

**Research Article****Association analysis in F<sub>1</sub> and F<sub>2</sub> generations of rice under reproductive stage drought stress**

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**Abstract**

Drought stress occurring at reproductive stages has severe impact in rice yield as it adversely affects grain filling. Rice genotypes with earliness (to avoid terminal drought), better internal water balance and deeper root system (to extract water from deeper layers of soil) tend to withstand to a greater extent and give nominal yields under drought situations. In order to understand the nature and extent of association between traits of drought tolerance and grain yield under reproductive stage drought stress, association analysis was performed in F<sub>1</sub> and F<sub>2</sub> generations of rice. In F<sub>1</sub>, days to 70% RWC and root traits *viz.*, root thickness, root/shoot ratio, root length, root volume and dry root weight exhibited significant positive association with grain yield/plant while in F<sub>2</sub>, spikelet fertility and root traits *viz.*, root length, dry root weight, root thickness and root/shoot ratio had positive and significant association with grain yield. Negative and significant association was noticed between grain yield and days to 50% flowering, leaf drying and drought recovery scores in F<sub>1</sub> and between grain yield and days to flowering in F<sub>2</sub>. Positive intercorrelation was noticed between spikelet fertility and root traits in both F<sub>1</sub> and F<sub>2</sub>. Hence selection based on earliness and root characters will be helpful in identifying genotypes with better drought tolerance capacity and grain yield under rainfed conditions. Productive tillers/plant, 100 grain weight and harvest index in F<sub>1</sub> and harvest index, root length and dry root weight in F<sub>2</sub> were the major contributors of grain yield by way of their positive and high direct effects.

**Key words:** Association analysis, drought recovery, root traits, RWC.

**Introduction**

Sustaining food production to meet the needs of growing population is a challenging task due to ever shrinking arable land and water source available for agriculture. A sizeable amount of rice production in India comes from rainfed uplands where drought at any stages of crop growth causes severe damages to rice crop ultimately reducing the grain yield. Developing drought tolerant rice varieties may be a probable solution to the rainfed ecosystems. High yield in rainfed situations has always been attributed to the drought tolerant nature of the genotype. Association analysis reveals the relationship between the various independent yield contributing characters with the dependent variable of interest, the grain yield. As yield improvement in rainfed upland situations is difficult without understanding the association of secondary and putative traits of drought tolerance with grain yield, the present study has been framed to identify the nature of association among

important yield contributing, physiological and morphological traits of drought tolerance with grain yield in F<sub>1</sub> and F<sub>2</sub> generations of rice.

**Materials and methods**

The present investigation was carried out in the Research farm, Agricultural College and Research Institute, Madurai using nine rice genotypes *viz.*, CPMB ACM 04001, CPMB ACM 04004, PMK 2, MDU 5, Norungan, Nootripathu, Kallurundaikar, Moroberekan and CT 9993 and their 36 F<sub>1</sub> hybrids during *kharif*, 2005 and F<sub>2</sub> segregating generation of 5 selected cross combinations during *Rabi*, 2005. The F<sub>1</sub> hybrids were raised in a Randomized block design replicated thrice in a single row plot of 3m length adopting a spacing of 20cm between rows and 15cm between plants. 150 plants each in 5 selected crosses were maintained for the study in F<sub>2</sub> generation in a randomized block design with 3 replications in rows of 2m length adopting a spacing of 20 x 15cm. Drought stress was imposed during the reproductive stage at 86<sup>th</sup> day of sowing for 20 days to assess the drought tolerance capacity of genotypes. Observations were recorded on 18 yield contributing and drought tolerant characters

*viz.*, days to 50% flowering, plant height, productive tillers/plant, panicle length, filled grains/panicle, 100grain weight, spikelet fertility, days to 70% RWC, leaf rolling, leaf drying, chlorophyll content, drought recovery rate, root length, dry root weight, root volume, root thickness, root/shoot ratio, harvest index and grain yield/plant were recorded in 5 plants selected at random in F<sub>1</sub> generation and on 7 drought tolerant attributes *viz.*, days to first flowering, spikelet fertility, root length, dry root weight, root thickness, root/shoot ratio and harvest index during and after imposition of drought stress and at the time of harvest as per the Standard evaluation system for rice (IRRI, 1996).

