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Research article

IDENTIFICATION OF RICE GENOTYPES FOR DROUGHT TOLERANCE BASED ON ROOT CHARACTERS

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ABSTRACT: Climate change needs us to look at various alternatives for more drought tolerant and tougher strains. Rice (Oryza sativa L.) is the most important food crop of the world; drought stress is a serious limiting factor to rice production and yield stability in rainfed areas. In order to design efficient varieties with virtues of drought tolerance and high yielding ability is necessary. Root system plays an important role under drought conditions. Among all the genotypes NLR 33671 showed highest root length (27.6cm) under moisture stress condition followed by NLR 3010 (24.5cm), NLR 40059 (23.6 cm), TELLAHAMSA (23.5 cm) ,NLR 40049 (23.5), NLR 3098 (23.5) were showed significantly superior mean values than remaining genotypes for most of the root traits included in this study. Therefore, these genotypes can be considered as drought resistance varieties. Whereas NLR 40054 (14.35 cm), BPT 5204 (14.55 cm), NLR 40045 (15 cm) and NLR 30491 (15.19cm) recorded lowest root length these can be consider as susceptible ones. The effects of drought stress on rice productivity were explicitly parameterized and addressed in the present study.
Key words: rice, water stress, root characters and yield components

INTRODUCTION

Drought is a major abiotic stress that causes severe yield loss in rice as a staple food crop affecting 20% of the total rice-growing area in Asia (Pandey and Bhandari, 2008). Improvement of drought resistant rice varieties has become an urgent task under the background of global crisis of water resource (Fangjun et al., 2012). Trade-off between water savings and grain yield happens because the withdrawal of irrigation causes water stress-induced changes in the crop's physical and biochemical root traits. There- fore, improving our understanding of the interactions between root function and drought in rice could have a significant impact on global food security (Veeresh et al., 2011). Roots are the principal plant organ for nutrient and water uptake. The nature and extent of root characteristics are considered to be major factors affecting plant response to water stress. Genotypes that have deep, coarse roots with a high ability of branching and penetration are reported as component traits of drought avoidance (Blum et al., 1989; Samson et al., 2002; Wang and Yamauchi, 2006). Kawata and Soejima (1974) suggested that roots produced after flowering may play an important role during the grain-filling period. The ability to grow deep roots is currently the most accepted target trait for improving drought resistance, but genetic variation has been reported for a number of traits that may affect drought response. Keeping these considerations present investigation was carried out to evaluate genetic variability for root characters of thirty rice lines under imposed moisture stress condition were studied.

MATERIALS AND METHODS

Experimental Details and Treatments

Experimental Details

The present investigation was conducted at green house, Department of Plant Physiology, College of Agriculture, Hyderabad during *Rabi*, 2010-2011 on specialized plastic pots with 30 rice genotypes.

Treatments

Treatments	:	Main	:	Moisture stress, control (Irrigated)
		Sub	:	Rice genotypes (30)

The design used in this study was FRBD with 3 replications. Where the plants were subjected to drought for a period of 15days before and after panicle initiation (reproductive) stage starting on 90 days after sowing.

Observations recorded

Observations were recorded after harvest on 4 important root traits viz., root length, root volume, root spread and root dry weight and yield characters. Root length (cm) was measured using a standard scale from the ground level to the tip of the root. Root spread (cc plant^{-1}) measured using standard scale from maximum spreading area of the root. Root volume (ml plant^{-1}) was measured by water displacement method by dipping the properly washed roots in a 1000 ml measuring cylinder containing water up to a certain point. Root volume was determined by displaced water method in the cylinder after root dipping. Harvested roots were washed and oven dried at 80^{0}C for 48 hrs and root dry weights (g) were recorded using sensitive electronic balance and expressed in g per plant. Yield attributes i.e seed yield, straw yield, harvest index and dry matter was measured at maturity.

