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Full Length Research Paper

Assessment for drought adaptive and reproductive traits of field-planted upland rice genotypes in a derived savannah ecology

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A field study was conducted in derived savannah ecology to evaluate sixteen upland rice genotypes comprising breeding lines, recent releases and established cultivars for the effect of different rainfall-seasons on genotypic trait expression and to identify those harbouring drought adaptive characters. Plantings were done in the early and late rain seasons of 2006 and 2007, respectively. Data were collected on root, vegetative and reproductive traits and analyzed using the analysis of variance (ANOVA) and simple correlation. The genotypes revealed some variability for root, shoot, and grain yield characters which can be exploited to improve drought tolerance and grain production. There were significant variety, season and variety-by-season effect for most of the root, vegetative and reproductive characters. IRAT 170 had relatively better root volume and dry weight making it a suitable parent for upgrading drought tolerance in new rice for Africa (NERICA) 1, ITA 150, WAB 56-50 and genotypes with superior grain production. Reproductive and vegetative characters were positively correlated with most root characters, suggesting possibility of joint inheritance. Root thickness notably was not correlated with other root and shoot characters. Continuous introgression of drought adaptive traits into promising genotypes for tolerance to variable soil moisture, typical of derived savannah ecologies, was canvassed.

Key words: Drought, rice, interspecific hybrids, derived savannah ecology, grain yield.

INTRODUCTION

Drought conditions in upland and lowland paddies, caused by variable levels of water deficit in rice cultivation have been reported to cause a reduction in many morphological characteristics resulting eventually the lowering of root and shoot dry matter and grain yield (Price et al., 2002; Boonjung and Fukai, 1996; Lafitte et al., 2006; Wang et al., 2009). Consequently, the quest for further understanding of drought tolerance for increased productivity in rice has continued to attract intensive research, especially for upland paddies which remain underutilized in regions having the ecology. Poor ability of varieties to produce economic quantities of grains, due to the concomitant poor panicle yield, caused by varying degrees of water stress, makes rice production in upland regions risky and unattractive due to low yield of 1 to 2 tonnes/hectare (Atlin et al., 2006).

This has become accentuated by the unpredictable cultivar performance in many rice growing regions (Samonte et al., 2005; Atlin et al., 2006; Nassir and Ariyo, 2011). Direct selection for yield has been the most commonly used selection strategy by cereal breeders to improve yield in water limiting environment (Araus et al., 2002; Banziger et al., 2006). Several secondary traits associated with the understanding of drought tolerance and the effects crop yields have been identified and studied to some extent (Fukai and Cooper, 1995; Price and Courtois, 1999; Price et al., 2002; Kumar et al., 2008). The detrimental effect of soil water deficit on

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Abbreviations: ANOVA, Analysis of variance; **QTL,** quantitative trait loci; **NERICA,** new rice for Africa; **WAP,** weeks after planting; **DMRT,** Duncan multiple range test; **MS,** mean square; **PMS,** percentage mean squares; **VT x SS,** variety-by-season interaction.

biomass production at the phenological stages, and eventually grain yield was extensively discussed by Boonjung and Fukai (1996). The additional influence of the water stress on photosynthesis and plant growth rate, which also run concurrently with the period of root development, is a major concern for breeding drought tolerant rice (Wang et al., 2009). The development of drought tolerant varieties would be aided by the influence of water deficit on root characters. Price et al. (2002) reiterated the importance of deep and thick root system to drought resistance, as it allows access to water in the soil profile. Other studies have focussed on the general introgression of quantitative trait loci (QTL) associated with drought tolerance (Price et al., 2002; Bernier et al., 2009). With this, it is hoped that specific traits related to drought tolerance would become accentuated and eventually result in better adaptation of genotypes to drought conditions, with concomitant improvement in grain yield.

With the inherent variability of upland ecologies, and the attendant interaction with environment for several rice traits, varieties and traits identified as having the potential for drought tolerance in a location may not necessarily exhibit consistency over a large area or overtime (Nassir and Ariyo, 2005, 2006; Botwright et al., 2008). Although some QTL with fairly wide adaptability have been reported, MacMillan et al. (2006), Bernier et al. (2009) and Degenkolbe et al. (2009) observed that most QTL are specific to a very limited environment alluding thereby to the need for the development of environment based drought tolerant cultivars.