The genotypic correlation coefficients between yield and 18 yield component and drought tolerant traits were worked out in F<sub>1</sub> and phenotypic correlation coefficient between yield and seven drought tolerant attributes were calculated in F<sub>2</sub> as suggested by Al-Jibouri *et al.* (1958). The relative influence of 18 components on yield by themselves (direct effects) and through other traits (indirect effects) in F<sub>1</sub> and that of seven drought tolerant traits with grain yield in F<sub>2</sub> generation of the five selected crosses was evaluated by the method of path coefficient analysis as suggested by Dewey and Lu (1959). The direct and indirect effects were classified from negligible to very high based on the scale given by Lenka and Misra (1973).

### Results and Discussion

In F<sub>1</sub> generation, significant and positive associations with grain yield/plant were exhibited by the yield contributing traits *viz.*, harvest index, productive tillers/plant, filled grains/panicle, 100 grain weight and plant height; by physiological trait *viz.*, days to 70% RWC and by root traits *viz.*, root thickness, root/shoot ratio, root length, root volume and dry root weight (Table 1). Similar results were reported earlier by Raju *et al.* (2004) for plant height, productive tillers/plant and 100 grain weight; by Surek and Beser (2003) for filled grains/panicle and harvest index and by Sheeba (2005) for days to 70% RWC, root length, dry root weight and root/shoot ratio. Significant and positive association of these traits indicates that selection based on these traits would ultimately improve grain yield under drought stress situations. A high positive correlation of root traits is a clear indication that thicker and deeper roots facilitate easy uptake of water from deeper layers of soil and help the plants improve their water relationship and

thereby yield. Similar results were already reported by Michael Gomez and Rangasamy (2002).

On the contrary, the traits like leaf drying and drought recovery rate had significant negative association with grain yield indicating their pronounced effect in reducing the grain yield under drought stress situations. Similar findings were also reported by Sheeba (2005) for both leaf drying and drought recovery rate.

In F<sub>2</sub> generation, all the drought tolerant characters except days to first flowering recorded positive and significant correlation with grain yield/plant (Table 2). This is in conformity to the findings of Rao and Shrivastav (1999) for spikelet fertility; Sheeba (2005) for root length; Anbumalarmathi (2005) for dry root weight; Sinha *et al.* (2000) for root thickness; Chandra and Das (2000) for root/shoot ratio and Shashidhar *et al.* (2005) for harvest index. The negative and significant correlation of days to first flowering with grain yield observed in the present study also corroborates with the results of Kumar *et al.* (2004).

The intercorrelation among the important component traits is also important in order to decide upon which traits to be given due weightage in exercising selection. It is interesting to note that the important yield contributing traits *viz.*, panicle length, filled grains/panicle, spikelet fertility and harvest index had significant negative correlation with leaf drying and drought recovery rate in F<sub>1</sub>. Hence this may be the reason for negative correlation of yield with leaf drying and drought recovery rate. Also the physiological traits of drought tolerance *viz.*, days to 70% RWC and leaf rolling exhibited significant and negative intercorrelation with leaf drying. Sheeba (2005) also reported the negative intercorrelation between days to 70% RWC and leaf drying. Hence pronounced leaf rolling tends to conserve more moisture and thereby prevent leaf drying.

The yield contributing traits *viz.*, plant height and productive tillers/plant showed positive and significant intercorrelation with most of the root traits studied. Positive and significant correlation was also noticed between panicle length and dry root weight; filled grains/panicle and root length and between 100 grain weight and root thickness. This indicates the favourable effect of root traits in improving the yield attributes and thereby grain yield. Similar were the findings of Adnankanbar *et al.* (2004) for plant height and productive tillers/plant with root traits *viz.*, root length and dry

root weight. Michael Gomez and Rangasamy (2002) also reported similar results for filled grains/panicle with root length. The root traits exhibited positive intercorrelation among themselves with some of them showing significance. This is in conformity to the findings of Gireesha *et al.* (2000).

In  $F_2$ , positive intercorrelation was noticed between spikelet fertility, all other root traits and harvest index while days to first flowering had negative and significant intercorrelation with all other traits of drought tolerance and harvest index. Ekanayake *et al.* (1985) already established the positive association of root traits *viz.*, root length, root thickness and dry root weight among themselves. Sathya *et al.* (1999) reported negative intercorrelation of days to 50% flowering and harvest index. Negative intercorrelation between flowering delay and spikelet fertility was reported by Kumar and Kujur (2003). Positive intercorrelation of spikelet fertility with root length, dry root weight and root/shoot ratio was reported by Sheeba (2005).

