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HERITABILITY ESTIMATES FOR YIELD AND RELATED TRAITS IN BREAD WHEAT

Kalimullah[1], Rahm Din[1], Shah Jehan[1] and Ibrarullah[2].

[1]*Department of PBG, Faculty of Agri:, Gomal Univ: D.I.Khan, Pakistan.* kalimpbgian@yahoo.com
[2] *Department of Horticulture, Faculty of Agri:, Gomal Univ: D.I.Khan, Pakistan.*

ABSTRACT

A set of 22 experimental wheat lines along with four check cultivars were evaluated in irrigated and unirrigated environments with objectives to determine genetic and phenotypic variation and heritability estimates for yield and its traits. The two environments were statistically at par for physiological maturity, plant height, spikes m^{-2}, spikelets $spike^{-1}$, and 1000-grain weight. Highly significant genetic variability existed among wheat lines ($P \leq 0.01$) in the combined analysis across two test environments for traits except 1000-grain weight. Genotypes x environment interactions were non-significant for traits indicating consistent performance of lines in two test environments. However lines and check cultivars were two to five days early in maturity under unirrigated environment. Plant height, spikes m^{-2} and 1000-grain weight also reduced under unirrigated environments. Genetic variances were greater than environmental variances for most of traits. Heritability estimates were of higher magnitude (0.74 to 0.96) for plant height, medium (0.31 to 0.56) for physiological maturity, spikelets $spike^{-1}$ (unirrigated) and 1000-grain weight, and low for spikes m^{-2}.

Key-words:

INTRODUCTION

Wheat (*Triticum aestivum L.*) is the most cultivated cereal crop of the world including Pakistan and ranks first among all the cereals. In Pakistan, it occupies around 8.5 million hectares with annual production of 21.0 million tones (Anon., 2005). Wheat yields of the country are much lower as compared to many other countries of the world due to abiotic (environmental stresses particularly high temperatures, drought and salinity) and biotic (diseases etc.) factors (Arain *et al.*, 1999; Reynolds *et al.*, 2001). Among the wheat growing countries of the world, Pakistan ranks 9th in average annual production. About 1.033 million hectares of wheat area in Pakistan entirely depends on natural precipitation. During 2002 grain yield averaged 2566 and 1178 kg ha^{-1} under irrigated and unirrigated regions of the country, indicating a yield gap of 1388 kg ha^{-1} between the two production environments. During 2002-03, total wheat area in NWFP was 732.1 thousand hectares of which 316.1 thousand hectares was irrigated and 416.0 thousand hectares unirrigated (rainfed). The average yield was 2018 kg ha^{-1} under irrigated vs 1025 kg ha^{-1} under unirrigated regions, indicating a decrease of 993 kg ha^{-1} under unirrigated, respectively.

To overcome the consumption pressure of ever increasing population, the wheat breeders are concentrating their efforts to improve the yield potential of wheat by developing new varieties with desirable genetic make up. The high heritability associated with high genetic advance for main quantitative traits in wheat offer better scope of selection of genotypes in early segregating generations. Wheat breeders are utilizing available genetic resources to reconstruct the ideotype of plant to meet the ever increasing requirements of the population. In this regard heritability estimates plays an important role for planning the breeding strategy. The heritability of the character determines the extent to which it is transmitted from one generation to the next and it is most valuable tool when used in conjunction with other parameters in predicting genetic gain that follows in the selection for that characters (Afiah *et al*, 2000; Baloch *et al*, 2003; Ansari *et al*, 2004, 2005). The heritability values become a measure of the genetic relationship between parents and progeny; hence considerable research work has been carried out to incorporate the desirable genes in present wheat varieties to increase the productivity of the crop.

This shows that genetic improvement in grain yields of the currently grown wheat cultivars are not expressed to full potentials under the unirrigated environment due to lack of inherent ability to resist moisture stress (Collaku, 2006; Mladenov *et al*., 2001). The crop under unirrigated area suffers a serious moisture stress through out its life cycle beginning from seedling stage to maturity. Even in areas where wheat is grown under the late stages of plant growth, showing considerable reduction in yield (Riaz and Chaudhary, 2003). Therefore, wheat yield improvement in the rainfed regions would provide the basis for eliminating hunger and instituting socio-economic development in the province.

