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SCREENING OF RICE (*Oryza sativa* L.) GERMPLASM FOR RESPONSE TO WATER STRESS CONDITIONS AT REPRODUCTIVE STAGE

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ABSTRACT

Drought is one of the most hazardous abiotic stresses that can cause considerable yield losses mainly in rainfed and minor irrigated ecosystems in Sri Lanka. Identification of drought tolerant rice germplasm and drought linked traits in those germplasm are essential in developing drought tolerant varieties. Present study was conducted to screen 46 rice germplasm (34 traditional, 4 improved, 7 exotic accessions and one wild relative of rice) for response to drought under induced water stressed condition at reproductive stage which is the most critical stage for drought stress. One plant house trial and two field trials were conducted for germplasm screening. Plant house trail was established using one meter long PVC pipes in a Randomized Complete Block Design with two replicates. Water stress was induced at early booting stage while control treatment was maintained under unstressed condition. Drought linked above ground traits and root traits were investigated. Tested rice germplasm significantly varied with respect to drought linked traits. Different adaptation mechanisms were shown by different accessions for their survival under water stressed condition. *Oryza eichingari*, Podi Niyanwee, Goda Heenati (4049), Al Wee (4919), Al Wee(4023), Mada Al Galle, Bg 300, Kinadang Patang, Ld 12-38 performed comparatively better under drought stressed conditions at reproductive stage. Suwandel, Rathnawalu, Nona Bokra and Rathu Heenati showed significantly inferior performances under drought

conditions. Correlation analysis revealed that the spikelet fertility, harvest index, grain weight and spikelet per panicle significantly contributed to yield stability under drought stressed conditions. High correlation was observed between spikelet fertility and delayed leaf rolling. No significant correlations were observed between yield and root traits. Selected accessions can be utilized as donor parents for development of high yielding rice varieties for low moisture stress conditions.

Key words: Abiotic stress, Drought linked traits, Response to drought, Traditional rice germplasm

INTRODUCTION

Drought stress is a major constraint of rice production and yield stability in rainfed ecosystems in the world. It imposes a serious economic burden on society with varying intensities. Rice cultivation in Sri Lanka is spreading over a wide range of ecosystems under diverse temperature and water regimes. Based on the water availability, rice cultivation can be categorized into three systems; major irrigation schemes, minor irrigation schemes and rainfed farming system. According to the rice cultivation statistics in *Yala* 2013 (dry season) and *Maha* 2013/14 (wet season), cultivated area of rice under rainfed conditions were recorded as 10.62% and 30.9%, respectively (Agstat, 2014), where drought stress is the major constraint for rice production and yield stability.

Due to global climatic changes most of the rice growing areas will become under threat of drought. Punyawardana *et al*. (2013) stated that by the year 2015 the dry zone begins to experience below annual rainfall. Therefore, development of drought tolerant rice varieties would be one of the strategies to stabilize rice production in the country. Further, with the development of North and East area of Sri Lanka, which is totally coming under the Dry Zone, development of drought tolerant varieties are essential to increase the productivity and the production of rice. In addition considerable percentage of crop losses is observed annually due to drought.

Drought tolerance is a complex trait that is affected by many morphological and physiological factors. Progress of developing high yielding drought tolerant varieties is slow mainly due to the complex nature of drought tolerant mechanism, low heritability of component traits of drought tolerance and large G × E interactions, involvement of large number of QTLs and QTL x environment interactions (Mishra *et al*., 2013). Yue *et al*., (2006) investigated the genetic basis of drought resistance at reproductive stage in rice and identified large number of QTLs associated with primary and secondary traits of drought resistance and some of them can be utilized as indirect indices for drought screening in rice.