Hence from the present study it could be inferred that grain yield in rice under drought stress could be improved by identifying genotypes with traits of drought tolerance *viz.*, spikelet fertility, root characters and yield contributing traits *viz.*, harvest index, productive tillers/plant, filled grains/panicle and 100 grain weight. Also the positive intercorrelation existing between root traits and spikelet fertility is a boon to rice workers as this provides opportunities for the simultaneous improvement of such characters. The study also indicated that delay in flowering has a pronounced negative effect on grain yield and other drought tolerant attributes. Hence earliness in flowering has to be concentrated while undertaking selection for drought tolerance in rice especially for reproductive stage stress. Enough care should also be given to select genotypes that show lesser leaf drying and low drought recovery scores.

Path coefficient analysis is done in order to study the direct and indirect effects of individual component characters on the dependent variable yield. Study of path coefficients enable breeders to concentrate on the variable which shows high direct effect on grain yield. Ultimately we can reduce the time in looking for more number of component traits by restricting selection to one or few important traits. In the present study, productive tillers/plant, 100 grain weight and harvest index had high direct effects on grain yield/plant, while filled grains/panicle had medium

direct effect on grain yield/plant in  $F_1$  (Table 3). This is in accordance to the findings of Raju *et al.* (2004) for productive tillers/plant; Bhattacharya and Ghosh (2004) for 100 grain weight. Most of the root traits also had low to medium indirect effects via productive tillers/plant and harvest index. Similar results were earlier obtained by Yogameenakshi *et al.* (2004) for root length through harvest index. In  $F_2$  generation, root characters like root length, dry root weight and harvest index had positive and high direct effects on grain yield (Table 4). The indirect effect of all other characters were moderate to high through root dry weight, root length and harvest index thus indicating their predominant role in influencing grain yield under drought stress situations. This coincides with the results of Sheeba (2005) for dry root weight; Shashidhar *et al.* (2005) for harvest index and Anbumalarmathi (2005) for root length and harvest index.

Hence the trait harvest index in  $F_1$  and  $F_2$  is the major yield contributing trait under drought conditions and should be considered for improving yield under moisture stress conditions.

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**Table 1. Genotypic correlation coefficients of different characters with grain yield/plant in F<sub>1</sub> generation**

Characters	PH	PT/P	PL	FG/P	HGW	SF	RWC	LR	LD	CC	DRR	RL	DRW	RV	RT	R/S	HI	GYP
<b>DDF</b>	0.512*	0.173	0.332*	-0.094	0.238	0.039	-0.155	-	-0.095	-	-0.277	0.018	0.225	0.246	0.305*	-	0.045	<b>0.143</b>
<b>PH</b>	1.000	0.373*	0.452*	0.165	0.123	-	0.199	0.227	-0.282	-	-0.182	0.271	0.517*	0.519*	0.378*	0.320	0.154	<b>0.306*</b>
<b>PT/P</b>		1.000	0.014	0.303*	0.053	-	0.118	-	-0.086	-0.084	-	0.359*	0.532*	0.525*	0.330*	0.501	0.572*	<b>0.709*</b>
<b>PL</b>			1.000	0.330*	0.160	0.015	0.306*	0.352	0.302	-0.057	-	0.258	0.296*	0.204	0.238	0.136	0.089	<b>0.257</b>
<b>FG/P</b>				1.000	0.095	0.384*	0.310*	0.134	-	0.108	-	0.325*	0.182	0.231	0.256	0.254	0.579*	<b>0.602*</b>
<b>HGW</b>					1.000	0.129	0.118	-	0.0052	-0.216	-0.249	0.124	0.115	0.073	0.431*	0.077	0.326*	<b>0.515*</b>
<b>SF</b>						1.000	0.347*	0.047	-	0.170	-	0.109	-0.024	-0.049	-0.106	-	0.173	<b>0.156</b>
<b>RWC</b>							1.000	0.672*	-	0.197	-0.120	0.364*	0.015	0.002	0.028	0.121	0.442*	<b>0.428*</b>
<b>LR</b>								1.000	-	0.093	0.040	0.113	-0.127	-0.142	0.140	-	0.196	<b>0.063</b>
<b>LD</b>									1.000	-0.143	0.467*	-0.248	0.041	0.027	-0.084	-	-0.250	-
<b>CC</b>										1.000	0.049	-0.030	-0.112	-0.064	-0.127	-	-0.004	<b>-0.038</b>
<b>DRR</b>											1.000	-0.088	-0.081	-0.046	-0.276	-	-0.320*	-
<b>RL</b>												1.000	0.579*	0.616*	0.242	0.594*	0.443*	<b>0.438*</b>
<b>DRW</b>													1.000	0.964*	0.378*	0.688*	0.193	<b>0.409*</b>
<b>RV</b>														1.000	0.345*	0.646*	0.219	<b>0.410*</b>
<b>RT</b>															1.000	0.249	0.358*	<b>0.450*</b>
<b>R/S</b>																1.000	0.362*	<b>0.446*</b>
<b>HI</b>																	1.000	<b>0.851*</b>