Drought is one of the major environmental factors reducing grain production of rainfed wheat in arid and semi-arid regions. Drought may be described as period in which a scarcity of soil moisture is limiting the normal growth of plants. Drought has sometimes been referred to as “a period in which the soil contains little or no moisture”. Agricultural drought is defined as a climatic excursion involving a shortage of precipitation sufficient to adversely affect crop production (Collaku, 2006).

Drought resistance in field crops is a major factor for sTable crop production in drought prone environments and thus is considered by breeders as a genuine breeding target (Riaz and Chaudhary, 2003; Aycicek and Yilirim, 2006). Although genetic improvement in wheat is continuously been made for its better adaptability to a wider range of environments. The production targets from the rainfed cropped area are not fully realized. The reason is that the arid or rainfed areas, consisting a considerable proportion of the total cropped area, are not planted with the genotypes having a better adaptability to low and uncertain moisture supply and specifically breed for these areas. This situation has come under sharp focus and efforts are being made to plan and organize arid zone research in a proper manner.

Sufficient genetic information regarding important economic characters of wheat under drought stress is not available without which the breeding strategies for drought prone areas may not prove fruitful. Wheat improvement in the country has so far been focused for irrigated areas, however, low production of wheat and increasing demand of food supply for the ever increasing population has compelled agricultural scientists to plan and focus their research for higher production in drought prone areas of Pakistan.

Therefore the present study was undertaken with the objectives to determine magnitude of genetic and phenotypic variation and the heritability for yield and yield related traits in wheat under irrigated and unirrigated production environments.

MATERIALS AND METHODS

This study was conducted at the research area, Faculty of Agriculture, Gomal university, D.I.Khan during crop season 2005-06. A set of 22 experimental wheat lines along with four check cultivars, (Dera-98, Fakher-e-sarhad, Ghaznavi-98 and Tatara) was evaluated as independent experiments under irrigated as well as unirrigated environments. A randomized complete block design with three replications was used for both environments. To avoid environmental influence, both the environments were established adjacently in the same field. The irrigated experiment was regularly irrigated whenever required throughout the growing season. In contrast, the unirrigated experiment did not receive any canal irrigation except the one for bringing the field into “Vatter” for sowing. Each plot had three meter long 2 rows, spaced 0.30 meters apart. The experiment was held on October 28th, 2005 with hand hoe using seed rate of 100 kg ha^{-1}. Fertilizer was applied to both irrigated and unirrigated environments at the rate of 90 kg ha^{-1} N and 60 kg ha^{-1} P_2O_5 at the time of sowing. Weeds were controlled manually in the experiment. The plots were sickle harvested about 15 days after reaching to physiological maturity.

Data were recorded on the following parameters at appropriate time using protocol described for each.

Days to physiological maturity

Days to physiological maturity were recorded as the number of days from sowing to the date when green color disappeared from peduncle immediately below spike

Plant Height

Plant height was recorded from the base of plant to the tip of the spike excluding awns. Height of five randomly selected plants was recorded in each plot and finally average plant height was computed.

Spikes m^{-2}

Number of spikes m^{-2} was estimated from two random measurements in each plot using 1x 1m area.

Number of Spikelets Spike^{-1}

The number of spikelets spike^{-1} was counted on the same ten randomly selected spikes from each plot.

1000- Grain Weight

One sample each of 100-random grains was weighed from the grain lot of ten spikes and then multiplied with ten to determine 1000- Grain weight.

Statistical analysis

Data recorded on 22 wheat lines (including check cultivars) were statistically analyzed using PRG GLM option in SAS following linear model for a randomized complete block design as proposed by Steel and Torrie (1980). Genetic and environmental variance for all traits were estimated for the 22 experimental lines under each environment independently using PROG VARCOMP option in SAS. Broad-sence heritability (h^2_{BS})

$h^2_{BS} = Vg / (Vg + Ve/r)$

Wherein

h^2_{BS} = broad sense heritability

Vg= genetic variance

Ve= environmental variance and

r= number of replications.