The time of drought stress in relation to the stage of crop development and severity of drought mainly influence on grain yield. Three common types of drought in terms of timing have been identified as vegetative stage drought, intermittent drought and terminal drought (Chang *et al*., 1979; Fischer *et al*., 2003). Terminal drought mainly develops towards the end of the growing season but sometimes begins well before flowering. Pandey *et al*. (2005) showed that in Eastern India terminal drought is the most frequent type that severely affects grain yield. Free water level from 3 weeks before anthesis until maturity is closely related to grain yield in rainfed lowland rice (Fukai *et al*., 2001; Ouk *et al*., 2006, 2007). In rice plant floral fertility is extremely sensitive to water stress conditions and it directly affects grain yield (Kumar, 2014). In addition delayed flowering and poor panicle excretion also occur with water stress at the reproductive stage. Grain yield under water stress is the primary trait for screening lines for tolerant to drought. Secondary traits that are associated with yield under low moisture stress also provide additional information in screening for tolerance.

Sri Lanka has a rich genetic diversity of rice and most of the germplasm have been conserved at Plant Genetic Resources Centre (PGRC). Even though the high diversity of rice germplasm is available, very few have been utilized for breeding purposes. Though the traditional cultivar comparatively low yielders they are highly adapt to the diverse biotic and abiotic stresses. Evaluation of those germplasm for biotic and abiotic stress is essential prior to utilize those for crop improvement. Such information is lacking for these conserved germplasm. Rice germplasm play a diverse range of mechanisms to withstand water stress conditions such as drought escape through short duration, drought avoidance through deep root system and drought tolerance through various mechanisms (Yue *et al*., 2006).

Present study was conducted to screen selected traditional rice germplasm that have been conserved at the PGRC for drought stress at reproductive stage using primary and secondary traits under induced drought stress conditions and compare with unstressed conditions under plant house and field conditions.

MATERIALS AND METHODS

Planting materials and trial establishment

Forty six rice accessions including 34 traditional germplasm, 4 improved varieties, 7 drought tolerant exotic varieties and one wild relatives of rice (*Oryza eichingari*) were used as planting materials for this study. Seven exotic varieties included two drought tolerant varieties developed at the International Rice Research Institute (IRRI) (DSN37 and DSN 11), five accessions; Azucina, Moraberekan, Kinagang Patang, UPIR15 and Blackglora, which have been identified as drought tolerant accessions at IRRI.

Screening under plant house condition

Trial was established under controlled plant house conditions at Plant Genetic Resources Centre (PGRC), Gannoruwa, Sri Lanka during *Yala* 2012. Individual plants were maintained in one meter long, 20 cm diameter PVC pipes. Pipes were loaded up to 75 cm with polythene bags which were filled with equal weight of thoroughly mixed soil. Half dose of basal fertilizer recommended by the Department of Agriculture (DoA) was applied at planting. Holes were made in PVC pipes to drain water when required and the draining was controlled using plugs. Pipes were arranged according to a Randomized Complete Block Design with two blocks.

Germinated seeds from each germplasm were directly sown in the pipes and kept only one plant per pipe at 20 days after sowing. Plants were kept under saturated conditions up to early booting stage. At early booting stage drought stress was imposed to one set of pipes and another set of pipes were kept as control treatment with no stress according to the procedure proposed by Yue *et al*. (2006). In stress treated pipes, plugs were removed and allowed water to drain off. Stress was given as two cycles. When leaves of the stressed plants became fully rolled as visualized at noon, pipes were irrigated to full capacity. Saturated conditions were maintained for one day until plants got recovered. Then the second cycle of drought stress was applied to the plants according to the same procedure. After completion of second cycle of drought stress watering was resumed for rest of the life cycle. Extra 4 pipes were maintained with rice plants to measure soil moisture at 30 cm soil depth at leaf rolling. Soil moisture was measured according to the gravimetric method.

Field screening

Two separate trials were conducted under controlled water supply condition at the Rice Research and Development Institute, Batalagoda in *Yala* 2013 season and the Field Crops Research and Development Institute, Mahailluppallam in *Yala* 2014 season. Accessions were evaluated under two water regimes; fully irrigated (non stressed) as the control and induced water stress. The experiment with 46 accessions was laid out in the field in a Randomized Complete Block Design with two replicates under each water regime. Three rows of 5 m length plots were used for the planting of rice varieties. Cultural practices were done according to the recommendation of the DoA. Half dose of basal fertilizer recommended by the DoA was applied at planting. At early booting stage water stress was imposed to stress plots by withholding irrigation until stress symptoms appeared.