Most West African selections were based on identification of genotypes with ample grain yield under variable field moisture conditions. The implication is that the selections may still have diffused traits fostering the drought adaptive performance. Quite a number or the existing selections would therefore harbour drought adaptive traits in many loci. This is due to years of adaptation to upland conditions where moisture conditions are naturally inconsistent. Consequently, there is the need for evaluation of some of the available high yielding selections using moisture stress as an underlying factor. The study has the possibility of identifying more drought tolerant varieties of tropical African origin; expose the drought adaptive trait relationship that can be of use in the evolution of genotypes with drought adaptation and improved grain yield. Additionally, recently released drought tolerant varieties, especially the new rice for Africa (NERICA) would also require further studies to extend the knowledge of ecology based trait -environment interaction for increased grain production. These constitute the focus of this study.

MATERIALS AND METHODS

Experimental site

Two field experiments were conducted in the late and early rain seasons 2006 and 2007, respectively at the Teaching and Research farm of Olabisi Onabanjo University, Agricultural Sciences, Ayetoro, Ogun State, Nigeria (6.5°N, 10°E). The site is located in the derived savannah zone of south-west, Nigeria. The soil is an alluvial loam with water condition ranging from very wet to dry in the early and late rain seasons, respectively. The site rainfall and temperature data for the experimental period is presented in Table 1.

Genotypes used for the experiments

The sixteen rice genotypes used for the experiments were obtained from the WARDA unit, International institute for tropical Agriculture (IITA), Ibadan, Nigeria. The genotypes include breeding lines: WAB 880-9-32-1-1-12-HB, WAB 56-50, WAB 224-8-HB, WAB 189-B-B-HB, WAB 337-B-B-20-1-12, WAB 181-18; established genotypes: ITA 150, ITA 321, ITA 257, 0S6, IRAT 170, and recent releases: NERICA I, NERICA 2, NERICA 3, NERICA 4, and NERICA 5.

Field establishment

The seedlings of each genotype were transplanted at three weeks after sowing (3WAS) in three-row plots of three meter long. Each row had ten plants with a spacing of 30 cm between and within rows. The plots were arranged in a randomized complete block design (RCBD) with four replicates. Fertilizer (120 kg N/ha) was uniformly at the seedling stage. Manual weeding was done at two and six weeks after planting (WAP). Insect control was done by spraying of Nuvacron (Monocrotophos) fortnightly at 2 ml/L of water from two WAP. Damages by birds were prevented with the use of human labour.

Data collection

Root characters

Plants in border rows were uprooted at different developmental stages that is, tillering, maximum tillering (panicle initiation stage) and panicle maturity stage to take their root characters and moisture status. Roots of three plants from each genotype were collected, washed and then air dried until obtain a constant weight. Root thickness and root branching were scored visually as following IRTP (1976) and used by Ekanayake et al. (1985); Root thickness: 1 = all roots thicker than 2 mm and 9 = all roots thinner than 1mm; Root branching: 1 = little branching and 4 = extensive branching. Root volume was measured as volume of displaced water when soil-free roots were inserted in clean distilled water.

Agronomic and yield characters

Six plants internal to the boarder rows were sampled for their agronomic characters and yield components as described by Anon (1988) (Table 1). At maturity, panicles were harvested on hill (plant) basis into paper bags. The panicle of the primary tiller (tallest culm) for each plant was harvested separately to obtain some panicle yield components.

Samples moisture content

The air-dried whole plants for each genotype were separated into roots and shoots. The fresh weights were measured in grams with the use of highly sensitive digital weighing balance. The plant parts were later air dried for many days till constant weights were

Table 1. Characters used in the analysis and their methods of measurement / scoring.

S/N	Character	Measurement / Score(s)
1.	Seedling height (cm)+	Measured
2.	Tillering ability (no)	Counted
3.	Leaf number (cm)	Counted
4.	Panicle number	Counted
5.	Panicle length (cm)	Measured
6.	Primary branches (no)	Counted
7.	Secondary branching	0 (Absent), 1 (Light), 2 (Heavy), 3 (Clustering)
8.	Grain weight per panicle (g)	Weighed
9.	Grain weight per plant (g)	Weighed
10.	100-grain weight (g)	Weighed
11.	Spikelet number per panicle	Counted
12.	Spikelet fertility per panicle(s)	1(90% or more spikelets filled), 3(75-89%filled), 3(50-74% filled), 7 (Less than 50% filled), 9(0%)
13.	Grain length (mm)	Measured
14.	Grain width (mm)	Measured
15.	Days to flowering	Number of days from seeding to 50% flowering on each plot

Source: Standard evaluation system for rice (Anon, 1988). +cm, Centimetre; no, number; g, grams; mm, millimetre; s, score.

obtained. The dry weight for both roots and shoots were thereafter taken.

