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Research Article

Studies on yield, root characters related to drought tolerance and their association in upland rice genotypes

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Abstract
Plant selections with desirable root characters have been a major objective in breeding drought resistant variety of rice. Present study was therefore conducted to study the performance of rice varieties for yield, yield contributing characters, root characters and their association with drought tolerance. Drought resistant entries had recorded higher root thickness, root volume and deep root system than the susceptible genotypes. Correlation studies revealed that, all the characters showed positive and significant correlation with single plant yield. Drought score on the other hand exhibited significant negative correlation with yield. Spikelet fertility positively correlated with 1000 grain weight and yield but negatively correlated with drought score. Root depth was found positively correlated with root volume, root thickness, fresh weight of shoot and root and dry weight of shoot and root and exhibited significant negative correlation with drought score. This means that deep rooted varieties tend to be drought tolerant and have thick roots. Strong association between drought score and root thickness suggested that this character to be an important trait in identifying varieties for use in upland rice improvement for drought tolerance. Hence the characters to be given importance in selection are panicle/m^2, spikelet fertility and 1000 grain weight as they exhibited highly positive correlation with grain yield and also a positive inter-correlation among themselves. Selection based on root thickness and root depth is highly suitable for identifying varieties for use in upland rice improvement for drought tolerance.

Key words
Rice, drought tolerance, correlation studies, root characters, yield

Introduction

Rice (*Oryza sativa* L.) is the second most cultivated cereal in the world and a primary source of food for about two-thirds of the world's population (Pirdashti *et al.,* 2009). It is cultivated in at least 114 developing countries and it is the primary source of income and employment for more than 100 million house hold in Asia (Singh *et al.,* 2015). The cultivation of rice faces many different challenges, according to region, climate and cultivation system, i.e. upland or lowland. In order to be successful, plants have multiple mechanisms to respond and adapt to adverse environmental conditions. Drought stress is a problem in approximately 45% of agricultural areas and the largest global constraint to productivity, becoming a major issue in scientific reports (Heinemann *et al.,* 2015; Todaka *et al.* (2015). At least 23 million hectares of rainfed rice area in Asia are estimated to be drought prone, and drought is becoming an increasing problem even in traditionally irrigated areas (Pandey *et al.,* 2005). In rainfed conditions, water deficit can become a primary limiting factor for productivity and its importance is increasing due to climate changes (Datta *et al,* 2012). In Asia, rice cultivation areas go through dry periods of varying intensity affecting different stages of the crop cycle (Dixit *et al,* 2012). The identification or development of rice cultivars that could resist drought stress and produce economic yields is imperative in order to alleviate that increasing food crisis. Most improved cultivars grown in drought prone rainfed lowlands were originally bred for irrigated conditions and were never selected for drought tolerance (Kumar *et al.,* 2008).

Among the several traits contributing to enhance stress tolerance, root characters are considered to be a vital component of dehydration postponement mechanism since they contribute to regulation of plant growth and extraction of water and nutrients from deeper layers. Several components of root morphology contributing to drought tolerance have been identified (Ekanayake *et al.,* 1985; Lafitte, 2003). A deep and thick root system able to extract water at depth and respond to evaporative demand, provided there is water in the profile, is the most consensual of the traits contributing to drought avoidance at least in upland conditions (Yoshida and Hasegawa, 1982). In rice, significant genetic variation has been observed in various root traits. (O'Toole, 1982; Degenkolbe *et al.,* 2009). Considering these aspects, the present study was undertaken with 15 rice genotypes and were screened for drought tolerance to study the performance of rice varieties for yield, yield contributing characters, root characters and their association with drought tolerance.

Materials and Methods

A field trial was conducted in RBD replicated thrice to screen the genetic efficiency of 15 rice cultivars for their drought tolerance capacity. Line sowing was adopted with a row to row spacing of 15 cm and the crop was raised to maturity as a rain fed crop. Recommended fertilizer schedule and necessary plant protection measures were adopted. The data were recorded on days to 50% flowering, plant height, panicle /m^2, 1000 grain weight, grain yield (q/ha) and root and shoot character *viz.,* root depth, root volume, root thickness, fresh weight of shoot and root and dry weight of shoot and root. Drought score of these genotypes were done by adopting standard evaluation system (SES).The mean and standard Error of mean were computed following standard statistical methods. Correlations among these characters were also calculated.