Data Collection

In plant house trial twelve above ground and below ground drought linked traits were recorded in each accession both under drought stressed and control treatments. Number of days to leaf rolling, days to flowering, days to maturity, spikelet fertility (%), grain yield (g), 1000 grain weight, total plant biomass (g), spikelet per panicle, harvest index (%), root length (m), total root volume by water displacement method, root volume below 30 cm depth were recorded according to the procedures described by Yue *et al*. (2006). The relative performance of the phenotypic data for each trait was calculated as the percentage of the measurements taken under drought stressed and control conditions. This gives an idea about how each accession perform under drought stressed conditions compared to the unstressed condition. At the end of first and second cycle of drought stress, soil moisture content was measured at 30 cm depth using gravimetric method.

In field screening trials upper ground yield related traits were recorded. Soil moisture content was measured at 30 cm depth according to the gravimetric method using seven random samples collected from the drought induced field.

Data analysis

Analysis of Variance (ANOVA) were performed to identify the variations among the tested accessions separately for field data and plant house data. Mean separation was done using Turkey's T test. Phenotypic correlations among the traits were computed for drought stressed, non-stressed conditions and relative data of drought and control conditions to identify association among tested traits. SAS software 9.0 was used for the analysis. Broad sense heritability (H) was computed from the estimates of genetic and residual variances from ANOVA (Singh and Chaudhary, 1977).

RESULTS AND DISCUSSION

Plant House Screening

Average soil moisture content at leaf rolling stage of first drought cycle varied from 9 - 9.8%. Average minimum and maximum atmospheric temperature inside the plant house ranged from 24.2 °C to 36.5 °C.

Above ground traits

Phenotypic differences of tested accessions for each trait were summarized in Table 1. Considerably vast range of performances was observed among tested accessions. Analysis of Variance was done using relative data and it indicated that variation due to genotypic differences were highly significant for all the tested traits.

Relative Yield - Mean relative yield of these tested accessions ranged from 0.6% to 95.9%. It shows significant variation at 0.001% probability level. Rice wild relative *O. echingari* showed the least yield reduction (5%) followed by Goda Heenati (10%) and Podi Niyan wee (20%) when exposed to water stressed condition. The highest yield reduction was observed in Suwandel (99%) followed by Nona Bokra 88% and Rathnawalu (88%).

O. echingari, Goda Heenati (4919), Podi Niyanwee, Kinandang Patong, Mada Al Galle, breeding line Ld12-38 and improved variety Bg 300 showed less than 30% yield reduction under water stressed condition.

Table 1. Relative data of tested drought linked traits of 46 accessions used for the study under water stressed and unstressed conditions