RESULTS

Root characters

Among the several factor contributing to enhance tolerance to drought, root length is the main organ for plant water uptake. The distribution of root length in the root system is an important indicator of the potential of water uptake. The data on root length was presented in Table 1. There is a significant difference between treatments and genotypes. Genotypic variability of 14.35 cm to 27.6 cm was observed. Among all the genotypes NLR 33671 showed highest root length (27.6cm) under moisture stress condition followed by NLR 3010 (24.51cm), NLR 40059 (23.66 cm), TELLAHAMSA (23.49 cm) and NLR 40049, NLR 3098 on par with TELLAHAMSA. Whereas NLR 40054 recorded lowest root length (14.35cm), BPT 5204 (14.55 cm), NLR 40045 (15 cm) and NLR 30491 (15.19cm). Better root spreading is observed in the genotypes grown under imposed moisture stress conditions compared to control (Table 1). Root spread is maintained high in NLR 33358 (6.9 cc plant^{-1}) followed by NLR 33671 (6.14 cc plant^{-1}) NLR 3059 (6.14 cc plant^{-1}), and NLR 40065 shows less root width (1.88 cc plant^{-1}), followed by NLR 40062 (2.13 cc plant^{-1}) BPT 5204 (2.15 cc plant^{-1}) and MTU (2.2 cc plant^{-1}).

The data pertains to root volume was given in (Table 2). Generally root volume is more under stress compared to control. There is a genotypic variability for root volume i.e. 15.6 to 31ml hill^{-1} was observed the interaction affect between treatment and genotypes were non-significant. Among all genotypes NLR 40059 recorded highest root volume (31.1 ml plant^{-1}) TELLHAMSA is on par with NLR 40059 followed by NLR 3010 (30.1 ml plant^{-1}) NLR 40049 (29.9 ml plant^{-1}) and NLR 3059 (28.2 ml plant^{-1}) in contrast to above cultivators NLR 40065 recorded lowest root volume (15.6 ml plant^{-1}) then NLR 40054 (15.8 ml plant^{-1}), NCR 40058(16.2 ml plant^{-1}) and NLR 40045 (16.3 ml plant^{-1}).

The data on root dry weight recorded after harvest of the rice crop (Table 2). Root dry weight is increased in all genotypes under moisture stress. More dry weight is maintained under stress compared to control. There were significant differences between treatments and genotypes but there is no significant difference in between interaction of genotypes and treatment. NLR 33671 shows more dry weight (2.81 g plant^{-1}) followed by NLR 3010 (2.49 g plant^{-1}) TELLAHAMSA (2.39 g plant^{-1}), NLR 40059 (2.37 g plant^{-1}) NLR 34242 (2.35 g plant^{-1}) and NLR 40049 on par with NLR 34242 in contrast to NLR 33671 the genotype NLR 40054 recorded dry weight (1.37 g plant^{-1}) followed by BPT 5204 (1.39 g plant^{-1}) NLR 30491 (1.4 g plant^{-1}) and NLR 40045 (1.45 g plant^{-1}).

Yield Components

Yield and yield attributes are the ultimate manifestation of a plant’s ability to survive grow and produce yield under water limited situation regardless of the tolerance mechanisms involved. Aerobic condition significantly reduced grain yield, mainly through reduction in filled grain percentage, spikelet number per panicle and number of productive tillers per plant in the rice cultivar. Genotypic variability of seed yield was recorded between (1.97 to 6.98 g plant^{-1}). Seed yield was comparatively low under moisture stress conditions than to control. Among the rice genotypes highest seed yield was observed in NLR 3010 (6.98 g plant^{-1}) (Table 3) followed by NLR40059 (6.40 g plant^{-1}), NLR 34242 (5.93 g plant^{-1}) and NLR 33671 (5.78 g plant^{-1}). In contrast the genotypes NLR 40058 and NLR 30491 recorded lowest seed yields (1.97 and 2.2 g plant^{-1}) respectively. The genotype TELLAHAMSA shows highest straw yield (11.4 g plant^{-1}) (Table3) followed by NLR 33359(10.72 g plant^{-1}), NLR 33636 (10.41 g plant^{-1}), NLR 33671 (10.04 g plant^{-1}), and NLR 34242 on par. The genotype NLR 40065 shows low straw yield (8.42 g plant^{-1}) fallowed by NLR 30491 and NLR 40058(8.67 g plant^{-1}).