RESULTS

GENETIC VARIABILITY

Mean square pertaining to maturity, plant height, spike and grain characteristics and yield traits are given in Table 1. The two test environments did not differ for physiological maturity ($P \leq 0.21$), plant height ($P \leq 0.46$), spikes m^{-2} ($P \leq 0.58$), spikelets $spike^{-1}$ ($P \leq 0.69$) and 1000-grain weight ($P \leq 0.94$). Highly significant genetic variation among the experimental lines ($P \leq 0.01$) in the combined analysis over the two environments was detected for days to physiological maturity, plant height, spikes m^{-2}, and spikelets $spike^{-1}$ except 1000-grain weight. Genotype x environment interaction was non significant for these traits indicating consistent performance of experimental lines across the two test environments (Table 1). However, means and genetic parameters about all the traits of the wheat experimental lines are being presented independently for each environment for comparison.

Table 1. mean squares for days to heading, physiological maturity, plant height, spikes m^{-2} and spike length of 22 spring wheat lines evaluated under irrigated and unirrigated environments at Faculty of agriculture during crop season 2005-06.

Source	df	Physiological maturity	Plant height	Spike m^{-2}	Spikelets $spike^{-1}$	1000-grain wt
Environment (E)	1	532.01 ^{NS}	41.48 ^{NS}	29820.12 ^{NS}	3.34 ^{NS}	0.38 ^{NS}
Reps w/n E	4	251.30	63.59	83577.21	18.45	80.69
Genotype (G)	21	16.46**	324.13**	12525.25**	4.50**	20.75 ^{NS}
Gx E	21	2.26 ^{NS}	2.78 ^{NS}	994.72 ^{NS}	1.42 ^{NS}	27.00*
Error	84	5.76	22.21	6459.24	2.05	13.84
CV(%)	…..	1.44	5.07	19.34	6.97	1.98

NS= non-significant

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

PHYSIOLOGICAL MATURITY

A perusal through the means (Table 2) indicated that the wheat genotypes significantly differ in the days to physiological maturity. Days to physiological maturity among the genotypes ranged from 207 to 213.8. The highest (213.8) days taken to physiological maturity were observed in Dera-98 (check). The lowest (207) days to physiological maturity were recorded in line RF3.

The effect of environment on physiological maturity was non significant. However, the maximum days to physiological maturity of 212.7 was observed under irrigated environment, which was at par with unirrigated environment.

There were non significant differences in the mean values of days to physiological maturity between genotypes and environment interaction. However, Dera-98 and Fakher-e-sarhad took maximum number of 215.7 days under irrigated environment, while R3 needed minimum number of 204.3 days in unirrigated environment.

Genetic variances for physiological maturity were four times less than the environmental variances and six times less than in unirrigated environment (Table 7). Heritability estimates for physiological maturity were 0.41 in irrigated and 0.35 in unirrigated environment indicating 60-65% environmental influence on maturity of wheat genotypes.

PLANT HEIGHT

Significant differences were observed among the genotypes for plant height. The maximum plant height of 108.8 cm was recorded in line RF36. Check cultivar ghaznavi-98 was the shortest with the plant height of 79.5 cm (Table 3).

The effect of environment on plant height was non significant. However, the maximum plant height of 91.9 cm was observed under irrigated environment, which was at par with unirrigated environment.

Table 2. Means for days to physiological maturity of 22 experimental lines and four check cultivars under irrigated and unirrigated environments during crop season 2005-06.

	Days to physiological maturity		
	Irrigated	Unirrigated	Mean
IR10	212.3	209.7	211.0
IR11	212.7	208.3	210.5
IR14	212.7	208.0	210.3
IR15	212.7	209.0	210.8
IR17	212.3	210.3	211.8
IR18	214.7	209.3	212.0
IR2	213.0	207.7	210.3
IR20	212.7	208.7	210.7
IR21	214.3	211.3	212.8
IR5	214.0	210.0	212.0
IR7	214.7	209.3	212.0
RF10	212.3	208.3	210.8
RF2	211.7	209.3	210.5
RF21	208.3	207.3	207.8
RF29	209.3	206.6	207.9
RF3	209.7	204.3	207.0
RF33	210.3	207.3	208.8
RF35	211.0	206.7	208.8
RF36	212.0	207.0	209.5
RF37	211.0	206.7	208.8
RF5	210.7	205.0	207.8
RF9	214.7	209.7	212.2
Dera-98*	215.7	212.0	213.8
F.Sarhad*	215.7	211.7	213.7
Ghaznavi-98*	215.0	209.7	212.3
Tatara*	215.0	211.7	213.7
Mean	212.7	208.6	

