CORRELATION AND PATH COEFFICIENT ANALYSIS OF YIELD COMPONENTS IN RICE (*ORYZA SATIVA* L.) UNDER SIMULATED DROUGHT STRESS CONDITION

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ABSTRACT

Morphological and yield related traits of twenty (20) genotypes were studied to ascertain the genetic and phenotypic correlation among some drought related and morphological traits and contribution of these traits to the yield under drought stress directly and indirectly in rice. The results indicate that root length (0.465**), root shoot ratio (0.242*), thousand grain weight (0.476**), grains per panicle (0.733**), spikelet fertility (0.709**) and drought response index (0.642**) showed positive and significant association with yield per plant under drought stress at genotypic level; whereas, leaf drying (-0.599**) had significantly negative correlation with yield. Higher phenotypic correlation values for all traits indicated that the environmental effects on traits under stress are high under drought stress. Root shoot length ratio showed highest positive direct effect (2.945**) on yield per plant under drought stress, followed by drought response index (2.449**), thousand grain weight (0.805**). Results suggest that root to shoot length ratio, thousand grain weight, leaf drying and drought response index may be used as reliable criteria for improving drought resistance. Higher heritability and Genetic Advance estimates for all the traits under drought condition indicates that these characters can be exploited more efficiently through selection in further generations.
Key Words: Yield; Morphological traits; Correlation; Path analysis; Drought stress; *Oryza sativa* L.

INTRODUCTION

Rice (*Oryza sativa* L.), an important food/cash crop, is the third largest crop of Pakistan after wheat and cotton. The annual production of the milled rice is about 5.5 million tones sharing 5.5 % in agriculture sector and 1.1% in GDP. Pakistan is famous for growing and exporting long grain Basmati rice (Anonymous, 2008-2009).

Drought stress is a major constraint to rice (*Oryza sativa* L.) production and yield stability in rainfed ecosystems (Dey and Upadhyaya, 1996). It may be defined as a 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).

Drought limits the agricultural production by preventing the crop plants from expressing their full genetic potential. Drought frequently causes loss of yield in rice, one of the staple foods in Asian countries. Grain yield can be drastically reduced if drought stress occurs during flowering. The global reduction in rice production due to drought averages 18 M t annually. This abiotic stress is therefore a major constraint to rice production in water-limited environments.

So developing drought resistant cultivars especially with good performance under late season drought stress is one of the major objectives in rice breeding programs (Boonjuing and Fukai, 1996; Pantuwan *et al.*, 2002).

Moreover, almost in all the experiments conducted before, drought stress was studied at early stages. In Pakistan, late drought stress is more common throughout the country. Drought occurs at reproductive stage of the crop.
Correlation and Path Coefficient Analysis of Yield Components in Rice (Oryza sativa L.) under Simulated Drought Stress Condition

therefore drought avoidance by delaying the flowering time does not help the crop to minimize the losses due to water scarcity.

Therefore, the present study was conducted to screen out the varieties that perform better in late season drought stress and to find out all the morphological parameters, both under ground and above ground, and drought related traits that are more affective in favor of plant under late season drought stress at the same time. So, in the present study, drought stress was applied at both vegetative phase in order to study the parameters such as leaf rolling, leaf drying, and at reproductive stage to minimize the effect of drought avoidance by the plant through delaying the heading date and screen out the varieties that also perform better in late season drought stress. In this study, a series of experiments were conducted in simulated drought stress environment to study the magnitude of yield responses of rice genotypes to late drought stress environments and to examine ways to identify genotypes that confer resistance to late season drought stress.

Genetic correlation about yield and yield contributing traits provide the information on extent and direction of association of plant traits (Kown, and Torrie, 1964). Path analysis furnishes information of influence of each contributing 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 study, 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 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 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 Poehlman and Sleper, 1995.

The genotypic and phenotypic correlation coefficient estimates were carried out using the formula given by Kown 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.