Table 1. Root length (cm plant-1) and root spread (cc plant-1) in rice genotypes as influenced by moisture stress at harvest

Sl. No.	Genotypes	Root length			Root spread		
		Control	Stress	Mean	Control	Stress	Mean
1	NLR33358	18.1	20.5	19.3	6.8	7.0	6.9
2	NLR33359	18.5	21.5	20.0	5.1	5.5	5.3
3	NLR33636	13.6	16.5	15.1	5.0	5.2	5.1
4	NLR33671	25.6	29.7	27.6	5.8	6.5	6.1
5	NLR34242	20.1	25.5	22.8	5.1	5.8	5.5
6	MTU1010	20.5	22.5	21.5	2.1	2.5	2.4
7	NLR3059	19.4	22.4	20.9	5.8	6.5	6.1
8	NLR3098	22.0	25.0	23.5	3.5	4.3	3.9
9	NLR40024	15.7	18.7	17.2	2.1	2.7	2.4
10	NLR40045	13.5	16.5	15.0	2.2	2.8	2.5
11	NLR40049	22.0	25.0	23.5	4.4	5.0	4.7
12	NLR40050	16.3	19.3	17.8	2.3	2.8	2.5
13	NLR40054	12.6	16.1	14.4	2.0	2.3	2.1
14	NLR40055	17.0	20.0	18.5	2.9	3.8	3.4
15	NLR40058	15.4	17.2	16.3	2.1	2.5	2.3
16	NLR40059	22.3	25.0	23.7	4.6	5.0	4.8
17	NLR40062	17.7	20.7	19.2	1.8	2.4	2.1
18	NLR40064	18.0	21.0	19.5	2.9	3.5	3.2
19	NLR40065	17.2	20.2	18.7	1.5	2.3	1.9
20	NLR40066	18.5	21.5	20.0	2.0	3.5	2.8
21	NLR40068	18.5	21.5	20.0	2.2	3.5	2.9
22	NLR40070	17.7	20.3	19.0	2.0	2.8	2.4
23	TELLAHAMSA	22.0	25.0	23.5	4.8	5.5	5.2
24	JGL1798	18.5	21.5	20.0	3.2	3.3	3.2
25	NLR145	21.1	24.3	22.7	5.0	5.3	5.2
26	NLR3010	22.5	26.5	24.5	5.1	5.8	5.5
27	NLR3042	16.2	19.2	17.7	2.9	3.5	3.2
28	RNR2458	18.0	21.0	19.5	4.1	4.5	4.3
29	NLR30491	13.7	16.7	15.2	1.8	2.6	2.2
30	BPT5204	13.6	15.5	14.6	2.0	2.3	2.2
	Mean	18.19	21.2	19.7	3.43	4.02	3.73
		T	G	T x G	T	G	T x G
	SEm±	0.08	0.15	0.26	0.03	0.06	0.11
	CD (P=0.05)	0.17	0.64	NS	0.07	0.27	NS

Table 2. Root volume (ml plant^{-1}) and root dry weight (g plant^{-1}) in rice genotypes as Influenced by moisture stress at harvest