$LSD_{0.01}$ genotype = 3.6; * = check cultivar

The interacting effects of genotypes x environments on plant height were non-significant. However, the maximum plant height of 109.7 cm was recorded by genotype RF36 under unirrigated environment.

Genetic variances for plant height were twice greater than the environmental variance in both the environments indicating less environmental influence (Table 7). The heritability estimates for plant height were identical under both environments; 0.85 in irrigated and 0.87 in unirrigated (Table 7).

SPIKES M^{-2}

Significant differences were observed among the genotypes for spike m^{-2}. The maximum spike m^{-2} of 505.3 was recorded in line RF21.while the minimum spikes m^{-2} of 336 was recorded in RF2 (Table 4).

The effect of environment on spike m^{-2} was non significant. However, the maximum spikes m^{-2} of 432.2 was observed under irrigated environment, which was at par with unirrigated environment.

The interacting effects of genotypes x environments on spikes m^{-2} were non-significant. However, the maximum spikes m^{-2} of 533.3 was recorded by genotype RF21 under irrigated environment.

Genetic variance in both irrigated and unirrigated environments were much smaller than the environmental variances with heritability estimates of 0.03 and 0.11, respectively (Table 7).

Table 3. Means for plant height of 22 experimental lines and four check cultivars under irrigated and unirrigated environments during crop season 2005-06.

	Plant height		
	Irrigated	Unirrigated	Mean
IR10	88.3	85.7	87.0
IR11	89.0	88.0	88.5
IR14	93.0	92.7	92.8
IR15	93.0	92.0	92.5
IR17	92.3	92.0	92.1
IR18	82.3	79.7	81.0
IR2	85.7	83.0	84.3
IR20	90.0	89.0	89.5
IR21	85.7	82.7	84.2
IR5	97.7	94.7	96.0
IR7	87.3	86.0	86.6
RF10	90.0	88.0	89.0
RF2	86.7	85.0	85.8
RF21	101.3	99.7	100.5
RF29	100.3	101.3	100.8
RF3	95.3	96.7	96.0
RF33	101.0	100.0	100.5
RF35	105.0	104.0	104.5
RF36	108.0	109.7	108.8
RF37	91.0	88.3	89.6
RF5	92.7	92.7	92.7
RF9	101.7	100.7	101.2
Dera-98*	90.0	92.0	91.0
F.Sarhad*	83.0	81.0	82.0
Ghaznavi-98*	80.0	79.0	79.5
Tatara*	81.3	84.0	82.6
Mean	91.9	91.0	

$LSD_{0.01}$ genotype = 8.4

* = check cultivar

SPIKELETS SPIKE^{-1}

A perusal through the means (Table 5) indicated that the wheat genotypes significantly differ for spikelets spike^{-1}. Spikelets spike^{-1} among the genotypes ranged from 19.3 to 23.6. The highest (23.6) spikelets spike^{-1} were observed in line RF21. The lowest (19.3) were recorded in line RF47.

Means given in Table 6 revealed that the effect of environment was non significant. However, the maximum number of spikelets spike^{-1} (20.8) was noted in unirrigated conditions which were at par with irrigated environment. There were non significant differences in the mean values of spikelets spike^{-1} between genotypes and environment interaction. However, line RF29 has maximum number of 23 spikelets spike^{-1} under unirrigated environment, while line RF10 has minimum number of 18.3 spikelets spike^{-1} in unirrigated environment.

Genetic, environmental and phenotypic variances and heritability under the two environments are given in Table 7. Genetic variance for spikelets spike^{-1} in both environments was of smaller magnitude (0.01 under irrigated and 0.6 under unirrigated environments respectively). The heritability estimates for spikelets spike^{-1} was 0.01 in irrigated vs 0.56 under unirrigated environments (Table 7).