Drought resistant indexes, including root length (RL), shoot length (SL), root shoot ratio (RL/SL), drought respond index (DRI), yield per plant (Y/p), number of grains per panicle (G/P), thousand grain weight (TGW), spikelet
fertility (SF), and plant water status related traits, including leaf rolling percentage (LR) and leaf drying percentage (LD), were also computed.

RESULTS AND DISCUSSION

Almost all the genotypes showed significant difference for traits under simulated drought stress condition (Table 1). Higher heritability estimates for yield per plant (0.97), grains per panicle (0.99), root length (0.87), leaf rolling (0.98), leaf drying (0.97) and thousand grain weight (0.68) under drought stress condition combined with high genetic advance indicated the presence of additive genes (Table 2) (Balan et al., 2000).

Table 1: Mean squares for morphological traits under drought stress

<table>
<thead>
<tr>
<th>Characters</th>
<th>RL (cm)</th>
<th>SL (cm)</th>
<th>RL/SL</th>
<th>TGW (g)</th>
<th>G/p</th>
<th>LR (%)</th>
<th>LD (%)</th>
<th>SF</th>
<th>DRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment SS</td>
<td>301.407 **</td>
<td>154.250 *</td>
<td>1.373</td>
<td>154119.311 **</td>
<td>14411.250 **</td>
<td>2310000 **</td>
<td>42632.957 *</td>
<td>800.832 *</td>
<td>6501.634 **</td>
</tr>
<tr>
<td>Replication SS</td>
<td>444.900</td>
<td>280.900</td>
<td>7.700</td>
<td>980.400</td>
<td>1522.500</td>
<td>2722.500</td>
<td>422.500</td>
<td>5062.500</td>
<td>58882.203</td>
</tr>
<tr>
<td>Error SS</td>
<td>89.100</td>
<td>49.100</td>
<td>1.498</td>
<td>111.600</td>
<td>147.500</td>
<td>183.500</td>
<td>51.500</td>
<td>583.500</td>
<td>495.274</td>
</tr>
<tr>
<td>Total SS</td>
<td>839.407</td>
<td>484.250</td>
<td>10.571</td>
<td>1579.247</td>
<td>13560.111</td>
<td>17347.250</td>
<td>2784.000</td>
<td>40078.597</td>
<td>60230.510</td>
</tr>
<tr>
<td>G.M.</td>
<td>12.820 (0.89)</td>
<td>14.732 (0.86)</td>
<td>0.869</td>
<td>28.136 (g)</td>
<td>161.807 (g)</td>
<td>74.250 (%</td>
<td>18.000 (%)</td>
<td>58.254 (%)</td>
<td>44.733</td>
</tr>
<tr>
<td>Replication MS</td>
<td>224.400</td>
<td>140.450</td>
<td>3.850</td>
<td>480.200</td>
<td>661.250</td>
<td>1561.250</td>
<td>211.250</td>
<td>2531.250</td>
<td>29441.102</td>
</tr>
<tr>
<td>Treatment MS (df = 19)</td>
<td>15.864</td>
<td>8.118</td>
<td>0.072</td>
<td>16.171</td>
<td>709.811</td>
<td>780.058</td>
<td>121.579</td>
<td>2243.840</td>
<td>46.781</td>
</tr>
<tr>
<td>Error MS (df = 1)</td>
<td>2.345</td>
<td>1.292</td>
<td>0.059</td>
<td>2.957</td>
<td>3.882</td>
<td>4.829</td>
<td>1.355</td>
<td>10.992</td>
<td>12.086</td>
</tr>
</tbody>
</table>

Genotypic and phenotypic correlation coefficients among all traits were estimated. Results clearly indicate that grains per panicle (0.733**), spikelet fertility (0.709**), thousand grain weight (0.476**), root length (0.465**), root to shoot length ratio (0.242*), drought response index (0.642**) has significant and positive relation with yield per plant; while leaf drying (-0.599**) is significant and negatively correlated with yield per plant under drought stress condition (Table 3). At phenotypic level, the similar results were observed (Yue
et al., 2002; Kanbar and Shashidhar, 2004; Pentuwan et al., 2006; Dang et al., 2006; Yang et al., 2002).