Sl. No.	Genotypes	Root volume			Root dry weight		
		Control	Stress	Mean	Control	Stress	Mean
1	NLR33358	24.4	27.5	26.0	2.1	2.3	2.2
2	NLR33359	17.5	20.3	18.9	2.0	2.3	2.1
3	NLR33636	14.3	17.2	15.8	1.6	1.8	1.7
4	NLR33671	23.7	26.5	25.1	2.6	3.0	2.8
5	NLR34242	22.4	25.5	24.0	2.1	2.6	2.4
6	MTU1010	16.9	19.7	18.3	1.9	2.1	2.0
7	NLR3059	25.1	28.2	26.7	2.1	2.4	2.3
8	NLR3098	21.2	23.1	22.2	2.1	2.4	2.3
9	NLR40024	18.7	21.6	20.2	1.5	1.8	1.6
10	NLR40045	13.5	16.3	14.9	1.3	1.6	1.5
11	NLR40049	27.9	29.9	28.9	2.2	2.5	2.4
12	NLR40050	14.5	17.3	15.9	1.6	1.8	1.7
13	NLR40054	12.6	15.8	14.2	1.2	1.5	1.4
14	NLR40055	16.3	19.7	18.0	1.7	2.0	1.8
15	NLR40058	13.3	16.2	14.8	1.4	1.7	1.5
16	NLR40059	28.1	31.0	29.6	2.2	2.5	2.4
17	NLR40062	15.5	18.3	16.9	1.6	1.9	1.8
18	NLR40064	25.4	27.5	26.5	1.7	2.0	1.9
19	NLR40065	12.7	15.6	14.2	1.6	1.9	1.7
20	NLR40066	19.4	22.3	20.9	1.7	2.1	1.9
21	NLR40068	19.3	22.1	20.7	1.7	2.1	1.9
22	NLR40070	15.8	18.3	17.1	1.6	1.9	1.8
23	TELLAHAMSA	27.8	31.0	29.4	2.2	2.6	2.4
24	JGL1798	17.4	20.7	19.1	1.8	2.1	1.9
25	NLR145	23.5	26.5	25.0	2.2	2.5	2.3
26	NLR3010	27.3	30.1	28.7	2.3	2.7	2.5
27	NLR3042	14.6	17.0	15.8	1.6	1.9	1.7
28	RNR2458	22.8	25.0	23.9	1.8	2.1	2.0
29	NLR30491	16.3	19.5	17.9	1.3	1.6	1.4
30	BPT5204	18.2	20.1	19.2	1.3	1.5	1.4
	Mean	19.6	22.3	20.9	1.8	2.1	2.0
		T	G	T x G	T	G	T x G
	SEm±	0.11	0.22	0.37	0.01	0.02	0.03
	CD (P=0.05)	0.24	0.91	NS	0.02	0.07	NS

Table 3. Grain and straw yield (g plant^{-1}) in rice genotypes as influenced by moisture stress at harvest

