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Research Note

Role of root and yield characters under drought stress in rice (*Oryza sativa L.*)

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Abstract
Drought is the major constraint to rice production and yield stability in rainfed areas. Association analysis was performed in F_1 generation of rice in order to understand the nature and extent of association among various traits and grain yield under drought stress condition. Grain yield per plant had positive association with number of productive tillers per plant, root length and root volume. Panicle length had positively correlated with 1000 grain weight, biomass yield, root length and root volume. Among root traits, dry root weight recorded highly positive significant association with root: shoot ratio, root length, root thickness and root volume. Root traits *viz.,* root volume, root thickness, root length, dry root weight and root length density were the major contributors of grain yield by way of their positive and high indirect effects.

Keywords
Rice, drought, root, yield

Rice (*Oryza sativa* L.) is the major staple crop for more than half of the global population. The present world population of 6.3 billion is likely to reach 8.5 billion by 2030. Out of this, 5 billion people will be rice consumers. Hence there is a need of 38 per cent more rice production by 2030 (Khush, 2005). To meet this challenge there is an urgent need to develop rice varieties with higher yield potential and greater yield stability. Drought is the major constraint to rice production and yield stability in rainfed areas. Land races are one of the important components of the germplasm and serve as the donors for the drought tolerance. Local land races are naturally adapted to utilize the natural resource-base better than the introduced modern cultivars (Bhattacharya and Ghosh, 2004).

Roots play key role in conferring tolerance to drought stress in rice as roots continue to elongate and can reach water in deeper soil. Root morphological traits responsible for drought tolerance include long and thick root system, secondary and tertiary roots and root penetration ability. Water capturing capacity is considered to be determined by three factors: rooting zone or depth, root length at depth and plant resistance (Dwivedi, 2014).

Complete knowledge on interrelationship of plant characters like grain yield with other characters is of paramount importance to the rice breeder for making improvement in complex quantitative characters like grain yield for which direct selection is not much effective. Hence, association analysis was undertaken to determine the direction of selection and number of characters to be considered in improving grain yield**.** Knowledge of correlation between yield and its contributing characters are basic and foremost endeavor to find out guidelines for plant selection. Partitioning of correlation into direct and indirect effect by path coefficient analysis helps in making the selection more effective (Priya and Joel, 2009). With this background the present study was undertaken.

The present scientific investigation was carried out at Agricultural Research Station, Tamil Nadu Agricultural University, Bhavani Sagar, Erode district, Tamil Nadu. Ten lines and six testers were subjected to crossing by 'Line x Tester' mating design (Kempthorne, 1957). Lines *viz.,* ADT 36, ADT 39, ADT 43, ADT(R) 49, ASD 16, BPT 5204, CO 47, CO(R) 49, CO(R) 50 and IR 50 (high yielding cosmopolitan rice varieties) and testers *viz.,* ANNA(R)4, Chandikar, Chinnar 20, Nootripathu, PMK(R) 3 and Vellaichitraikar and their 60 hybrids were sown in raised nursery beds during *Kharif*, 2013. Twenty two days old seedlings of 60 crosses along with parents were transplanted under moisture stress condition in a Randomized Block Design replicated twice adopting a spacing of 25cm between rows and 15cm between plants within a row. Single seedling was transplanted per hill in two rows of three meter row length (20 plants per row) for each cross combination and in each replication. Drought stress was imposed in field condition during the reproductive stage at 60 th day of sowing for 20 days to assess the drought tolerance capacity of genotypes.

Observations were recorded for the 15 yield and component traits *viz*., days to 50% flowering (50 F), plant height (PH), number of productive tillers per plant (NPT), panicle length (PL), spikelet fertility (SF), 1000 grain weight (1000 GW), biomass yield (BMY), relative water content (RWC), dry root weight (DRW), root / shoot ratio (R/S), root length (RL), root thickness (RT), root volume (RV), root length density and single plant yield (YLD).

The phenotypic correlation coefficients among yield and other traits were worked out in F_1 as suggested by Al-Jibouri *et al.* (1958). The relative influence of 15 components on yield by themselves (direct effects) and through other traits (indirect effects) were 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).