Name/ Accession no	RY%		RSF %	RBM%	RHI%	RGW %	RSPP %	DIRRL %	DIRTV %	RDRV% >30 cm	DLfR
	Plant house	Field at MI									
Al Wee (4919)	69.42	71.74	86.58	83.49	87.7	98.87	67.89	26.95	18.57	82.84	41
Al Wee (4023)	56.52	56.08	98.96	85.57	63.52	80.25	73.83	9.13	65.01	112.69	39.5
Al Wee (5395)	25.6	-	57.86	52.61	38.92	67.76	116.75	11.67	17.37	103.62	29.5
Azucena (6780)	36.13	-	54.78	54.7	55.91	80.59	88.05	5.32	36.82	25.02	27
BG 300	73.07	61.7	82.53	63.06	73.09	84.91	95.64	24.98	42.05	69.73	39.5
BG 304	54.3	32.19	70.93	83.85	70.2	89.65	83.31	42.15	21.3	0	31.5
BG 357	54.85	28.13	69.78	92.6	71.44	91.45	85.71	14.05	39.8	118.64	25
Black glora (5387)	58.15	-	72.54	85.71	72.07	70.98	91.52	7.71	88.68	23.67	26.5
DSN 11	62.42	86.91	74.8	66.74	95.66	83.99	92.67	7.83	29.7	55.28	31.5
DSU 37	40.93	56.65	64.49	65.82	74.03	78.41	83.08	11.94	42.36	22.91	29
El Wee (3578)	31.16	43.55	40.09	80.85	42.41	70.92	121.11	15.48	40.86	12.35	28.5
Elay Wee (3503)	13.8	-	8.01	151.44	9.06	89.08	126.55	14.95	35.67	76.78	10
Goda al Wee (4724)	17.85	-	79.94	68.94	31.21	60.58	40.13	17.32	30.12	82.57	29.5
Goda Al Wee (6338)	51.08	39.04	71.02	75.21	81.19	81.03	109.77	10.42	22.61	9.3	42.5
Goda Heenati(3724)	59.92	51.44	59.25	91.22	69.95	81.09	110.71	4.32	92.41	92.5	27
Goda Heenati(4049)	89.37	75.63	83.62	93.27	89.88	77.91	96.54	6.37	18.82	25	28
Hal Al (4930)	43.78	55.54	55.85	103.95	49.05	83.84	79.16	40.34	19.8	82.65	25
Kahamalan Wee (5470)	66.78	41.63	63.05	82.08	85.76	88.72	89.87	16.4	46.24	31.85	28
Kahata Wee (3478)	56.82	22.44	65.14	83.48	72	82.26	93.44	15.37	14.04	251.99	31
Kalu mada al (4266)	29.23	23.63	43.3	65.3	50.81	86.51	64.99	18.01	41.75	60.16	32
Kalu Wee (3212)	51.4	-	56.44	99.53	56.76	75.75	90.32	6.84	100.23	61.74	26.5
Kinadang Patang (6924)	70.8	54.45	75.35	88.32	79.95	83.6	100.13	10	72.42	20.19	35
Kolanathi Wee (6454)	34.72	-	42.89	86.27	39.74	94.79	73.39	15.63	54.68	56.66	26
Kuru Wee (3254)	39.86	-	75.16	67.52	49.26	74.47	49.14	3.98	43.67	61.36	20

Table 1. Cont.

Name/ Accession no	RY%		RSF %	RBM%	RHI%	RGW %	RSPP %	DIRRL %	DIRTV %	RDRV% >30 cm	DLfR
	Plant house	Field at MI									
Ld 12-38	70.39	71.13	56.55	121.07	67.59	82.45	92.05	14.52	41.07	77.23	25
M 302 (3110)	53.19	-	65.72	77.22	72.4	77.85	79.79	17.04	30.95	65.28	27
Mada Al (4292)	46.09	42.78	49.51	74.12	57.72	81.01	74.85	4.85	22.92	49.43	31
Mada Al Galle (3508)	74.02	-	97.74	74.1	95.92	98.9	120.99	17.77	18.34	47.21	25.5
Mada Al Kaluthara(3514)	40.71	-	63.96	75.18	57.33	63.52	117.12	0	47.9	38.01	28
Mada Al Wee (4436)	33.67	57.31	70.63	90.68	49.32	94.73	89.66	18.06	43.12	306.07	28
Mada Heenati (4119)	38.59	-	50.09	107.89	48.98	70.14	91.12	28.1	53.47	85.73	18.5
Magoda Al (4905)	66.26	-	90.24	82.34	80.78	86.01	111.9	16.74	68.28	139.31	25.5
Maha Goda Al (4948)	52.37	-	52.33	93.89	44.28	74.09	128.31	16.99	28.27	14.61	26
Moraberekan (6897)	27.13	48.64	53.01	86.64	33.99	81.26	82.33	9.04	52.27	76.81	37.5
Niyan Wee (4909)	20.42	-	39.45	79.26	20.68	74.44	110.41	10.67	38.55	245.94	22
Niyan Wee (4952)	56.4	-	67.15	122.66	62.27	87.62	90.06	30.09	4.99	78.78	20.5
Nona Bokra (8269)	12.86	-	16.22	76.24	15.96	76.22	79.21	10.2	15.33	12.32	19
O.echinagari	95.88	-	100.01	66.24	93.84	92.7	119.39	10.43	4.76	138.26	48.5
Pachchaperumal (3136)	42.16	36.73	69.69	68.08	69.13	84.22	103.05	16.97	51.18	60.88	31
Podi Niyan Wee (4913)	79.38	86.54	95.95	76.76	101.27	83.1	100.62	21.78	33.93	39.23	28.5
Rath Al (4171)	42.1	-	31.4	96.8	44.11	90.4	93.02	14.01	36.36	47.32	25
Rathna Walu (5566)	12.77	42.07	36.91	64.06	20.46	66.93	73.26	13.53	18.21	19.79	30
Rathu Heenati (4992)	32.81	39.94	58.47	50.11	58.66	80.02	77	23.97	9.57	174.53	32
Suwada Al (4802)	0.63	-	1.6	127.12	0.64	72.74	59.56	21.25	73.91	52.7	19
UPIR 15 (5393)	41.56	-	55.29	92.03	59.29	83.94	63.3	9.45	36.33	0	20
USA Batapola al (6718)	49.94	18.25	39.49	98.37	65.69	74.22	119.42	4.82	45.88	4.31	30