Table 2: Estimates of Genotypic, Phenotypic and Environmental variances and coefficient of variability for morphological traits under drought condition and Heritability (Broad sense) and Genetic Advance estimates

<table>
<thead>
<tr>
<th>Characters</th>
<th>RL</th>
<th>SL</th>
<th>RL/SL</th>
<th>TGW</th>
<th>G/p</th>
<th>LR</th>
<th>LD</th>
<th>SF</th>
<th>DRI</th>
<th>Y/p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotypic variances (Vg)</td>
<td>4.506</td>
<td>2.275</td>
<td>0.011</td>
<td>4.411</td>
<td>2351.677</td>
<td>251.74</td>
<td>40.075</td>
<td>744.583</td>
<td>11.565</td>
<td>114.762</td>
</tr>
<tr>
<td>Phenotypic variances (Vp)</td>
<td>6.851</td>
<td>3.568</td>
<td>0.050</td>
<td>7.348</td>
<td>2355.558</td>
<td>256.57</td>
<td>41.430</td>
<td>754.675</td>
<td>23.651</td>
<td>117.404</td>
</tr>
<tr>
<td>Environmental variances (Ve)</td>
<td>2.345</td>
<td>1.292</td>
<td>0.039</td>
<td>2.937</td>
<td>3.882</td>
<td>4.829</td>
<td>1.355</td>
<td>10.092</td>
<td>12.086</td>
<td>2.642</td>
</tr>
<tr>
<td>Phenotypic coefficient of Variability (PCV)</td>
<td></td>
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<tr>
<td>Genotypic coefficient of Variability (GCV)</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heritability B.S.</td>
<td>0.658</td>
<td>0.638</td>
<td>0.217</td>
<td>0.600</td>
<td>0.998</td>
<td>0.981</td>
<td>0.967</td>
<td>0.987</td>
<td>0.489</td>
<td>0.977</td>
</tr>
</tbody>
</table>

RL=root length, SL=shoot length, RL/SL=root shoot length ratio, TGW=1000 grain weight, Y/p=yield per plant, LR=Leaf area, LD=Leaf drying, G/p=grains per panicle, DRI=Drought response index

Table 3: Genotypic (above) and phenotypic (below) correlation coefficients for drought related traits with yield per plant under simulated drought stress condition