\* Significant at 5% level

**DDF** – Days to 50% flowering

**PH** – Plant height

**PT/P** - Productive tillers /plant

**PL** – Panicle length

**FG/P** – Filled grains/panicle



**HGW** – 100 grain weight      **SF** – Spikelet fertility      **RWC** – Days to 70% RWC      **LR** – Leaf rolling      **LD** – Leaf drying  
**CC** – Chlorophyll content      **DRR** – Drought recovery rate      **RL** – Root length      **DRW** – Dry root weight      **RV** – Root volume  
**RT** – Root thickness      **R/S** – Root/Shoot ratio      **HI** – Harvest index      **GY/P** – Grain yield/plant

**Table 2. Phenotypic Correlation coefficients between different traits in F<sub>2</sub> generation**

<i>Traits</i>		Correlation coefficient ( r )				
		Cross 1	Cross 2	Cross 3	Cross 4	Cross 5
Grain yield/plant Vs	Days to first flowering	-0.6460*	-0.4311*	-0.3808*	-0.3174*	-0.1965*
	Spikelet fertility	0.5118*	0.3086*	0.4213*	0.2690*	0.3251*
	Root length	0.9361*	0.9166*	0.5705*	0.6596*	0.5956*
	Root dry weight	0.9311*	0.9248*	0.6866*	0.6491*	0.5539*
	Root thickness	0.9175*	0.8713*	0.3610*	0.3465*	0.5164*
	Root/shoot ratio	0.8125*	0.8339*	0.6869*	0.5687*	0.2421*
	Harvest index	0.9143*	0.9295*	0.9540*	0.9054*	0.9154*
<b>Days to flowering Vs</b>	Spikelet fertility	-0.4743*	-0.2337*	-0.4771*	-0.5590*	-0.3608*
	Root length	-0.6424*	-0.3834*	-0.4570*	-0.6021*	-0.3144*
	Root dry weight	-0.6626*	-0.4021*	-0.4894*	-0.5597*	-0.2890*
	Root thickness	-0.6354*	-0.4464*	-0.3075*	-0.3251*	-0.3158*
	Root/shoot ratio	-0.5400*	-0.3686*	-0.4289*	-0.5394*	-0.2355*
<b>Spikelet fertility Vs</b>	Harvest index	-0.6710*	-0.4367*	-0.4157*	-0.3064*	-0.2054*
	Root length	0.5553*	0.3049*	0.5565*	0.5063*	0.5507*
	Root dry weight	0.5778*	0.3323*	0.5258*	0.4923*	0.4916*
	Root thickness	0.5163*	0.3411*	0.2818*	0.3040*	0.4923*
	Root/shoot ratio	0.5185*	0.2616*	0.4819*	0.5103*	0.2537*
<b>Root length Vs</b>	Harvest index	0.5413*	0.3798*	0.4384*	0.2859*	0.3148*
	Root dry weight	0.9627*	0.8616*	0.7814*	0.9479*	0.957*
	Root thickness	0.9175*	0.8299*	0.5003*	0.5707*	0.8909*
	Root/shoot ratio	0.8245*	0.7611*	0.7399*	0.8467*	0.5310*
<b>Root dry weight Vs</b>	Harvest index	0.9283*	0.8770*	0.5459*	0.6664*	0.5652*
	Root thickness	0.8953*	0.8562*	0.4673*	0.5521*	0.8549*
	Root/shoot ratio	0.8416*	0.8893*	0.9139*	0.9103*	0.5670*
<b>Root thickness Vs</b>	Harvest index	0.9023*	0.9299*	0.6449*	0.6430*	0.5198*
	Root/shoot ratio	0.7691*	0.7411*	0.4109*	0.4815*	0.4668*
<b>Root/shoot ratio Vs</b>	Harvest index	0.9181*	0.8591*	0.3690*	0.3615*	0.4765*
	Harvest index	0.7754*	0.7411*	0.6564*	0.5872*	0.2566*