** relative yield (RY), relative spikelet fertility (RSF), relative biomass (RBM), relative harvest index (RHI), relative 1000 grain weight(%GW), relative spikelet per panicle(%RSPP) drought induced relative root length (DIRRL), drought induced relative root volume (DIRRV) and relative deep root volume >30 cm (RDRV), Days to leaf rolling (DLfR). -Data not available*

Relative spikelet fertility - Relative spikelet fertility of these tested accessions showed that it significantly varied among accessions. It ranged from 1.6 % (Suwandel) to 100% (*O. echingari*). Except wild relative accession of rice all other accessions showed reduction of spikelet fertility under drought conditions in varying extents.

Six traditional rice accessions (Al Wee (4023), Mada Al Galle, Podi Niyanwee, Magoda al, Al Wee (4919), Goda Heenati (4049) and improved variety Bg 300 showed less than 20% reduction in spikelet fertility due to drought stress. Suwandel, Elay Wee and Nona Bokra showed more than 80% reduction in spikelet fertility due to drought. Previous studies showed that spikelet fertility is the most sensitive trait that affects yield (Lafitte *et al*., 2002). Further he highlighted that if rice plant is faced to the drought at flowering stage, the grain yield reduces drastically due to the reduction in spikelet fertility. Therefore, it can be used as one of the selection criteria to select drought tolerant lines.

Relative Plant biomass - Plant biomass is an important trait that can indicate direct effect of drought on dry matter production. Traditional varieties normally have high biomass compared to improved varieties. By considering relative biomass of each accession under drought and controlled conditions performances can be evaluated. In these tested accessions Relative total biomass showed significant variation among tested accessions. It varied from 52.1% (Rathuheenati) to 151.4 % (Elay Wee). Five traditional rice accessions (Niyan Wee (4952), Suwandel, Hal Al, Elay Wee, Mada Heenati) and one improved line (Ld 12-38) showed no reduction in biomass under stressed conditions.

Relative Harvest Index - The most important parameter that decides yield in rice is the harvest index (HI). Drought that occurs near flowering stage has a large effect on spikelet fertility and thus HI and grain yield (Fischer and Fukai, 2003). Relative HIs of accessions were studied using above ground biomass. Significant variation in HIs was observed at 0.001 probability level. It ranged from 0.637% (Suwandel) to 101.3% (Podi Niyanwee). Podi Niyanwee showed zero reduction in HI under drought stressed conditions. HI is the most important criterion in the development of improved varieties. Shorter plants and greater spikelet number have positive effects on HI. Therefore, all improved varieties tested in the present study showed high harvest indices. Traditional varieties are poor yielders and HI of traditional varieties is comparatively less (Fischer and Fukai, 2003). However, reduction in HI due to drought stress in some of the traditional accessions (Podi Niyanwee, Mada Al Galle, Goda Heenati (4049), Al Wee (4919), Kahamalan wee, Goda Al Wee (6338), and Magoda Al (4905) was less than 20% .

Reductions in 1000 grain weight and spikelet per panicle among these tested accessions due to drought stress were not significantly different.