<table>
<thead>
<tr>
<th>Characters</th>
<th>SL</th>
<th>RL/SL</th>
<th>TGW</th>
<th>G/p</th>
<th>SF</th>
<th>DRI</th>
<th>Y/p</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL</td>
<td>G</td>
<td>-0.428**</td>
<td>0.284**</td>
<td>-0.159**</td>
<td>0.286**</td>
<td>0.127**</td>
<td>0.105**</td>
</tr>
<tr>
<td>P</td>
<td>-0.316**</td>
<td>0.652**</td>
<td>0.212*</td>
<td>-0.407*</td>
<td>-0.157*</td>
<td>0.155*</td>
<td>0.008*</td>
</tr>
<tr>
<td>SL</td>
<td>G</td>
<td>-0.762**</td>
<td>0.037**</td>
<td>-0.387**</td>
<td>-0.488*</td>
<td>0.096*</td>
<td>0.159**</td>
</tr>
<tr>
<td>P</td>
<td>-0.483**</td>
<td>0.149*</td>
<td>-0.149*</td>
<td>-0.434*</td>
<td>0.073*</td>
<td>0.135**</td>
<td>0.240*</td>
</tr>
<tr>
<td>RL/SL</td>
<td>G</td>
<td>0.183**</td>
<td>0.632**</td>
<td>0.255**</td>
<td>0.073**</td>
<td>-0.049**</td>
<td>-0.224**</td>
</tr>
<tr>
<td>P</td>
<td>0.064</td>
<td>0.375**</td>
<td>0.124**</td>
<td>0.037**</td>
<td>-0.032**</td>
<td>-0.016**</td>
<td>0.189**</td>
</tr>
<tr>
<td>TGW</td>
<td>G</td>
<td>-0.130**</td>
<td>-0.472**</td>
<td>0.412**</td>
<td>0.161**</td>
<td>0.044*</td>
<td>0.416**</td>
</tr>
<tr>
<td>P</td>
<td>-0.133**</td>
<td>-0.403**</td>
<td>0.343**</td>
<td>0.115**</td>
<td>-0.116*</td>
<td>0.358**</td>
<td></td>
</tr>
<tr>
<td>LR</td>
<td>G</td>
<td>0.322*</td>
<td>-0.188*</td>
<td>-0.199**</td>
<td>0.020**</td>
<td>0.050*</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.322*</td>
<td>-0.185*</td>
<td>-0.202**</td>
<td>0.032*</td>
<td>-0.041**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>G</td>
<td>-0.577**</td>
<td>-0.556**</td>
<td>-0.718**</td>
<td>-0.599**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>-0.565**</td>
<td>-0.544**</td>
<td>-0.646**</td>
<td>-0.560**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G/P</td>
<td>G</td>
<td>0.836**</td>
<td>0.570**</td>
<td>0.731**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.827**</td>
<td>0.518**</td>
<td>0.707**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF</td>
<td>G</td>
<td>0.696**</td>
<td>0.709**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.637**</td>
<td>0.677**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRI</td>
<td>G</td>
<td>0.642**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.628**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RL=root length, SL=shoot length, RL/SL=root shoot length ratio, TGW=1000 grain weight, Y/p=yield per plant, LR=Leaf area, LD=Leaf drying, G/p=grains per panicle, DRI=Drought response index
Under drought stress, direct effect of root length was negative and high. Indirect effect via root shoot ratio was positive and high (2.436). Total correlation coefficient (0.465) between yield per plant and root length was mainly due to root to shoot length ratio. It emphasizes that selection of root length alone in drought stress would not be reliable criteria for improving yield per plant (Table 4).

Table 4: Direct and indirect effects of drought related traits on yield per plant under simulated drought stress condition

<table>
<thead>
<tr>
<th>Characters</th>
<th>RL</th>
<th>SL</th>
<th>RL/SL</th>
<th>TGW</th>
<th>LR</th>
<th>LD</th>
<th>G/P</th>
<th>SF</th>
<th>DRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL</td>
<td>-0.645</td>
<td>0.276</td>
<td>-0.534</td>
<td>-0.186</td>
<td>-0.311</td>
<td>0.125</td>
<td>-0.133</td>
<td>-0.080</td>
<td>-0.068</td>
</tr>
<tr>
<td>SL</td>
<td>-0.653</td>
<td>1.527</td>
<td>-1.164</td>
<td>0.010</td>
<td>-0.606</td>
<td>-0.745</td>
<td>0.131</td>
<td>0.242</td>
<td>0.479</td>
</tr>
<tr>
<td>RL/SL</td>
<td>2.436</td>
<td>-2.244</td>
<td>2.945</td>
<td>0.539</td>
<td>1.861</td>
<td>0.751</td>
<td>0.212</td>
<td>-0.118</td>
<td>-0.659</td>
</tr>
<tr>
<td>TGW</td>
<td>0.231</td>
<td>0.006</td>
<td>0.147</td>
<td>0.805</td>
<td>-0.105</td>
<td>-0.38</td>
<td>0.332</td>
<td>0.129</td>
<td>0.003</td>
</tr>
<tr>
<td>LR</td>
<td>-0.752</td>
<td>0.620</td>
<td>-0.988</td>
<td>0.203</td>
<td>-1.562</td>
<td>-0.503</td>
<td>0.293</td>
<td>0.311</td>
<td>-0.031</td>
</tr>
<tr>
<td>LD</td>
<td>-0.297</td>
<td>-0.744</td>
<td>0.389</td>
<td>-0.720</td>
<td>0.491</td>
<td>1.526</td>
<td>0.880</td>
<td>0.849</td>
<td>-1.095</td>
</tr>
<tr>
<td>G/P</td>
<td>-0.062</td>
<td>-0.060</td>
<td>-0.022</td>
<td>-0.125</td>
<td>0.057</td>
<td>0.174</td>
<td>-0.302</td>
<td>-0.253</td>
<td>-0.172</td>
</tr>
<tr>
<td>SF</td>
<td>0.047</td>
<td>-0.060</td>
<td>0.0151</td>
<td>-0.061</td>
<td>0.071</td>
<td>0.209</td>
<td>-0.316</td>
<td>-0.378</td>
<td>-0.263</td>
</tr>
<tr>
<td>DRI</td>
<td>0.257</td>
<td>0.769</td>
<td>-0.548</td>
<td>0.009</td>
<td>0.049</td>
<td>-1.759</td>
<td>1.396</td>
<td>1.705</td>
<td>2.449</td>
</tr>
</tbody>
</table>