\* Significant at 5% level



**Table 3. Direct and indirect effects of different characters on grain yield in F<sup>1</sup> generation**

Characters	DFE	PH	PT/P	PL	FG/P	HGW	SF	RWC	LR	LD	CC	DRR	RL	DRW	RV	RT	R/S	HI	GYP	
<b>DFE</b>	<b>0.009</b>	-	0.072	0.031	-	0.091	-	-0.021	0.004	0.017	0.008	-	-	0.008	0.035	-	0.000	0.017	<b>0.143</b>	
<b>PH</b>	0.005	<b>0.069</b>	-	0.156	0.042	0.038	0.047	0.004	0.026	-	0.051	0.011	-	-	0.019	0.075	-	-	0.056	<b>0.306*</b>
<b>PT/P</b>	0.002	<b>0.134</b>	-	<b>0.418</b>	0.001	0.069	0.020	0.002	0.016	0.005	0.016	0.002	-	-	0.019	0.076	-	-	0.210	<b>0.709*</b>
<b>PL</b>	0.003	0.050	-	0.006	<b>0.092</b>	0.075	0.061	-	0.047	-	0.098	0.001	-	-	0.011	0.029	-	-	0.033	<b>0.257</b>
<b>FG/P</b>	-	0.061	-	0.127	0.030	<b>0.227</b>	0.036	-	0.042	0.023	0.098	0.001	-	0.023	0.035	0.011	0.029	-	0.013	0.003
<b>HGW</b>	0.001	0.022	-	0.022	0.015	0.021	<b>0.383</b>	-	0.041	-	0.058	-	-	-	0.007	0.033	-	-	0.213	<b>0.602*</b>
<b>SF</b>	0.002	-	0.022	0.015	0.021	<b>0.383</b>	-	0.016	0.015	-	0.005	-	-	0.004	0.011	-	-	0.120	<b>0.515*</b>	
<b>RWC</b>	0.000	0.017	-	0.028	0.087	0.050	-	0.046	-	0.074	-	-	-	-	-	0.023	0.001	0.063	<b>0.156</b>	
<b>LR</b>	-	0.004	0.006	0.049	0.032	0.070	0.045	-	<b>0.139</b>	0.004	0.004	0.028	0.015	0.001	0.007	0.007	-	-	0.163	<b>0.428*</b>
<b>LD</b>	0.001	0.027	-	0.049	0.032	0.070	0.045	-	<b>0.132</b>	-	0.127	-	-	0.001	0.000	-	-	0.163	<b>0.428*</b>	
<b>CC</b>	-	-	-	0.028	0.030	-0.074	-	0.048	0.052	0.004	0.004	0.007	0.049	0.002	0.002	0.002	0.002	0.072	<b>0.063</b>	
<b>DRR</b>	0.001	0.030	0.024	-	-	0.020	0.056	-0.092	0.043	-	0.102	-	0.002	-	-	-	-	0.002	0.072	<b>0.063</b>
<b>RL</b>	-	0.038	-	-	-	0.020	0.056	-0.092	0.043	-	0.102	-	0.002	-	-	-	-	0.002	0.072	<b>0.063</b>
<b>DRW</b>	0.001	-	0.036	0.049	0.072	-	-	-	<b>0.183</b>	0.026	-	0.003	0.004	-	-	0.007	0.002	-	0.092	<b>0.294*</b>
<b>RV</b>	-	0.065	-	-	0.024	-0.083	-	0.026	-	0.026	-	0.003	0.004	-	-	0.007	0.002	-	0.092	<b>-0.038</b>
<b>RT</b>	0.003	-	0.035	0.005	-	-	0.024	0.026	-	0.026	-	0.003	0.004	-	-	0.007	0.002	-	0.092	<b>-0.038</b>
<b>R/S</b>	-	0.024	-	-	-	-0.096	0.069	-0.016	-	-	-	<b>0.057</b>	0.012	-	-	0.015	0.001	-	-	<b>0.001</b>
<b>HI</b>	0.002	-	0.158	0.037	0.074	-	-	0.003	0.085	0.001	0.001	-	-	0.003	0.007	0.015	0.001	-	0.117	<b>0.421*</b>
<b>GYP</b>	0.000	-	0.150	0.024	0.074	0.048	-	0.048	-	0.045	0.001	-	-	0.021	0.089	-	-	0.163	<b>0.438*</b>	
<b>DFE</b>	0.002	0.036	-	0.223	0.027	0.041	0.044	0.003	0.002	0.010	-	0.003	-	<b>0.037</b>	0.139	-	-	0.071	<b>0.409*</b>	
<b>PH</b>	0.002	-	0.220	0.019	0.052	0.028	0.007	0.000	0.011	-	0.001	-	-	0.035	<b>0.144</b>	-	-	0.080	<b>0.410*</b>	
<b>PT/P</b>	0.003	0.070	-	0.138	0.022	0.058	0.165	0.015	0.004	-	0.015	0.003	-	0.014	0.050	-	-	0.132	<b>0.450*</b>	
<b>PL</b>	0.000	-	0.209	0.013	0.058	0.029	0.012	0.016	0.007	0.007	0.002	-	-	0.025	0.093	-	-	0.133	<b>0.446*</b>	
<b>FG/P</b>	0.000	0.043	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>HGW</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>SF</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>RWC</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>LR</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>LD</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>CC</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>DRR</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>RL</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>DRW</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>RV</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>RT</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>R/S</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>HI</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	
<b>GYP</b>	0.000	0.021	-	0.239	0.008	0.131	0.125	-	0.059	-	0.046	0.000	-	0.007	0.031	-	-	<b>0.367</b>	<b>0.851*</b>	