After drought induction at early booting stage days taken to leaf rolling was observed. It showed significant variation among the accessions. Wild species *O. eichingari* took maximum days (48 days) to show leaf rolling symptoms. Accessions *O. eichingari*, Al Wee (4023), Al Wee (4919), Goda Al Wee (6338), Moraberekan and Bg 300 took significantly high number of days to leaf rolling. In contrast Elay Wee (3503) showed leaf rolling symptoms 10 days after drought induction (Table 1). Accessions which took few days for leaf rolling showed considerable yield reduction and very low spikelet fertility under induced drought conditions. Blum (1988) reported the use of delayed leaf rolling under water stress as an important selection criterion for dehydration avoidance. Delayed leaf rolling is an indication of turgor maintenance and a component of dehydration avoidance. Further, it is considered as an good indicator of stress in drought stress experiments (Coutois *et al*., 2000).

Below ground traits

Root traits are key components of plant adaptation to drought environments. Drought tolerant rice cultivars have the ability to penetrate into deep soil to exploit moisture available at deep soil layers (Blum, 2002). Normally traditional cultivars have comparatively large root systems. Contribution of root system to yield under water stress conditions can be investigated using relative performances. Significant variations among accessions were observed in drought induced root length (DIRL), drought induced total root volume (DIRV) and drought induced deep root volume below 30cm depth (DIDRV ($P < 0.001$).

Drought Induced Root Length

Hal Al, Niyan Wee (4952), Al Wee (4919), Mada Heenati, Rathu Heenati, Bg 300 and Suwandel showed significantly high relative root length. Significantly low drought induced root length was observed in Kuru Wee, USA Batapola Al, Mada Al (4292) and Mada Al Kalutara (Table 1).

Drought Induced Total Root Volume - Total root volume gives an idea about adjustment to the drought stress by increasing water absorption surface. All tested accessions showed increase in root volume with drought stress, but the magnitude varies among accessions. Significantly high drought induced root volume was observed in Kaluwee (100.2%) and Goda Heenati (4049) (92.4%). It is comparable with exotic drought tolerant accessions Blackgora (88.7%) and Kinandang Patong (72.4%).

Drought Induced Deep Root Volume - Root volume below 30cm depth is contributing more to the drought tolerance. Significant variation of root volume below 30cm depth was observed among accessions. Mada Al Wee (4436), Kahata Wee (3478), Niyan Wee (4909), Rathu Heenati (4992), Magoda Al (4905) and *O. eichingari* showed significantly high root volume below 30cm depth (Table 1).

Correlations among traits under stressed and unstressed conditions - Phenotypic correlations among traits both under water stressed and control or unstressed conditions were summarized in Table 2. It showed that all the traits directly related to productivity. Yield, spikelet fertility, harvest index, 1000 grain weight and spikelets per panicle were significantly positively correlated under both controlled and water stressed conditions. Correlation coefficients of these traits were high under drought condition than unstressed condition (Table 2). Though there is significantly high correlation observed between yield and plant biomass under unstressed condition, no such correlation was observed under drought condition.

Under water stressed condition spikelet fertility and harvest index were negatively correlated with plant biomass. Further, 1000 grain weight was positively correlated with yield and spikelet fertility and not significantly correlated with relative biomass and root traits. However, root length and root volume significantly correlate with plant biomass, date of flowering and date of maturity under water stress and control conditions. Under water stressed condition harvest index negatively correlated with root length and total root volume.

Table 2. Correlation coefficients among tested traits in the plant house study. Upper and below diagonal represent the coefficients under non-stressed and stressed conditions, respectively .

