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Research Paper

Effect of drought stress on some grain quality traits in rice (*Oryza sativa* L.)

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ABSTRACT

Grain shape quality traits of twenty (20) rice genotypes were studied in order to understand the effects of drought stress on these quality traits. The result of Analysis of Variance clearly indicates that genotypes significantly differ for studied grain quality traits under both for normal as well as drought prone environments. Higher heritability estimates for grain length and length to width ration under normal and all quality traits under stress environment indicate that these characters are controlled by multiple genes and selection of these characters would be effective at early generation. Results showed that grain length was positively correlated with length to width ratio (0.863* and 0.668*) and negatively correlated with grain width (-0.614** and -0.313**) and grain breadth (-0.321**and -0.030^{ns}) under both normal and stress conditions respectively. Grain width was positively correlated with grain breadth (0.711** and 0.486**) and negatively correlated with length to width ratio (-0.926* and -0.910*) under both conditions respectively. Grain width was highly correlated with yield per plant (0.386** and 0.315**) under both, normal and drought stress respectively while grain breadth was positively correlated (0.553**) only under normal condition. It shows that reduction in grain width has direct effect on grain yield. Under normal condition, yield was positively correlated with grain width (0.386**) and grain breadth (0.552*) indicating that grain width and grain breadth should be considered while screening high yielding genotypes under normal condition and grain width alone should be considered for drought stress among the studies characters.

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Key words: Yield, grain shape quality traits, correlation, path coefficient analysis, drought stress, *Oryza sativa* L.

INTRODUCTION

Drought is the meteorological event, which implies absence of rainfall for a period of time, long enough to cause moisture depletion in soil and water deficit with a decrease of water potential in plant tissues (Kramer, 1980). A definition of drought generally accepted by plant breeders is: "a shortfall of water availability sufficient to cause loss in yield", or "a period of no rainfall or irrigation that affects crop growth" (Price, 2002; Fukai and Cooper, 1995). Using a similar definition, it has been estimated that 25% of the fields used for upland crop production (Kasuka et al., 2005) are prone to yield reductions as a consequence of drought. Drought therefore has a major impact on world agriculture.

Although rice is consumed worldwide, therefore is no universal rice quality attribute (Veronic et al., 2007). Nevertheless, rice appearance and cooked rice texture are the characters considered as main quality attributes by consumers (Okabe, 1979; Rousset et al., 1999). Thus, measuring and understanding factors that influence appearance and texture properties are a great challenge for industries and breeders in meeting consumer preferences. About 13% of the world's 147 million ha of rice is cultivated as rain fed rice under upland conditions (Crosson, 1995) where moisture stress affects rice growth and reduces grain yield and quality (Carlos et al., 2008). Water is a major constituent of plant tissue as reagent for chemical reactions and solvent for translocation of metabolites and minerals as well as an essential component for cell enlargement through increasing turgor pressure (Carlos et al., 2008). The occurrence of soil moisture stress affects many of the physiological processes such as photosynthesis and transpiration resulting in poor grain filling and poor quality (Samonte et al., 2001).

Incorporation of preferred grain quality features has become important objective in rice improvement programs next to enhancement in yield. Therefore, it is very crucial to identify how quality is affected when rice crop is under drought stress. Grain size is an important quality trait in rice trade with different preferences among consumers (Fan et al., 2006). For example, consumers in the USA and most Asian countries prefer long slender grains (Unnevehr et al., 1992; Juliano and Villareal, 1993). Gupta et al. (2006) also stated that grain size has an impact on end quality products such as flour yield after milling and protein content.

Genetic correlation provides the information about type of relationship of traits among themselves as well as with yield (Known and Torrie, 1964). Path analysis furnishes information of influence of each trait to yield under drought stress directly as well as indirectly and also enables the breeders to rank the genetic attributes according to their contribution (Dewey and Lu, 1959).

MATERIALS AND METHODS

In the present research work, twenty rice genotypes were studied for morphological traits during the summer of 2009. Plants were grown in vicinity of University of Agriculture Faisalabad, Pakistan.

The nursery was sown on 29 may, 2009 and transplanted to the earthen pots after 25 days. Two seedlings of each variety were transplanted into one pot, with the distance of 16.5 cm between the plants within a pot. The experiment was conducted in two water regimes: fully irrigated (control) and simulated water stress condition under a randomized complete block design. Both the treatments were replicated three times. All lines were tested under control (with normal irrigation) and drought stress (by stopping irrigation) condition respectively. While P and K were applied in full dose at the time of sowing, N was applied in four splits as top dressing. Insect and weed control measures were applied periodically as required.