1000-GRAIN WEIGHT

The data in Table 6 indicated that there were non significant differences for 1000-grain weight. The highest (39.5) 1000-grain weight were observed in line RF29. The lowest (19.6) 1000-grain weight were recorded in Fakhar-e-sarhad (check).

The effect of environment on 1000-grain weight was also non significant. However, the maximum 1000-grain weight of 35.7 was observed under irrigated environment, which was at par with unirrigated environment.

There were significant differences in the mean values of 1000-grain weight between genotypes and environment interaction. Line RF35 gives maximum 1000-grain weight of 41 under irrigated environment, while line IR18 gives minimum 1000-grain weight of 31.5 in unirrigated environment.

Environmental variances were 2.9 and 6.6 times greater than the respective genetic variance resulting in heritability estimates of 0.51 and 0.31 under irrigated and unirrigated environment, respectively (Table 7).

Table 4. Means for spikes m^{-2} of 22 experimental lines and four check cultivars under irrigated and unirrigated environments during crop season 2005-06.

	Spikes m^{-2}		
	Irrigated	Unirrigated	Mean
IR10	378.7	362.7	370.7
IR11	424.0	381.3	402.6
IR14	442.7	496.0	469.3
IR15	456.7	432.0	444.2
IR17	402.7	349.3	376.0
IR18	373.3	336.0	354.6
IR2	485.3	421.3	453.3
IR20	434.7	408.0	421.3
IR21	408.0	376.0	392.0
IR5	397.3	338.7	368.0
IR7	474.7	440.0	457.3
RF10	378.7	360.0	369.3
RF2	357.3	314.7	336.0
RF21	533.3	477.3	505.3
RF29	450.7	405.3	428.0
RF3	413.3	426.7	420.0
RF33	389.3	384.0	386.6
RF35	474.7	445.3	460.0
RF36	480.0	434.7	457.3
RF37	480.0	445.3	462.6
RF5	458.7	424.0	441.3
RF9	378.7	352.0	365.3
Dera-98*	384.0	320.0	352.0
F.Sarhad*	108.0	389.3	398.6
Ghaznavi-98*	514.7	456.0	485.3
Tatara*	458.7	413.3	436.0
Mean	432.2	399.5	

$LSD_{0.01}$ genotype = 132.5
* = check cultivar

Table 5. Means for spikelets $spike^{-1}$ of 22 experimental lines and four check cultivars under irrigated and unirrigated environments during crop season 2005-06.

	Spikelets $spike^{-1}$		
	Irrigated	Unirrigated	Mean
IR10	20.0	19.6	19.8
IR11	20.6	21.3	20.8
IR14	20.0	20.3	20.1
IR15	19.6	20.3	20.0
IR17	21.0	21.6	21.3
IR18	20.6	21.0	20.8
IR2	20.3	20.6	20.4

Cont'd….

IR20	20.3	21.0	20.1
IR21	20.0	20.0	20.0
IR5	20.3	20.3	20.3
IR7	21.6	22.3	21.9
RF10	21.3	18.3	19.8
RF2	21.0	19.6	20.3
RF21	20.6	26.6	23.6
RF29	22.6	23.0	22.8
RF3	19.3	20.3	19.8
RF33	20.3	22.0	21.1
RF35	22.0	22.0	22.0
RF36	19.3	20.6	20.0
RF37	19.0	19.6	19.3
RF5	19.3	20.3	19.8
RF9	19.3	20.6	20.0
Dera-98*	19.0	18.6	18.8
F.Sarhad*	20.6	21.3	20.0
Ghaznavi-98*	20.0	20.3	20.1
Tatara*	19.6	20.0	19.8
Mean	20.28	20.8	

LSD $_{0.01}$ genotype = 1.9
* = check cultivar

Table 6. Means for 1000-grain weight of 22 experimental lines and four check cultivars under irrigated and unirrigated environments during crop season 2005-06.