Residual = 0.0294

\* Significant at 5% level

Direct effects on the main diagonal



**DFF** – Days to 50% flowering      **PH** – Plant height      **PT/P** - Productive tillers /plant      **PL** – Panicle length      **FG/P** – Filled grains/panicle  
**HGW** – 100 grain weight      **SF** – Spikelet fertility      **RWC** – Days to 70% RWC      **LR** – Leaf rolling      **LD** – Leaf drying  
**CC** – Chlorophyll content      **DRR** – Drought recovery rate      **RL** – Root length      **DRW** – Dry root weight      **RV** – Root volume  
**RT** – Root thickness      **R/S** – Root/Shoot ratio      **HI** – Harvest index      **GY/P** – Grain yield/plant

**Table 4. Direct and indirect effects of different traits on grain yield/plant in F<sub>2</sub> generation**

Cross	Trait	Days to flowering	Spikelet fertility	Root length	Dry root weight	Root thickness	Root: shoot ratio	Harvest index	Phenotypic correlation with Grain yield/plant
1.	Days to flowering	<b>-0.0180</b>	0.0237	-0.1169	-0.2094	-0.1680	-0.0394	-0.1180	-0.646*
	Spikelet fertility	0.0085	<b>-0.0500</b>	0.1011	0.1826	0.1365	0.0379	0.0952	0.5118*
	Root length	0.0115	-0.0278	<b>0.1820</b>	0.3043	0.2426	0.0602	0.1632	0.9361*
	Dry root weight	0.0119	-0.0289	0.1752	<b>0.3160</b>	0.2367	0.0615	0.1586	0.9311*
	Root thickness	0.0114	-0.0258	0.1670	0.2829	<b>0.2644</b>	0.0562	0.1614	0.9175*
	Root/shoot ratio	0.0097	-0.0259	0.1501	0.2660	0.2034	<b>0.0730</b>	0.1363	0.8125*
	Harvest index	0.0121	-0.0271	0.1690	0.2852	0.2428	0.0566	<b>0.1758</b>	0.9143*
	Residual effect = 0.0866								
2.	Days to flowering	<b>-0.0241</b>	0.0082	-0.1314	-0.0885	-0.0529	-0.0234	-0.119	-0.4311*
	Spikelet fertility	0.0056	<b>-0.0352</b>	0.1045	0.0731	0.0404	0.0166	0.1035	0.3086*
	Root length	0.0092	-0.0107	<b>0.3427</b>	0.1896	0.0983	0.0484	0.239	0.9166*
	Dry root weight	0.0097	-0.0117	0.2953	<b>0.2200</b>	0.1015	0.0566	0.2535	0.9248*
	Root thickness	0.0108	-0.0120	0.2844	0.1884	<b>0.1185</b>	0.0471	0.2341	0.8713*
	Root/shoot ratio	0.0089	-0.0092	0.2609	0.1957	0.0878	<b>0.0636</b>	0.2263	0.8339*