Results and Discussion

Analysis of variance revealed significant differences among fifteen genotypes for all the characters studied. The mean performance of genotypes for yield and root characters was given in Table 1 & 2. The genotypes RR 345-2 had recorded the maximum single plant yield of 14.67 gm and found to be drought tolerant with the score of 3. The increase in yield in this genotype is due to more number of panicles and high spikelet fertility and high fresh shoot weight (52.2 g). Whereas, the genotype RR 361-3 found to be highly susceptible to drought (score 7) and recorded the lowest grain yield of 2.17 gm. The yield reduction in this genotype is due to reduction in panicle/m^2 and spikelet fertility. Root thickness ranged from 0.49 to 1.20. Drought resistant entries had recorded higher root thickness than the susceptible genotypes. Namuco & Ingram (1993) also reported that the drought tolerant varieties have thick root system than the susceptible ones.
Highest rooting depth was recorded in RR 433-1 (17.37 cm), followed by RR 345-2 (16.9 cm). Drought susceptible lines *viz.,* RR 286-1 (9.0cm) and RR 361-3 (12.00) had exhibited shallow root system. Similar findings of deep root system for drought resistant varieties were also reported by Chang *et al.* (1972), Ghil dyal and Tomar (1982). Similarly high variations were observed for root volume. Drought resistant varieties like RR 433-1 (20.60) and RR 348-6 (19.50) had recorded highest root volume than the susceptible entries.

Correlation implies a cause and effect relationship between variables. In rice, it is used to find the effect of various traits on yield. It is an index of degree of relationship between two continuous variables. Correlating genetic information with physio-morphological traits related to drought resistance will allow the development of drought resistant rice cultivars through indirect selection. The genotypic correlation co-efficients of yield with yield contributing character and drought score are presented in Table 3. In the present investigation, all the characters showed positive and significant correlation with single plant yield. Drought score on the other hand exhibited significant negative correlation with yield. Similar findings were earlier reported by Nadarajan and Kumaravelu (1994) and Yogameenakshi *et al.,* (2004) for plant height, panicle length, productive tillers and thousand grain weight.

Inter correlation among yield components and drought score revealed positive and significant association of plant height with days to 50 per cent flowering and panicle length. This was in accordance with the results obtained by Yogameenakshi *et al.* (2004). Drought score on the other hand exhibited significant negative correlation with yield. Negative correlation was observed between drought score with days to 50 per cent flowering, number of productive tillers, panicle/m^2, panicle length, spikelet fertility and 1000 grain weight. These results indicated earliness is a critical trait for performance under reproductive stage stress as was detailed by Jonaliza *et al.* (2004), Manickavelu *et al.* (2006) and Pantuvan *et al.* (2002). Spikelet fertility positively correlated with thousand grain weight and yield but negatively correlated with drought score.
Correlation between drought score and selected shoot and root characters are given in Table 4. Root depth was found positively correlated with root volume, root thickness, fresh weight of shoot and root and dry weight of shoot and root. This result is in agreement with earlier findings of Armenta – Sato *et al.* (1982) and Toorchi *et al.* (2003) and they also observed significant positive correlation of root depth with plant height and root thickness in aerobic condition. Michael Gomez and Rangasamy (2002), Sinha *et al.* (2000) and Yogameenakshi (2002) have reported that root volume showed highly significant and positive correlation with grains per panicle and 1000 grain weight at both genotypic level and phenotypic level. A well developed root system will help the plant in maintaining high plant water status Kato *et al.,* 2008). Maintaining higher leaf water status under receding soil moisture conditions during grain filling is crucial for better grain yield. Rooting depth on the other hand exhibited significant negative correlation with drought score. This means that deep rooted varieties tend to be drought tolerant and have thick roots. Chandan

kumar and Nilanjaya (2014) has studied interrelationship and cause-effect analysis of grain yield and its component traits using thirty aerobic rice genotypes. The results indicated that relative water content, chlorophyll content, root length, panicle per plant, 1000 grain weight, grains per panicle, spikelet fertility, root volume showed significant and positive association with grain yield per plant.

Negative correlation of drought score with root volume, root thickness, shoot fresh weight, shoot dry weight, root fresh weight and root dry weight were observed. Ekanayake *et al*., (1985) also reported significant negative correlation between visual drought score and root length, thickness, number of thick roots and root density. Strong association between drought score and root thickness suggested that this character to be an important trait in identifying varieties for use in upland rice improvement for drought avoidance mechanism.

Hence the characters to be given importance in selection are panicle/m^2, spikelet fertility and 1000 grain weight as they exhibited highly positive correlation with grain yield and also a positive inter-correlation among themselves. Selection based on root thickness and root depth is highly suitable for identifying varieties for use in upland rice improvement for drought tolerance.