The single plant yield had significant and positive association with number of productive tillers per plant (0.314), root length (0.263) and root volume (0.342) (Table 1). This is in conformity with the findings of Sheeba (2005), Yogameenakshi and Vivekanandan (2010) and Renuka Devi *et al.* (2013) for root length and Surek and Beser (2003) for number of productive tillers per plant. Significant and positive association of these traits indicating selection based on these traits would improve grain yield under drought stress conditions. A high positive correlation of root traits are also indicating that thicker and deeper roots would facilitate easy uptake of water from deeper layers of soil and help the plants to improve their water relationship and yield. This is in accordance with the findings of Michael Gomez and Rangasamy (2002).

Plant height exhibited positively significant association with 1000 grain weight (0.410) and panicle length (0.338). Similar results were reported by Gunasekaran *et al.* (2010). Number of productive tillers showed positively significant association with spikelet fertility (0.243) and biomass yield (0.307). Panicle length had positively significant association with 1000 grain weight (0.379), biomass yield (0.295), root length (0.435) and root volume (0.372) while negatively correlated with root length density (-0.376). Biomass yield registered highly positive significant association with dry root weight (0.815), root length (0.399), and root volume (0.651). Hence these traits viz., plant height, panicle length, number of productive tillers per plant spikelet fertility, 1000 grain weight, biomass yield, root length and root volume are to be given importance during selection as they expressed positive and significant correlation with grain yield under drought stress situation. This was in conformity with the findings of Muthuramu *et al.* (2010).

Dry root weight recorded highly positive significant association with root: shoot ratio (0.478), root length (0.322), root thickness (0.266) and root volume (0.676). Root: shoot ratio was highly associated with root length density (0.619). Root length exhibited positively and significant association with root volume (0.479) and root thickness (0.396). Root thickness was positively intercorrelated with the trait root volume (0.488) and root volume was negatively associated with root length density (-0.505). Similar results were reported by Sinha *et al.* (2000), Yogameenakshi *et al.* (2004) and Muthuramu *et al.* (2010).

Number of productive tillers (0.360), dry root weight (0.410) and root volume (0.605) had positive and high direct effect (Table 2). The traits viz., plant height (0.207) and 1000 grain weight (0.258) exhibited moderately positive effects on single plant yield indicating that these traits there had a significant linear relationship with single plant yield. This is in accordance with the findings of Kole *et al.* (2008) and Kiani and Nematzadeh (2012).

Root volume showed positively high indirect effect with single plant yield via biomass yield (0.395), dry root weight (0.413) and root thickness (0.293) while positively moderate indirect effect through panicle length and root length. Biomass yield registered positively high indirect effect with single plant yield via root length density. These results indicated that root traits viz., root volume, root thickness, root length, dry root weight and root length density play a vital role in improving grain yield. This was in conformity with the findings of Mohan Kumar *et al.* (2011) and Renuka Devi *et al.* (2013).

Knowledge on contribution of each drought tolerant trait to grain yield in rice genotypes will be useful to assist rice breeders in indirect selection of grain yield. Based on the above discussion, number of productive tillers, dry root weight, root thickness, root volume and root length can be useful selection criteria under drought stress situation.

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Table 1. Phenotypic correlation for yield and drought tolerant traits with single plant yield

Characters	PH	NPT	PL	SF	1000GW	BMY	RWC	DRW	R/S	RL	RT	RV	RLD	SPY
50 F	0.024	-0.078	-0.028	-0.044	-0.249*	0.215	-0.020	0.215	0.067	0.062	0.222	0.195	0.003	0.108
PH	1	-0.250*	0.338**	-0.213	0.410**	-0.056	0.192	-0.09	-0.022	0.181	0.024	0.069	-0.075	0.119
NPT		1	-0.097	0.243*	-0.167	0.307**	-0.133	0.220	-0.083	-0.001	0.063	0.162	-0.238*	0.314**
PL			1	-0.185	0.379**	0.295*	0.043	0.179	-0.123	0.435**	0.113	0.372**	-0.376**	0.012
SF				1	-0.093	0.086	0.101	0.021	-0.057	-0.128	-0.073	-0.041	-0.017	0.022
1000GW					1	0.017	0.074	-0.056	-0.130	0.171	-0.009	-0.026	-0.099	0.098
BMY						1	-0.128	0.815**	-0.071	0.399**	0.214	0.651**	-0.493**	0.117
RWC							1	-0.124	-0.117	0.134	0.085	0.105	-0.105	-0.093
DRW								1	0.478**	0.322**	0.266*	0.676**	-0.101	0.172
R/S									1	-0.099	0.050	0.154	0.619**	0.104
RL										1	0.396**	0.479**	-0.336**	0.109
RT											1	0.488**	-0.286*	0.263*
RV												1	-0.505**	0.342**
RLD													1	-0.165