Sl. No.	Genotypes	Grain yield			Straw yield		
		Control	Stress	Mean	Control	Stress	Mean
1	NLR33358	5.65	4.18	4.92	8.47	9.47	8.97
2	NLR33359	4.88	3.69	4.29	10.27	11.18	10.73
3	NLR33636	4.81	3.49	4.15	9.96	10.86	10.41
4	NLR33671	7.27	5.78	6.53	9.59	10.50	10.05
5	NLR34242	7.38	5.93	6.66	9.67	10.42	10.05
6	MTU1010	5.89	5.59	5.74	9.47	9.38	9.43
7	NLR3059	4.32	3.41	3.87	9.08	9.06	9.07
8	NLR3098	4.39	3.61	4.00	8.87	8.77	8.82
9	NLR40024	5.34	3.90	4.62	9.67	9.57	9.62
10	NLR40045	4.29	3.42	3.86	9.49	8.77	9.13
11	NLR40049	5.38	3.98	4.68	9.32	9.22	9.27
12	NLR40050	4.29	3.10	3.70	8.96	8.87	8.92
13	NLR40054	4.18	3.20	3.69	8.96	9.17	9.07
14	NLR40055	4.39	3.35	3.87	9.96	9.86	9.91
15	NLR40058	3.19	1.97	2.58	8.72	8.62	8.67
16	NLR40059	7.78	6.40	7.09	9.67	9.57	9.62
17	NLR40062	4.49	3.40	3.95	8.96	8.87	8.92
18	NLR40064	5.96	4.71	5.34	9.27	9.38	9.33
19	NLR40065	5.88	4.74	5.31	8.47	8.37	8.42
20	NLR40066	4.61	3.47	4.04	9.57	9.47	9.52
21	NLR40068	4.34	3.24	3.79	8.96	8.87	8.92
22	NLR40070	5.08	4.01	4.54	9.06	9.47	9.27
23	TELLAHAMSA	5.08	5.00	5.04	11.45	11.36	11.41
24	JGL1798	5.18	3.88	4.53	9.17	9.06	9.12
25	NLR145	6.47	5.39	5.93	9.17	8.57	8.87
26	NLR3010	7.87	6.98	7.43	9.57	9.47	9.52
27	NLR3042	4.98	3.91	4.45	9.86	9.76	9.81
28	RNR2458	4.98	3.98	4.48	9.57	9.47	9.52
29	NLR30491	3.28	2.20	2.74	8.57	8.77	8.67
30	BPT5204	3.98	3.11	3.55	9.96	9.86	9.91
	Mean	5.15	4.06	4.61	9.39	9.47	9.43
		T	G	T x G	T	G	T x G
	SEm±	0.03	0.057	0.099	0.015	0.029	0.05
	CD (P=0.05)	0.06	0.24	NS	0.03	0.12	0.17

Data on harvest index (Table 4) revealed that genotypic variability of harvest index was recorded as 22.93 to 41.99 percent. Harvest index was decreased with imposed moisture stress conditions among all tested genotypes NLR 3010 has highest harvest index (41%), NLR 40059 (41%), NLR 34242 (40%) and NLR 33671 (40%).

Highest harvest index in NLR 3010 can be attributed to more grain filling percentage and more grain weight per plant^{-1} as compared to other genotypes. NLR 40058 and NLR 30491recorded as (22% and 23%) lowest harvest index due to more spikelet sterility. Genotypic variability of total dry matter production was presented in (Table 4) as 11.75 to 17.54 g plant^{-1}. NLR 3010 was recorded highest dry matter production (17.4 g plant^{-1}) fallowed by NLR 40059 (17.07 g plant^{-1}), TELLAHAMSA (16.92 g plant^{-1}), NLR 34242 (16.66 g plant^{-1}), NLR 33671(16.57 g plant^{-1}) and the lowest dry matter recorded in NLR 40058 (11.75 g plant^{-1}) and NLR 30491 (11.89 g plant^{-1}).

Table 4. Harvest index (%) and dry matter (g plant^{-1}) in rice genotypes as influenced by moisture stress at harvest