	TY	SF	PBM	HI	GW	SPP	DF	DM	RL	RV	DRV
TY	*	**0.507**	**0.654**	**0.63**	**0.409**	**0.329**	**0.212**	0.189	0.152	**0.373**	**-0.358**
SF	**0.796**	*	0.145	**0.479**	**0.521**	0.143	-0.102	-0.189	-0.053	-0.027	-0.102
TBM	0.008	**-0.296**	*	-0.16	0.141	0.116	**0.608**	**0.554**	**0.457**	**0.698**	**-0.497**
HI	**0.774**	**0.766**	**-0.437**	*	**0.413**	0.155	**-0.425**	**-0.417**	**-0.358**	**-0.263**	**0.266**
GW	**0.400**	**0.486**	-0.167	**0.437**	*	-0.14	**-0.289**	-0.206	0.145	0.019	-0.106
SPP	**0.289**	0.115	0.203	0.175	-0.037	*	**0.341**	**0.278**	0.067	0.186	-0.093
DF	-0.052	**-0.215**	**0.611**	**-0.504**	**-0.327**	0.172	*	**0.854**	**0.432**	**0.631**	**-0.484**
DM	-0.211	**-0.309**	**0.554**	**-0.593**	**-0.335**	0.075	**0.858**	*	**0.501**	**0.624**	**-0.600**
RL	-0.134	**-0.271**	**0.468**	**-0.48**	-0.048	0.126	**0.514**	**0.529**	*	**0.429**	**-0.374**
RV	0.011	-0.226	**0.708**	**-0.427**	-0.131	**0.218**	**0.677**	**0.664**	**0.58**	*	**-0.675**
DRV	0.013	0.157	**-0.461**	**0.367**	0.041	-0.002	**-0.473**	**-0.524**	**-0.328**	**-0.689**	*
DLfR	0.040	**0.301**	**-0.662**	**0.179**	0.054	-0.182	**-0.42**	**-0.354**	**-0.293**	**-0.451**	**0.358**

•Bolded Coefficient values are significant at probability level < 0.001
Total yield (TY), spikelet fertility (SF), plant biomass (PBM), harvest index (HI), 1000 Grain weight(GW) and spikelet per panicle (SPP), Days to flowering (DF), days to maturity (DM), root length (RL), root volume (RV), deep root volume below 30 cm (DRV) and days to leaf rolling (LfR).

However, total biomass positively correlated with root traits. It revealed that under drought condition deep root growth increased dry matter production for survival of plant and it did not increase grain yield proportionately. Similar results were observed by Yue *et al*. (2006). Under water stressed condition days to leaf rolling positively correlated with spikelet fertility, harvest index and root volume below 30 cm depth. It indicated that drought induced deep root growth may have a positive effect on availability of water in the plant and delaying leaf rolling. Similar correlation patterns were observed by Yue *et al*. (2006); Babu *et al*. (2003).

Heritability of traits under stressed and unstressed conditions

Broad scene heritability (Hb) of yield, spikelet fertility, harvest index, root length and total root volume below 30 cm depth under stressed condition were high and it is comparable with heritability under non stressed conditions (Table 3). Similar results were recorded by Babu *et al.* (2003), Kumar *et al*. (2007). Heritability of total biomass and total root volume were lower under water stressed condition than that of under control condition. This indicated that these traits are partly influenced by the environment and the environment influence are comparatively higher under drought conditions. Heritability of a trait determines the extent to which plant improvement through selection of the particular trait can be done. Thus, drought tolerance can be improved by selecting varieties for relative yield, spikelet fertility, harvest index and drought induced root volume below 30 cm depth.

Table 3. Heritability values of tested traits under stressed and non-stressed conditions

Trait	**Broad Sense Heritability**	
	Hb (unstress)	***Hb (stress)***
Yield	0.75	0.77
Spikelet fertility	0.85	0.79
Total plant biomass	0.78	0.52
Harvest index	0.74	0.83
Grain weight	-	-
Spikelet per panicle	-	-
Root length	0.81	0.71
Total root volume	0.96	0.61
Drought induced root volume	0.83	0.83
Days to Leaf rolling	-	0.81

Field Screening

Same set of accessions were evaluated under field conditions at the Rice Research and Development Institute, Batalagoda and the Field crop Research and Development Institute, Mahailluppalama. The trial at Batalagoda failed due to rain at flowering and seed filling stages. At Mahailluppallama a severe drought was observed. Average soil moisture content at leaf rolling stage was measured according to the gravimetric method at 30 cm soil depth and it varied from 9.2-9.6 %.