	Harvest index	0.0105	-0.0134	0.3006	0.2046	0.1018	0.0528	<b>0.2726</b>	0.9295*
	Residual effect = 0.0732								
3.	Days to flowering	<b>0.0506</b>	0.0126	-0.0090	-0.0770	0.0071	0.0053	-0.3704	-0.3808*
	Spikelet fertility	-0.0241	<b>-0.0264</b>	0.0109	0.0827	-0.0065	-0.0060	0.3906	0.4213*
	Root length	-0.0231	-0.0147	<b>0.0196</b>	0.1230	-0.0116	-0.0092	0.4864	0.5705*
	Dry root weight	-0.0248	-0.0139	0.0153	<b>0.1574</b>	-0.0108	-0.0113	0.5746	0.6866*
	Root thickness	-0.0156	-0.0074	0.0098	0.0735	<b>-0.0232</b>	-0.0051	0.3288	0.3610*
	Root/shoot ratio	-0.0217	-0.0127	0.0145	0.1438	-0.0095	<b>-0.0124</b>	0.5849	0.6869*
	Harvest index	-0.0210	-0.0116	0.0107	0.1015	-0.0085	-0.0081	<b>0.8910</b>	0.9540*
	Residual effect = 0.078								
4.	Days to flowering	<b>-0.0208</b>	0.0142	0.0292	-0.1673	0.0082	0.0758	-0.2568	-0.3174*
	Spikelet fertility	0.0116	<b>-0.0255</b>	-0.0246	0.1472	-0.0076	-0.0717	0.2396	0.2690*



	Root length	0.0125	-0.0129	<b>-0.0486</b>	0.2834	-0.0144	-0.1190	0.5585	0.6596*	
	Dry root weight	0.0116	-0.0125	-0.046	<b>0.2990</b>	-0.0139	-0.1279	0.5389	0.6491*	
	Root thickness	0.0068	-0.0077	-0.0277	0.1651	<b>-0.0251</b>	-0.0677	0.3030	0.3465*	
	Root/shoot ratio	0.0112	-0.0130	-0.0411	0.2722	-0.0121	<b>-0.1405</b>	0.4921	0.5687*	
	Harvest index	0.0064	-0.0073	-0.0324	0.1923	-0.0091	-0.0825	<b>0.8381</b>	0.9054*	
	Residual effect t = 0.1681									
5.	Days to flowering	<b>0.0115</b>	0.0021	-0.0186	-0.0162	-0.0134	0.0130	-0.1748	-0.1965*	
	Spikelet fertility	-0.0041	<b>-0.0058</b>	0.0326	0.0276	0.0209	-0.0140	0.2679	0.3251*	
	Root length	-0.0036	-0.0032	<b>0.0591</b>	0.0537	0.0378	-0.0293	0.4810	0.5956*	
	Dry root weight	-0.0033	-0.0028	0.0566	<b>0.0561</b>	0.0363	-0.0313	0.4423	0.5539*	
	Root thickness	-0.0036	-0.0028	0.0527	0.0480	<b>0.0424</b>	-0.0257	0.4055	0.5164*	
	Root/shoot ratio	-0.0027	-0.0015	0.0314	0.0318	0.0198	<b>-0.0551</b>	0.2184	0.2421*	
	Harvest index	-0.0024	-0.0018	0.0334	0.0292	0.0202	-0.0141	<b>0.8509</b>	0.9154*	
	Residual effect = 0.1503									

Values on main diagonal denote direct effects \* Significant at 5% level