For stress treatment, two consecutive drying cycles were imposed in order to prevent the plants from dying completely and make most of the lines experience drought stress, first round was well before flowering and second one at reproductive stage when plants had started panicle initiation. Stress was realized by stopping irrigation and keeping off rainfall using the shelter. After drought stress, normal irrigation was followed throughout the late stages of rice.

Analysis of variance was conducted for all the traits following Steel et al. (1997). Heritability and Genetic advance was estimated for all traits using the formula given by Falconer and Mackey (1996). Genetic advance was computed at 20% selection intensity (i = 1.4) following Poehlmam and Sleper (1995).

The genotypic and phenotypic correlation coefficient estimates were carried out using the formula given by Known and Torrie (1964). Genotypic estimates were used in path coefficient analysis (using formula given by Dewey and Lu, 1959) in order to determine direct and indirect effects of traits on yield under simulated drought stress condition. Yield per plant was considered as the resultant variables and others as causal variables. Statistical significance of phenotypic environmental correlation was determined by using t-test as described by Steel et al. (1997).

Observation regarding grain length, width and thickness were recorded with the help of digital caliper on ten randomly selected three times of full healthy grain.

RESULTS AND DISCUSSION

The results of Analysis of Variance clearly indicate that genotypes vary significantly for all the studies grain shape quality traits under both, normal as well as drought prone environments, except grain breadth /thickness under stress condition (Rasheed et al., 2002), that emphasizes that grain length, breadth and width of the genotypes have genetic variability that can be exploited in breeding program (Tables 1 and 2). Mean values for grain quality traits under normal and drought stress conditions are presented in Tables 1 and 2 respectively. Mean grain lengths under normal and drought condition are 9.55 and 9.057 mm, means of grain widths are 2.238 and 2.011 mm and that of grain breadths are 1.607 and 1.77 mm respectively. The results indicate that grain lengths and grain widths were reduced due to drought stress and grain breadth was slightly increased on average in almost all the observed genotypes.

The results in Tables 3 and 4 shows that the phenotypic coefficients of variability of all the genotypes were higher than its respective genotypic coefficient of variability for all grain quality traits under both environments, indicating the effects of environment constitute the major portion of the total phenotypic variation. Under normal conditions, there was a higher difference in PCV and GCV for grain width (9.445 and 7.771) and grain *L/W* ratio (12.389 and 10.652) respectively indicating that these traits had more environmental influence as compared to all the other traits that showed less difference in PCV and GCV values (Table 3 and 4). Moderate estimates of PCV and GCV values were recorded for grain length, grain breadth and grain Length/Breadth ratio under both the conditions. These

Table 1. Mean square values for some grain quality traits under normal condition.

Characters	GL	GW	GB	L/W
Treatment SS	13.061**	1.999**	0.317**	13.466**
Replication SS	0.036	0.001	0.002	0.0014
Error SS	0.629	0.549	0.061	2.835
Total SS	13.725	2.549	0.378	16.301
G.M. (mm)	9.550	2.238	1.607	4.316
Replication MS (df = 2)	0.018	0.001	0.001	0.0007
Treatment MS (df = 19) MS[1]	0.687	0.105	0.017	0.709
Error MS[2]	0.017	0.014	0.002	0.075
C.V	1.347	5.369	2.492	6.328

Table 2. Mean square values for some grain quality traits under simulated drought stress condition.

Characters	GL	GW	GB	L/W
Treatment SS	14.197**	2.173**	0.599*	19.348**
Replication SS	0.015	0.014	0.028	0.117
Error SS	3.266	0.242	0.107	2.064
Total SS	17.478	2.430	0.733	21.529
G.M. (mm)	9.057	2.011	1.777	4.557
Replication MS (df = 2)	0.007	0.007	0.014	0.059
Treatment MS (df = 19) MS[1]	0.747	0.114	0.032	1.018
Error MS[2]	0.086	0.006	0.003	0.054
C.V	3.237	3.970	2.988	5.115

GL=grain length, GW=grain width, GB=grain breadth, L/W=grain length to width ratio, *significant at 5%, **significant at 1%.

Table 3. Estimates of Genotypic, Phenotypic and Environmental variances and coefficient of variability for grain quality traits under normal condition.