***Significant at 5% level, **Significant at 1% level

50 F- Days to 50 % flowering, PH - Plant height, NPT- No. of productive tillers, PL- Panicle length, SF- Spikelet fertility, 1000GW- Thousand grain weight, BMY- Biomass yield, RWC- 70 % relative water content, DRW- Dry root weight, RL- Root length,
RT- Root thickness, RV-Root volume, RLD- Root length density, SPY- Single plant yield

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Table 2. Direct and indirect effects for single plant yield through yield and drought tolerant traits

Characters	50 F	PH	NPT	PL	SF	1000GW	BMY	RWC	DRW	R/S	RL	RT	RV	RLD	Correlation with SPY
50 F	0.175	0.005	-0.033	0.007	-0.008	-0.065	-0.184	0.008	0.090	-0.014	0.002	0.003	0.118	-0.003	0.108
PH	0.004	0.207	-0.094	-0.076	-0.018	0.109	0.048	-0.080	-0.038	0.004	0.007	0.003	0.043	0.007	0.119
NPT	-0.016	-0.054	0.360	0.024	0.020	-0.044	-0.268	0.071	0.094	0.016	-0.001	0.000	0.101	0.022	0.314**
PL	-0.006	0.072	-0.040	-0.216	-0.016	0.104	-0.254	-0.018	0.076	0.025	0.017	0.001	0.231	0.035	0.012
SF	-0.008	-0.045	0.089	0.041	0.084	-0.025	-0.070	-0.038	0.006	0.013	-0.005	-0.001	-0.024	0.001	0.022
1000GW	-0.044	0.087	-0.062	-0.087	-0.008	0.258	-0.013	-0.031	-0.022	0.026	0.006	-0.001	-0.016	0.009	0.098
BMY	0.038	-0.0120	0.115	-0.065	0.007	0.004	-0.837	0.056	0.335	0.015	0.015	0.003	0.395	0.045	0.117
RWC	-0.004	0.051	-0.079	-0.012	0.009	0.024	0.145	-0.324	-0.067	0.029	0.006	0.001	0.085	0.011	-0.093
DRW	0.038	-0.019	0.083	-0.040	0.001	-0.014	-0.685	0.053	0.409	-0.096	0.012	0.004	0.413	0.010	0.172
R/S	0.012	-0.004	-0.029	0.027	-0.005	-0.034	0.062	0.047	0.193	-0.204	-0.003	0.000	0.096	-0.055	0.104
RL	0.010	0.039	-0.001	-0.097	-0.011	0.043	-0.338	-0.057	0.134	0.020	0.039	0.006	0.293	0.031	0.109
RT	0.039	0.004	0.022	-0.025	-0.006	-0.002	-0.182	-0.036	0.111	-0.010	0.016	0.015	0.302	0.028	0.263*
RV	0.034	0.014	0.060	-0.082	-0.003	-0.007	-0.547	-0.046	0.280	-0.032	0.019	0.007	0.604	0.046	0.342**
RLD	0.001	-0.016	-0.090	0.086	-0.001	-0.026	0.428	0.042	-0.048	-0.126	-0.013	-0.004	-0.313	-0.089	-0.165

Diagonal values indicate direct effects; Residual effect = 0.30

50 F- Days to 50 % flowering, PH - Plant height, NPT- No. of productive tillers, PL- Panicle length, SF- Spikelet fertility, 1000GW- Thousand grain weight, BMY- Biomass yield, RWC- 70 % Relative water content, DRW- Dry root weight, DRW- Dry root weight, RL- Root length, RT- Root thickness, RV-Root volume, RLD- Root length density, SPY- Single plant yield