Statistical analysis

Data were analysed using the means of character measurements on characters for each variety. Computer analysis of variance (ANOVA) was done using the statistical analysis system (SAS) and statistical package for the social sciences (SPSS) packages following simple factorial procedure. Simple correlation analysis involving vegetative, root and yield characters from different moisture condition were also carried out. Means were separated using the Duncan multiple range test (DMRT).

RESULTS

Root characters

The mean square (MS) and percentage mean squares (PMS) for the root characters are presented in Table 2. The MS for variety and season were significantly different for all the root characters except for root thickness. There was significant for variety-by-season (VT × SS) interaction for all the characters. The season-by-stage of growth interaction was significant for root volume, weight of fresh root and dry root. The PMS for season was highest with the value of 85.5, 30.0 86.1 and 76.5 for root volume, root branching, weight of fresh and dry root respectively. Variety recorded highest PMS of 24.9 for root thickness (Table 2). IRAT 170 had the largest mean value for root volume, dry, and fresh root weight of 12.19 ml, 22.19 and 40.6 g, respectively (Table 3). A recent release, NERICA 2, had a root volume of 10.6 ml which was not significantly different from that of IRAT 170. It also had appreciable weight for dried and fresh root (Table 3). ITA 257 recorded the highest mean score for root thickness of 8.11 but not significantly different from 0S 6 and WAB 224-8-HB with value of 7.67 and 6.33, respectively. Similarly, WAB 880-9-32-1-1-12-HB recorded the highest mean scores for root branching though this was not significantly different from that of NERICA 1.

Vegetative characters

The MS for season and stage of growth were significant for all the vegetative characters. Season recorded highest PMS for all the characters (Table 4). In terms of tiller number, WAB 56-50 and ITA 150 were not significantly different from one another and indeed most of the other genotypes, but were significantly better than WAB-224-B-HB (Table 5). All the NERICA entries had moderate tillers. NERICA 1 recorded highest mean value for the plant height of 133.33 cm. All the genotypes were similar in terms of leaf number.

Reproductive characters

The MS analysis for variety and season and their interaction were significantly different for all panicle characters with the exception of VT × SS interaction for panicle number (Table 6). Season recorded consistently

Table 2. Mean square and percentage mean square for root characters of sixteen varieties field-planted upland rice.

Character	Root volume (ml)[+]		Root thickness (mm)		Root branching (s)		Fresh root weight (g)		Dry root weight (g)	
Source of variation	**MS**	**PMS (%)**	**MS**	**PMS (%)**	**MS**	**PMS (%)**	**MS**	**PMS (%)**	**MS**	**PMS (%)**
Replicate	110.994*	0.88	38.000	17.2	2.816	7.0	1908.369*	1.3	494.590**	1.7
Variety (VT)	67.204**	0.54	54.993**	24.9	11.702**	29.1	595.605**	0.4	264.179**	0.9
Season (SS)	10732.834**	85.5	43.556	19.8	12.087**	30.0	126136.321**	86.1	22358.371**	76.5
Stage of growth (ST)	667.567**	5.3	2.667	1.2	0.181	0.5	9223.727**	5.3	3068.041**	10.5
VT × SS	65.524**	0.52	39.289**	17.8	8.613**	21.4	650.517**	0.4	287.016**	1.0
VT × ST	17.586	0.14	11.200	5.1	1.573	3.9	123.229	0.8	80.819	0.3
SS × ST	838.097**	6.67	11.556	5.2	0.514	1.3	7633.630**	5.2	2528.599**	8.7
VT × SS × ST	28.279	0.23	5.867	2.7	1.084	2.7	125.394	0.09	82.924	0.3
Error MS	26.605	0.21	13.298	6.	1.683	4.2	152.776	0.10	60.796	0.2
Total	12554.69		220.366		40.253		146549.53		29225.335	
Adjusted R^2	0.66		0.17		0.332		0.8		0.706	

*,**, Mean square values are significant at 5% and at 1% probability level respectively; [+]ml, millilitre; mm, millimetre; s, score; g, grams.

the largest component of MS for all the panicle characters. For grain yield components (Table 7), variety and season as treatments were significantly different for all grain yields characters. VT × SS were significant for all the grain yield components except for grain weight per panicle and spikelets number per panicle. The interaction component of variation as measured by the PMS was equally larger than the variety variation for most of the characters (Table 7).