Characters	GL	GW	GB	L/W
Genotypic variances (Vg)	0.224	0.030	0.005	0.211
Phenotypic variances (Vp)	0.240	0.045	0.007	0.286
Environmental variances (Ve)	0.017	0.014	0.002	0.075
Phenotypic coefficient of Variability (PCV)	5.132	9.445	5.064	12.389
Genotypic coefficient of Variability (GCV)	4.952	7.771	4.408	10.652
Heritability ($h^2_{B.S.}$)	0.931	0.677	0.758	0.739
GA	0.616	0.165	0.075	0.476

Table 4. Estimates of Genotypic, Phenotypic and Environmental variances and coefficient of variability for grain quality traits under drought condition.

Characters	GL	GW	GB	L/W
Genotypic variances (Vg)	0.220	0.036	0.010	0.321
Phenotypic variances (Vp)	0.306	0.042	0.012	0.376
Environmental variances (Ve)	0.086	0.006	0.003	0.054
Phenotypic coefficient of Variability (PCV)	6.112	10.237	6.262	13.450
Genotypic coefficient of Variability (GCV)	5.184	9.436	5.503	12.440
Heritability ($h^2_{B.S.}$)	0.719	0.850	0.772	0.855
GA	0.473	0.226	0.106	0.679

GL=grain length, GW=grain width, GB=grain breadth, L/W=grain length to width ratio.

Table 5. Estimates of genotypic (above) and phenotypic (below) correlation coefficients for grain quality traits with bran under normal condition.

Characters	GW	GB	L/W	Y/P	Y/P*
GL	-0.614** -0.563**	-0.321* -0.259*	0.863** 0.840**	-0.367^{ns} -0.318	-0.121^{ns} -0.094
GW		0.711** 0.638**	-0.926** -0.916**	0.386* 0.363*	-0.165^{ns} -0.180
GB			-0.586* -0.520*	0.552** 0.455**	-0.309* -0.265*
L/W				-0.402** -0.368*	0.042^{ns} 0.068

GL = grain length, GW = grain width, GB = grain breadth, L/W = grain length to grain width ratio, Y/P* = yield per plant under simulated drought stress condition, Y/P = yield per plant under normal condition.

results were in consonance with the findings of Subbaiah et al. (2011) for grain length, width, breadth and *L/W* ratio and Sarkar and Bhutia (2007) for *L/W* ratio.

Higher broad sense heritability genetic advance estimates for grain length (0.931 and 0.616 respectively) and length to width ration(0.739 and 0.476 respectively) under normal condition; while grain *L/W* ratio (0.855 and 0.679 respectively) indicate that these characters can be exploited more efficiently through selection in further generations (Tables 3 and 4) (Rasheed et al., 2002). Estimates for genetic advance for length width ratio and length of the grain were higher as compared to others under normal condition. Yoshida et al. (2002) also reported high heritability estimates for grain length (0.916) under normal irrigated condition. Mzengeza et al. (2010) also found that the comparatively lower heritability and genetic advance estimates for grain breadth and grain width in their experiment and suggested that it could be prudent to delay selection for these characters to advanced generations, for example, in the F5 generation. Subbaiah et al. (2011) also found out higher heritability and Genetic Advance estimates for grain length and grain *L/W* ratio and lower for other traits.

Based on narrow-sense heritability estimates, selection for grain length under normal and selection for both, length and L/W ratio could be effective in early generations because of their high heritability and genetic advance estimates, while selection for grain *L/W* ratio and grain breadth would be effective in advanced generations. Predominance of additive gene action, as indicated by higher heritability estimates for these traits also suggest that selection for grain length and grain *L/W* ratio would be effective in early generations, while selection for grain breadth and grain width would have to be delayed because of its negative or weak association with the other traits and yield per plant. Same results were found out by Mzengeza et al. (2010).

Results showed that grain length was positively correlated with length to width ratio and negatively correlated with grain width and grain breadth under normal condition (Table 5). Shanthala et al. (2005) also found that grain length was negatively and significantly correlated with grain breadth (-0.7440). Grain width was highly and positively correlated with grain breadth and negatively correlated with length to width ratio. Grain breadth was negatively correlated with *L/W* ratio. Yield per plant was found positively correlated with grain breadth and grain width and negatively correlated with *L/W* ratio under normal condition. There was no significant relation of yield per plant with grain length. The results clearly indicated that grain yield is positively influenced by grain breadth and grain width, while selection for grain length and grain *L/W* ratio would reduce the yield per plant.

However, under drought stress, grain length was positively correlated with grain width and positively correlated with grain *L/W* ratio. Grain width was found to have positive association with grain breadth and negative with grain *L/W* ratio. Grain breadth showed negative correlation with *L/W* ratio. Under drought stress condition, grain width showed positive correlation with yield per plant that shows that reduction in grain width has direct effect on grain yield while grain length and breadth were non-significantly correlated with yield per plant under drought stress condition (Table 6).