In this location only the accessions matured within 3-3.5 months faced drought stress at flowering stage and for rest of the accessions induction of drought stress at flowering stage failed due to rain. Therefore, only 25 accessions were selected for the study. A significant yield reduction was observed among the tested accessions under water stressed condition. Percentage relative yield of these accessions varied from 86.9% (DSN11) to 18.3% (USA Bata Pola Al). Out of these tested accessions DSN11, Podi Niyanwee and Goda Heenati (4049) gave significantly less yield reductions due to drought (Table 1). USA Bata Pola Al, Kahata Wee, Kalu Mada Al, Bg 357 showed significantly low relative yields, which gave more than 70% yield reductions. Podi Niyanwee, DSN11, and Goda Heenati (4049) showed good performance under induced drought conditions in plant house screening as well as in the field. Lafitte *et al*. (2003) stated that the withhold water about a period of 14 days from 10 days before flowering until 4 days after flowering can reduce yield by 20-40% when compared to the fully irrigated control. Even relatively mild stress at this stage has a large impact on grain yield. In the present study drought stress was induced at early booting stage and continued nearly 35-40 days. Thus a considerable phenotypic variation among accessions was observed in respect to drought response. Some accessions withstood drought conditions without drastic yield reductions i.e. *O. eichingari*, Podi Niyanwee, Goda Heenati (4049), Al Wee (4919), Mada Al Galle, Bg 300, Kinandang Patong, Ld 12-38. Accessions, which gave significantly high relative yield performed well in other traits.

Based on the results of the present study different adaptations were observed by the accessions for the survival of plants at water stress condition. Some accessions such as Suwandel (4802) and Elay Wee (3503), maintained high total biomass under drought conditions however, significant yield reductions were observed. However, spikelet fertility and harvest index of these accessions were drastically reduced with drought. Low yield of these accessions might be associated with high spikelet sterility under droughts. Correlation analysis showed that there was a significant positive correlation between days to leaf rolling and spikelet fertility under water stressed condition. However, Rang *et al*. (2011) identified a positive relationship of flag leaf rolling due to drought stress with spikelet sterility. Some of the accessions [Niyan wee (4909), Al Wee (5395), Mada Al Wee(4436), Kahata Wee (3478), Rathu Heenati (4992)] showed good root systems under drought conditions. However, it was not reflected through high yield. These accessions can be used as donors for improvement of root system in a drought resistant breeding program.

Seven exotic accessions were used in this evaluation. Out of those Kinandang

Patong, and IRRI developed improved varieties DSN 37 and DSN 11 performed well under water stressed conditions. Azucina, which has been identified as a drought resistant parent (Kamoshita *et al*., 2008) performed poorly in all the tested traits. Moraberakan showed comparatively less relative yield, relative harvest index but comparatively more number of days to leaf rolling. However, the improved line developed using Moraberakan, Ld 12-38 performed well under water stressed conditions.

Based on overall performance wild rice accession *O. eichingari*, traditional accessions; Al Wee (4919), Magoda al (4905), Al Wee (4023), Podi Niyanwee, Mada Al Galle, and Goda Heenati (4049) can be identified as drought tolerant accessions and the improved variety Bg 300, which is the most popular variety with short maturity duration in Sri Lanka, and improved line Ld 12-38 performed well under water stressed conditions.

These finding may have important inference in the development of drought tolerant rice varieties. Using these donor accessions drought tolerant traits can be incorporated into the improved breeding lines to develop high yielding drought tolerant lines. Further, genotypic and molecular studies have to be followed to exploit important genes responsible for drought tolerance in these selected accessions.

CONCLUSION

Based on the relative performances among accessions, significant morphological variations both in above and below ground traits were observed. Different adaptation mechanisms such as good root system, less reduction of spikelet fertility, less reduction of harvest index, maintain good plant biomass, comparatively more days for leaf rolling were shown by different accessions for their survival of plants under water stressed condition. Wild relative of rice *O. eichingari* showed the highest adaptation for the drought conditions. Traditional accessions Podi Niyanwee, Goda Heenati (4049), Al Wee (4919), Al Wee (4023), Mada Al Galle, improved accession Bg 300, Ld 12-38 and exotic accessions Kinandang Patong, DSN11 and DSN37 performed well under induced drought conditions.

These promising accessions can be utilized as donor parents in rice improvement programs for drought tolerance.

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