For primary branching (Table 8), NERICA 3, NERICA 2, WAB 880-9-32-1-1-12-HB and WAB 56-50 had similar primary branching ability with mean values of 10.8, 10.7, 10.5 and 10.4 cm, respectively though this was not significantly better than those of WAB 189-B-B-HB, ITA 150 and NERICA 1. The least mean number of primary branches of 5.10 and 5.13 cm were recorded by WAB 337-B-B-20-1-12 and IRAT 170, respectively though these were not significantly different from the value for a few other genotypes. The recent releases: NERICA 1, NERICA 2 and NERICA 3 had the highest scores for secondary branching of the panicles with mean score value of 1.67 each. WAB 880-9-32-1-1-12-HB recorded highest mean value of 25.08 cm for panicle length though not significantly different from those of WAB 56-50, ITA 150, NERICA 2, NERICA 3 and NERICA 1 with mean value of 24.77, 23.2, 23.15, 23.02 and 22.7 cm, respectively. IRAT 170 recorded least mean value for the panicle length with value of 12.71 cm (Table 8).

In terms of grain yield components, NERICA 3 had the most mean grain length of 0.84 mm but not significantly different from those of WAB 56-50, ITA 150, WAB 189-B-B-HB, WAB 880-9-32-1-1-12-HB and NERICA 2 and NERICA 1 (Table 9). The remaining genotypes are comparable in grain length though NERICA 5 and WAB 224-8-HB had the least value of 0.39 mm. WAB 56-50 and NERICA 1 had comparably the most spikelets number per panicle at mean value of 162.27 and 143.07, respectively. ITA 321, NERICA 5, WAB 337-B-B-20-1-12 and WAB 181-18 recorded highest score of 6.0 each for spikelets fertility per panicle (Table 9).

Correlation coefficients

Table 10 shows the correlation coefficients among vegetative and root characters of the studied genotypes. Most of the characters exhibited significant correlation *inter se* except for root thickness which was not significantly correlated with any character. Root volume, dry root weight and tiller number were correlated with other characters except root thickness.

DISCUSSION

The significant MS for variety reported in the studies for root characters imply differences in the performance of the varieties with respect to rooting. Even though the percentage of variation accounted for was smaller relative to the season

Table 3. Mean values for root characters of sixteen varieties of field-planted upland rice.

Variety	Root volume (ml)+	Root thickness (s)	Root branching (s)	Fresh root weight (g)	Dry root weight (g)
WAB 880-9-32--1-1-12-HB	6.91 bc	2.78 ef	3.94 a	22.45 bc	8.87 bc
NERICA 1	6.15 c	5.44 abcde	3.67 a	20.48 bc	8.45 bc
ITA 150	5.62 c	3.67 cdef	2.33 def	18.73 bc	10.15 bc
WAB 56-50	8.24 bc	1.89 f	1.50 gf	27.53 b	7.81 bc
NERICA 2	10.64 ab	5.89 abcd	2.67 bcde	24.66 bc	10.12 bc
NERICA 3	5.96 c	3.22 def	1.17 g	19.99 bc	7.72 bc
WAB 224-8-HB	8.28 bc	6.33 abc	3.50 ab	27.58 b	12.90 b
NERICA 4	6.29 c	3.67 cdef	3.00 abcd	21.14 bc	9.63 bc
ITA 321	7.75 bc	5.07 bcdef	2.00 efg	25.77 b	9.63 bc
NERICA 5	5.79 c	4.56 cdef	3.11 abcd	17.99 bc	6.38 c
WAB 189-B-B-HB	4.71 c	5.00 bcde	1.83 efg	15.4 c	5.78 c
OS6	6.30 c	7.67 ab	2.00 efg	21.04 bc	7.85 bc
ITA 257	5.95 c	8.11 a	3.17 defg	19.81 bc	7.34 bc
WAB 337-B-B-20-1-12	6.90 bc	3.22 def	2.33 abcd	22.97 bc	11.81 bc
IRAT 170	12.19 a	6.33 abc	2.50 def	40.60 a	22.19 a
WAB 181-18	7.12 bc	4.56 cdef	3.33 abc	23.83 bc	11.83 bc

Means with similar alphabet are not significantly differently at p<0.05 using Duncan multiple range test (DMRT). +ml, millilitre; s, score; g, grams.

