (Chowdhry *et al.*, 1999). The data was subjected to analysis of variance given by Steel and Torrie (1985). Generation mean analysis was carried out using methods proposed by Mather and Jinks (1982). Genetic parameters were estimated according to weighted least square method. Joint scaling test was achieved to assess goodness of simple additive-dominance model. Method of Kearsy and Pooni (1998) was used to computation gene effects and genetic variance components. Broad and narrow-sense heritability was estimated using method proposed by Warner (1952).

RESULTS AND DISCUSSION

Analysis of variance (Table 1) showed significant difference between treatments (generations) for all the traits. Therefore, genetic analysis impossible. Significant difference between treatments designated genetic variability in genetic materials for traits studied. Degree of dominance $\left(\sqrt{H/D}\right)$ indicated over-dominance effect and more important role of non-additive gene effects in genetic control of the traits (Table 2). Hence, degree of dominance designated average dominance. Redhu (1988) and Dhanda and Sethi (1996, 1998) reported similar results for these traits.

Simple additive-dominance model accounted for genetic changes of harvest index and biological yield, while not for relative flag leaf water content and mean of grain filling rate. Therefore, six-parameter genetic model fit for these traits (Table 3). After eliminating the non-significant interactions from six-parameter models, m-d-h-i-j and m-d-h-i determined as the best models for relative flag leaf water content and mean of grain filling rate, respectively. Ehdaie and Waines (1994) Dhanda and Sethi (1996 and 1998) Yadav and Narsinghani (1999) also recommended relatively similar genetic models for these traits.

Component [m] was highly significant for all the traits. On the other hand, additive component [d] was non-significant for all the traits revealed low importance of additive gene effects in genetic control of traits studied (Sharma, 1998). Dominance component [h] was significant for all the traits except harvest index designated hybrid production possibility for these traits (Yadav and Narsinghani, 1999). Additive interaction effect is important for plant breeders and genetic improvement of traits via selection (Dhanda and sethi, 1998; Yadav and Narsinghani, 1999). Among the traits studied these

Table 1: Analysis of variance for traits studied in cross Sakha8×Pishtaz for six generations

Source of variation	df	Mean of squares: Relative flag lea water content (%)	Mean of grain filling rate (g day^{-1})	Harvest Index (%)	Biological yield (g)
Reps.	2	0.93	0.002	0.001	0.36
Treatments	5	32.4**	0.008**	0.004*	12.95**
Error	10	2.83	0.001	0.001	0.07
CV (%)		3.16	17.76	8.32	2.07

*and** Significant at 5% and 1% probability levels, respectively

Table 2: Components of diversity and estimation of broad and narrow-sense heritability for traits studied in cross Sakha8 × Pishtaz for six generations

Traits	V_A	V_D	V_E	$\sqrt{H/D}$	H_b	H_n
Relative flag leaf water content (%)	27.70	31.30	46.60	1.50	56	26.20
Mean of grain filling rate (g day^{-1})	0.03	0.03	0.03	1.41	66.70	33.30
Harvest Index (%)	0.07	0.08	0.06	1.51	71.40	33.30
Biological yield (g)	7.04	6.50	11.02	1.35	55.10	28.70

V_A, V_D and V_E: Additive, dominance and environment variances, respectively., $\sqrt{H/D}$: Degree of dominance, Hb and H_n: Broad and narrow-sense heritability, respectively.

Table 3: Estimation of genetic effects in six parametric model of generation mean analysis

Traits	[m]	[d]	[h]	[I]	[j]	[l]	x^2
Relative flag leaf water content (%)	60.05**±2.71	-1.52^{ns}±0.89	-9.96**±3.53-	6.35**±2.9	17.20**±4.41	-	0.82^{ns}
Mean of grain filling rate (g day^{-1})	0.38**±0.07	0.01^{ns}±0.02	-0.24**±0.09-	0.25**±0.07	-	-	0.40^{ns}
Harvest Index (%)	0.35**±0.03	0.02^{ns}±0.03	0.03^{ns}±0.05	-	-	-	0.34^{ns}
Biological yield (g)	10.49**±0.40	0.13^{ns}±0.40	4.90**±0.72	-	-	-	4.53^{ns}

^{ns} and ** : Non-significant and significant at 1% probability level, respectively. [m], [d], [h], [I], [j], [l] and : mean, sum of additive, dominance, additive×additive, additive×dominance and dominance×dominance effects, respectively

interaction effect was significant only for relative flag leaf water content and mean of grain filling rate (Table 3).

Overall, small additive effect for polygenic traits (Table 3) is predictable, because parameters that determine gene effects are average effect of total segregating loci. Therefore, because additive parameter or interaction effect related with additive effect is the function of dispersion degree of increasing genes between parents, additive effect estimates may be small (Chugan, 2002; Ghanadha, 1999; Amawate and Behl, 1995; Mather and Jinks, 1982). Non-significant dominance effect for harvest index may be arising from bidirectionality or small genetic variance (Kearsy and Pooni, 1998). Also, estimation of additive effect for traits relative flag leaf water content and harvest index is negative (Table 3), While these traits have positive additive genetic variance. This problem is due to in generation mean analysis additive parameters or interaction effect related with additive effect is the function of dispersion degree of increasing genes between parents. On the other hand, genetic variances are not affected by equilibrate effect and are mean of squares of loci that expressed in form of sum of additive effect deviation (Chugan, 2002; Ghanadha, 1999; Amawate and Behl, 1995; Mather and Jinks, 1982).

Estimation of broad-sense heritabilities (Table 2) indicated higher importance of genetic effects in control of traits studied. Comparison between broad and narrow-sense heritabilities revealed equal importance of additive and non-additive effects in genetic control of traits that disagreement with results of degree of dominance estimation. Narrow-sense heritability designated average genetic efficiency for traits studied in stress conditions specifically in early generations. Ehdaie and Wains (1994) and Dhanda and Sethi (1996) reported possibility of selection for improvement of biological yield and harvest index in early generations that disagreement with results of present study. For relative flag leaf water content, Dhanda and Sethi (1998) reported similar results. High mean on grain filling rate prevents decrease in grain weight and yield specifically in terminal stress conditions. Genotypes having higher value of these traits show higher drought tolerance (Lazar *et al*., 1995; Quarrie *et al*., 1999). Grain yield has low narrow-sense heritability specifically in stress condition. Because of that indirect selection is proposed for genetic improvement of this trait in stress environments (Golparvar, 2003; Dhanda and Sethi, 1996; Ehdaie and Waines, 1994; Richards, 1996).

In conclusion, we can propose indirect selection via traits mean of grain filling rate and harvest index for genetic improvement of grain yield in stress conditions. High and significant correlation between grain yield and other traits have been emphasized in many researches (Golparvar *et al.*, 2003; Dhanda and Sethi, 1996, 1998; Lazar *et al.*, 1995; Quarrie *et al.*, 1999). Considerable non-additive genetic effects and non-significant additive effects observed in this study suggests that selection in advanced generations may be more appropriate because effective selection in early generations of segregating material can be achieved only when additive gene effects are substantial and environmental effects are small.

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