Shoot length had positive and high direct effect (1.527) on yield per plant (Khan et al., 2004) but Indirect effect via root shoot ratio and leaf drying was highly negative (-2.244 and -0.744 respectively) and genotypic correlation between yield per plant and shoot length was non significant (0.123ns). It indicates that shoot length did not contribute in yield because of it negative indirect effect via root shoot ratio and leaf drying (Table 4).

Direct effect of root shoot length ratio was positive and high (2.945). Its genotypic correlation with yield per plant was significantly positive (0.242). It
indicates that root to shoot length ratio may be used as reliable criteria for screening high yielding genotypes in drought stress environments.

Grains per panicle had negative but negligible direct effect (-0.302) on yield per plant and had indirect effect via DRI was high and positive (1.705). Value of genotypic correlation coefficient (0.773) between yield per plant and grains per panicle was highly positive. It indicates that grains per panicle would not be reliable criteria for improving yield per plant (Table 4).

Direct effect of thousand grain weight was positive and high (0.805) and its indirect effects via root length was negative and high, via root shoot ratio (0.539) was positive but pronounced and via leaf drying (-0.720) negative but high. Genotypic correlation coefficient value between yield per plant and thousand grain weight (0.476) was highly significant and positive (Munir et al., 2007). It indicates that thousand grain weight may be used as reliable criteria for improving yield per plant (Table 4).

Leaf rolling had negative and high (-1.562) direct effect on yield per plant and its indirect effect via root shoot ratio (1.861) were high and positive. Likewise, genotypic correlation coefficient value between yield per plant and leaf rolling (-0.050) was negative but significant. It indicates that leaf rolling would not be reliable criteria for improving yield per plant (Table 4).

Under drought stress, direct effect of leaf drying was positive and high (1.526) and indirect effects via shoot length (-0.745) was negative and high, via root shoot ratio (0.751) was positive and pronounced, via leaf rolling negative and high, and via DRI (-1.759) was negative and high. Its genotypic correlation coefficient value (-0.599) with yield per plant was highly negative. So, it may be used as reliable criteria for improving yield per plant under drought prone environments (Table 4).

Direct effect of drought response index on yield per plant was positive and high (2.449). Indirect effects via shoot length (0.479) was positive but negligible
while indirect effect via root shoot ratio (-0.659) and leaf drying (-1.095) was negative and high. Its genotypic correlation coefficient value (0.642) with yield per plant was highly positive. The results indicate that DRI may be used as direct criteria for improving drought resistance in rice (Table 4).

From the concluded results it can be suggested that that root to shoot length ratio, thousand grain weight, leaf drying and drought response index may be used as reliable criteria for improving drought resistance in rice.

CONCLUSIONS

Results suggested that root to shoot length ratio, thousand grain weight, leaf drying and drought response index may be used as reliable criteria for improving drought resistance. Higher heritability and Genetic Advance estimates for all the traits under drought condition indicates that these characters can be exploited more efficiently through selection in further generations.

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