	1000-grain weight		
	Irrigated	Unirrigated	Mean
IR10	37.5	37.5	37.5
IR11	33.8	32.7	33.2
IR14	37.6	36.7	37.1
IR15	33.0	33.5	33.2
IR17	33.5	33.2	33.3
IR18	35.3	31.5	32.4
IR2	35.0	37.7	36.3
IR20	37.1	35.8	36.4
IR21	36.6	35.5	36.0
IR5	39.5	33.7	36.6
IR7	35.4	37.1	36.2
RF10	29.9	38.4	34.1
RF2	37.4	37.7	37.5
RF21	37.4	32.8	29.6
RF29	40.5	38.5	39.5
RF3	33.3	39.3	36.3
RF33	37.4	35.0	36.2
RF35	41.0	33.2	37.1
RF36	39.6	39.3	39.4
RF37	35.0	38.4	36.8
RF5	33.8	32.7	33.2
RF9	30.4	40.1	35.2
Dera-98*	37.5	31.7	34.8
F.Sarhad*	36.1	33.0	19.6
Ghaznavi-98*	37.7	34.7	36.2
Tatara*	37.7	34.9	34.0
Mean	35.7	35.4	
LSD	5.9	6.1	

* = check cultivar

Table 7. genetic variance (Vg), environmental variance (Ve), phenotypic variance (Vp) and heritability estimates (h^2) for various traits of 22 experimental wheat lines evaluated under irrigated and unirrigated environment during crop season 2005-06.

	Irrigated				Unirrigated			
	Vg	Ve	Vp	h^2	Vg	Ve	Vp	h^2
Physio-maturity	1.4	5.7	3.3	0.41	1.04	5.8	2.9	0.35
plant height	40.9	20.6	47.8	0.85	53.2	23.8	61.1	0.87
Spikes m^{-2}	-61.4	6683.2	2166.3	-0.03	261.9	6235.4	2340.3	0.11
Spikelets $spike^{-1}$	-0.01	2.7	0.9	-0.01	0.6	1.5	1.2	0.56
1000-grain wt	4.5	13.2	8.9	0.51	2.2	14.6	7.1	0.31

DISCUSSION

The results obtained are briefly discussed in the following paragraphs.

PHYSIOLOGICAL MATURITY

Development of wheat cultivars with optimum maturity is the main objective in most breeding programs. Early maturity not only reduces the fertilizer and irrigation application but also help the growers to cultivate another crop in the same field. The experimental lines as well as the check cultivars were 2 to 6 days early in maturity under unirrigated environment. All check cultivars took more days (215.0) to maturity under irrigated environment. Genotype RF3 took fewer days (204.3) to mature under unirrigated environment.

PLANT HEIGHT

Plant height is important selection trait in wheat breeding programs. Plant breeders are interested in short stature uniform plant because of their lodging resistance and positive response to fertilizers and irrigation. Both the environments showed significant differences among the genotypes for plant height. There was a general tendency of shorter plant stature under unirrigated environment. Check cultivar Dera-98 and Tatara were 2 to 3 c taller under unirrigated environment. Heritability estimates were of greater magnitude (0.85 and 0.87) in both the environments.

SPIKES M^{-2}

Maximum number of spikes m^{-2} leads to an increase in total biological and grain yield. Biological yield is considered important for fodder purposes in developing countries like Pakistan. More spikes m^{-2} was observed in irrigated environments than unirrigated. Maximum spikes m^{-2} (533.3) was produced by experimental line RF21 followed by check cultivar Ghaznavi-98 (514.7) under irrigated environment. Lowest magnitudes of heritability (-0.03 and 0.11) were observed under both the irrigated and unirrigated environments.

SPIKELETS $SPIKE^{-1}$

Highly significant differences among genotypes were obtained for spikeltes $spike^{-1}$ in unirrigated environment. Maximum numbers of spikelets $spike^{-1}$ (22.6 and 23.0) were recorded for genotype RF29 under both the environments. Medium (0.56) heritability was estimated for spikelets $spike^{-1}$ in unirrigated environment, while zero under irrigated.

1000-GRAIN WEIGHT

1000-grain weight is very important yield contributing character and is given more emphasis during cultivar selection. Maximum 1000-grain weight of 41.0 g was recorded for genotype RF35 under irrigated and 40.1 g for genotype RF9 under unirrigated environment. Average heritability for 1000-grain weight was medium in irrigated, but low in unirrigated.

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