Positive and high phenotypic and genotypic correlation of yield with grain width (0.386 and 0.363 respectively) and grain breadth (0.552 and 0.455 respectively) indicated that grain width and grain breadth should be considered while screening high yielding genotypes under normal condition and grain width (0.315 and 0.297 respectively) alone should be considered while screening high yielding genotypes under drought stress. Mzengeza et al. (2010) also found correlation between grain length and grain length to width ratio was positive and strong. Rabiei et al.

Table 6. Estimates of genotypic (above) and phenotypic (below) correlation coefficients for grain quality traits with bran under simulated drought stress condition.

Characters	GW	GB	L/W	Y/P
GL	-0.313* -0.243*	-0.030^{ns} -0.010	0.668** 0.650**	0.027^{ns} -0.020
GW		0.486** 0.475**	-0.910** -0.886**	0.315** 0.297**
GB			-0.404* -0.380*	-0.042^{ns} -0.030
L/W				-0.265^{ns} -0.263

GL = grain length, GW = grain width, GB = grain breadth, L/W = grain length to grain width ratio, Y/P* = yield per plant under simulated drought stress condition, Y/P = yield per plant under normal condition.

Table 7. Estimates of direct (Bold figures) and indirect effects (Vertically arranged) of grain quality traits on yield under normal condition.

Characters	GL	GW	GB	L/W
GL	-0.886	0.432	0.426	-0.657
GW	-0.352	0.721	0.437	-0.678
GB	0.519	0.653	-1.079	0.059
L/W	0.722	-0.915	-0.054	0.974

GL = grain length, GW = grain width, GB = grain breadth, L/W = grain length to grain width ratio.

(2004) also found positive and strong correlation (r=0.729) between grain length and grain *L/W* ratio. The strong and positive correlation found suggests that grain length and grain L/W ratio could be selected for simultaneously. Alternatively, either grain length or grain L/W ratio could be used to select for both traits.

Under normal condition, direct effect of grain length on yield per plant was negative and high, while indirect effects via grain breadth; length to width ratio was positive and high and via grain width was negative and pronounced. Direct effect of grain width on yield per plant was positive and high, while indirect effects via grain breadth; length to width ratio was positive and high, via grain width was negative and pronounced and via grain length was positive and pronounced. Direct effect of grain breadth on yield per plant was negative and high, while indirect effects via grain length; width was positive and high and via length to width ratio was negative but negligible. Direct effect of length to width on yield per plant was positive and high, while indirect effects via grain length; width was negative and high and via grain breadth was positive but negligible (Table 7 and 8).

Under simulated drought stress conditions, direct effect of grain length on yield per plant was positive and high, while indirect effects via length to width ratio was negative and high and via grain width was positive and pronounced. Direct effect of grain width on yield per plant was negative and high, while indirect effects via grain breadth; grain length was negative and high, via length to width ratio was positive and very high. Direct effect of grain breadth on yield per plant was negative but not pronounced, while indirect effects via grain length was negative and negligible, via length to width ratio was positive and pronounced and via grain width was negative and high. Direct effect of length to width on yield per plant was negative and very high, while indirect effects via grain length; width was positive and high and via grain length to width ratio was positive but negligible (Tables 3 and 4).

Conclusion

Simple correlation co-efficient directs the breeder in determining the direction and the number of characters to be considered for selection in improving grain yield (Shanthala et al., 2005). Thus, from the studies it can be concluded that a selection for grain width and grain breadth automatically enhances the grain yield under

Table 8. Estimates of direct (Bold figures) and indirect effects (Vertically arranged) of grain quality traits on yield under simulated drought stress condition.

Characters	GL	GW	GB	L/W
GL	1.887	-0.590	-0.057	1.261
GW	0.820	-2.563	-1.246	2.332
GB	0.011	-0.173	-0.357	0.144
L/W	-2.673	3.641	1.617	-4.002

GL = grain length, GW = grain width, GB = grain breadth, L/W = grain length to grain width ratio.

normal and drought stress condition, while, selection for grain length would reduce the yield per plant. All the studied genotypes showed significant variability for all the traits that can further be exploited in breeding programs. Higher phenotypic and genotypic correlation coefficients indicate higher influence of environment on these traits. Higher heritability and genetic advance estimates for grain length and grain length to width ration under normal condition and all traits under drought stress indicates additive gene action responsible for these traits under specific condition and suitability for selection at early generations.

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