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Table 1. Mean performance of genotypes for yield & yield contributing characters

Entry	PH (cm)	DFF	PT	Pan./m ^{2}	PL (cm)	SPF (%)	TGW (g)	GY (q/ha)	Drought Score
RR 166-645	83	70	15.7	572	19.1	67.2	18.3	13.42	3.0
RR 286-1	65	55	22.5	808	17.2	25.4	15.9	2.33	6.3
RR 345-2	87	71	18.1	663	17.8	73.7	20.6	14.67	3.0
RR 347-1	70	67	18.6	653	17.2	68.3	20.3	10.12	2.3
RR 348-6	49	57	19.2	705	11.9	64.0	17.6	13.08	1.0
RR 354-1	88	64	18.6	659	18.1	57.1	15.0	10.12	3.0
RR 361-3	59	60	9.8	328	18.7	43.8	16.6	2.17	7.0
RR 363-4	108	66	8.3	289	23.6	46.2	17.3	3.68	6.3
RR 433-1	82	78	19.6	688	18.9	62.3	21.1	12.92	1.0
RR 434-3	67	61	15.1	704	16.9	60.9	16.1	9.87	5.0
IR 61608-213	81	61	18.1	634	17.2	78.9	17.7	10.50	3.7
Anjali	67	70	12.4	477	17.1	69.2	17.8	9.75	3.0
Vandana	78	69	16.4	587	16.2	72.1	21.1	10.00	3.0
Kalinga III	85	59	16.9	579	17.0	76.1	15.8	10.58	5.7
Browngora	67	63	19.5	555	17.0	82.6	22.7	7.46	3.0

PH – Plant Height, DFF - Days to 50% flowering, PT– Productive tillers,
Pan. /m ^{2} – Panicle/m ^{2}, PL – Panicle length, SPF – Spikelet fertility,
TGW – Thousand grain weight, GY–Grain Yield

Table 2. Mean performance of genotypes for root characters

Entry	Root depth (cm)	Root vol	Root thickness (cm)	FW. Shoot (g)	FW Root (g)	DW Root (g)	DW root (g)	Drought Score
RR 166-645	15.27	17.50	1.03	41.57	30.47	21.47	19.33	3.0
RR 286-1	9.00	9.07	0.53	21.50	13.40	16.20	10.50	6.3
RR 345-2	16.90	15.53	0.93	52.20	24.33	16.83	8.20	3.0
RR 347-1	14.33	18.00	1.05	23.80	18.03	9.83	3.90	2.3
RR 348-6	15.40	19.50	1.05	20.07	9.10	15.77	6.23	1.0
RR 354-1	17.10	18.37	0.93	26.80	11.73	12.10	5.53	3.0
RR 361-3	12.00	12.83	0.49	25.73	10.57	14.20	6.47	7.0
RR 363-4	13.46	10.90	0.64	20.83	18.43	12.77	6.00	6.3
RR 433-1	17.37	20.60	1.20	35.77	15.70	21.63	10.67	1.0
RR 434-3	11.43	12.70	0.99	24.73	10.50	15.50	4.90	5.0
IR 61608-213	13.70	10.70	0.90	23.53	9.97	15.03	6.10	3.7
Anjali	14.50	12.50	1.03	18.90	12.93	11.97	6.00	3.0
Vandana	13.83	11.70	0.94	25.80	16.00	17.67	6.60	3.0
Kalinga III	14.00	12.13	0.84	20.77	4.63	14.17	2.60	5.7
Browngora	13.83	11.53	1.05	32.20	9.17	22.50	3.97	3.0

Table 3. Correlation between yield with yield contributing characters and drought

Characters	DFF	PT	Pan / m2	PL	SPF	TGW	Drought score	Grain yield
PH	0.4432*	-0.2731	-0.3107	0.7916**	0.0625	-0.0138	0.1814	0.0680
DFF		-0.1270	-0.1310	0.3726	0.3142	0.5915**	-0.5266*	0.4701*
PT			0.9149**	-0.5797*	0.1601	0.2357	-0.4993*	0.3707
Pan/m2				-0.6053**	0.0569	0.0269	-0.4445*	0.4430*
Pan.Length					-0.3104	-0.0620	-0.4822*	0.3956
SPF						0.5428*	-0.5803*	0.7113**
TGW							-0.5732*	0.3258
Drought score								-0.8086

Table 4. Correlation between drought score and selected root and shoot characters

Characters	Root volume	Root thickness	FW. shoot	FW. root	DW. shoot	DW. root	Drought score
Root depth	0.6773**	0.6840**	0.4891**	0.3037	0.1514	0.1165	-0.7875**
Root volume		0.5079*	0.5299**	0.4736*	0.1114	0.3256	-0.4726*
Root thickness			0.2821	0.1490	0.3397	0.0718	-0.9305**
FW. shoot				0.6805**	0.5837*	0.5349*	-0.2808
FW. root					0.2564	0.7575**	-0.1429
DW.shoot						0.5442*	-0.2894
DW. root							-0.0926