Sl. No.	Genotypes	Harvest Index			Dry matter		
		Control	Stress	Mean	Control	Stress	Mean
1	NLR33358	39.9	30.5	35.2	14.1	13.7	13.9
2	NLR33359	32.1	24.7	28.4	15.2	14.9	15.0
3	NLR33636	32.4	24.2	28.3	14.8	14.4	14.6
4	NLR33671	43.0	37.1	40.0	16.9	16.3	16.6
5	NLR34242	43.2	37.7	40.4	17.1	16.3	16.7
6	MTU1010	38.2	35.0	36.6	15.4	15.9	15.6
7	NLR3059	32.1	25.2	28.6	13.4	13.5	13.4
8	NLR3098	33.0	26.9	29.9	13.3	13.4	13.3
9	NLR40024	35.5	26.8	31.2	15.0	14.5	14.7
10	NLR40045	31.0	25.8	28.4	13.8	13.2	13.5
11	NLR40049	36.5	28.0	32.2	14.7	14.2	14.5
12	NLR40050	32.2	23.8	28.0	13.3	13.0	13.1
13	NLR40054	31.7	23.8	27.8	13.2	13.4	13.3
14	NLR40055	30.4	23.5	27.0	14.3	14.2	14.3
15	NLR40058	26.7	17.0	21.8	11.9	11.6	11.8
16	NLR40059	44.5	38.0	41.2	17.4	16.7	17.1
17	NLR40062	33.2	25.5	29.4	13.5	13.3	13.4
18	NLR40064	39.0	31.1	35.0	15.2	15.1	15.2
19	NLR40065	40.8	33.5	37.2	14.3	14.1	14.2
20	NLR40066	32.4	24.9	28.6	14.2	13.9	14.1
21	NLR40068	32.5	24.6	28.5	13.3	13.1	13.2
22	NLR40070	31.0	21.6	26.3	13.2	13.4	13.3
23	TELLAHAMSA	30.6	28.7	29.7	16.5	17.3	16.9
24	JGL1798	36.0	27.7	31.8	14.3	14.0	14.2
25	NLR145	41.3	35.8	38.5	15.6	15.0	15.3
26	NLR3010	45.0	39.0	42.0	17.4	17.7	17.5
27	NLR3042	33.4	26.6	30.0	14.8	14.7	14.8
28	RNR2458	34.1	27.5	30.8	14.6	14.4	14.5
29	NLR30491	27.5	18.3	22.9	11.9	11.9	11.9
30	BPT5204	28.5	22.2	25.3	14.0	13.9	13.9
	Mean	34.9	27.8	31.4	14.5	14.4	14.5
		T	G	T x G	T	G	T x G
	SEm±	0.14	0.28	0.48	0.03	0.06	0.11
	CD (P=0.05)	0.30	1.17	NS	0.07	0.26	N

DISCUSSION

It reveals that all the genotypes maintained maximum root length under moisture stress conditions compared to control. Similar results were reported by Kanbar et al. (2009). It was also supported by (Nguyen et al., 1997 and Mane et al., 2003) maximum root length is a good indicator of drought tolerance in upland rice. Similar results found by Ingram et al., (1994) suggested that total root length is strongly related to drought tolerance in rice under upland conditions. Hence root length showed a strong relationship with grass yield as well as stress indicators under water limited conditions. Increased root thickness improves drought resistance as the roots are capable of increasing root length density and water uptake by producing more and larger root branches.

Similar positive correlation between high root volume and grain yield and dry matter production was reported by Ganapathy et al., (2010) reported that increased root thickness improves drought resistance as the roots are capable of increasing root length and water uptake by producing more and larger root branches. Root volume and root weight were positively associated with grain yield and dry matter production which are in agreement with result of Yogameenakshi et al. 2004 and Rajesh et al. (2008). Songsri et al. (2008) reported that root dry weight decrease with drought under moisture conditions, the genotype with large root dry weight had high WUE and could maintain better water uptake. High and positive direct effect of harvest index on grain yield per plant (41.99) was noticed in the genotypes NLR 3010, NLR 40059. This was in accordance with earlier findings of Surek and Beser (2003) and Yogameenakshi et al. (2004). Lu et al. *(*2000) also observed reduction in the dry matter production and grain yield was might be due to reduction in growth rate resulted from decrease in the net assimilation rate due to non availability of appropriate water quantity at proper time. The highest yield in NLR 3010 can be attributed to highest total dry matter production and harvest index further highest grains filling percentage and more grain weight per hill have also contributed in getting highest yield.

CONCLUSION

The identified tolerant genotypes viz., NLR 3010, NLR 40059, NLR 34242, and NLR 33671 shown good performance in moisture stress condition at reproductive stage, might be because successful pollen formation and fertilization, continued photosynthesis and effective metabolism of stored reserves are essential phenomena for drought tolerance. The main basis for this variation appears to be because of constitutive root architecture allows maintenance of more favorable plant water status. These findings reveal the importance of these traits for selection for improving drought tolerance, as they showed high variability under moisture stress condition.

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