Table 4. Mean square and percent mean square for vegetative characters of sixteen varieties of field-planted upland rice.

Character	Fresh shoot weight (g)+		Dry shoot weight (g)		Tiller number		Plant height (cm)		Leaf number	
Source of variation	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)
Replicate	68152.225**	0.7	3775.282**	0.8	77.853**	0.67	3231.580	0.68	857.107**	0.35
Variety (VT)	12523.562**	0.1	677.562	0.2	9.864	0.08	3171.885	0.67	105.311	0.04
Season (SS)	8692153.177**	85	357497.836**	79.9	10032.240**	86.35	394753.147**	83.3	207424.891**	85.3
Stage of growth (ST)	739721.167**	7.2	48021.585**	10.7	1230.787**	10.6	44612.373**	9.4	23155.271**	9.5
VT × SS	13062.242**	0.1	731.541	0.16	17.954**	0.15	3588.399	0.76	182.831	0.08
VT × ST	6814.510	0.07	389.609	0.09	2.421	0.02	3485.572	0.74	54.942	0.02
SS × ST	673616.228**	6.6	37511.166**	8.3	237.964**	2.05	13812.340	2.9	11160.059**	4.6
VT × SS × ST	6452.189	0.06	328.903	0.07	2.309	0.002	13812.340	2.0	58.539	0.02
Error MS	5121.419	0.05	441.152	0.098	7.120	0.06	3586.391	0.76	121.999	0.05
Total	10217615		449374.6		11618.212		473856.9		243120.91	
Adjusted R^2	0.890		0.809		0.332		0.322		0.887	

***,**,** Mean square values are significant at 5% and at 1% probability level, respectively; +g, grams; cm, centimetre.

Table 5. Mean value for vegetative traits of sixteen varieties of field-planted upland rice.

Variety	Fresh shoot weight (g)[+]	Wt of dried shoot wt (g)	No. of tillers	Plant height (cm)	No. of Leaves
WAB 880-9-32--1-1-12-HB	207.16[ab]	41.61[abc]	9.78[abc]	86.67[b]	39.86[a]
NERICA 1	135.69[d]	29.71[a]	10.67[abc]	133.33[a]	38.86[a]
ITA 150	162.59[bcd]	32.66[bc]	11.10[a]	81.78[b]	43.61[a]
WAB 56-50	191.12[abcd]	44.47[abc]	11.16[a]	85.13[b]	43.99[a]
NERICA 2	203.14[ab]	48.53[ab]	10.08[abc]	77.39[b]	39.23[a]
NERICA 3	174.99[bcd]	39.02[abc]	10.21[abc]	80.88[b]	39.05[a]
WAB 224-8-HB	206.51[ab]	44.50[abc]	8.68[c]	81.91[b]	38.33[a]
NERICA 4	188.51[abcd]	43.33[abcd]	10.00[abc]	48.15[b]	37.94[a]
ITA 321	193.13[abc]	42.86[abc]	10.73[abc]	78.28[b]	42.47[a]
NERICA 5	157.82[bcd]	32.23[bc]	10.54[abc]	78.04[b]	40.13[a]
WAB 189-B-B-HB	145.01[cd]	31.56[bc]	10.00[abc]	81.39[b]	39.56[a]
OS6	179.59[bcd]	37.26[abc]	8.97[bc]	81.72[b]	36.18[a]
ITA 257	164.57[bcd]	38.17[abc]	10.76[abc]	83.56[b]	42.81[a]
WAB 337-B-B-20-1-12	170.43[bcd]	39.86[abc]	10.87[ab]	93.17[b]	41.77[a]
IRAT 170	240.76[a]	51.20[a]	11.02[ab]	86.90[b]	41.21[a]
WAB 181-18	191.68[abcd]	36.84[abc]	11.05[ab]	79.44[b]	40.86[a]

*Means with similar alphabets are not significantly different at p≤0.05 using Duncan multiple range Test (DMRT). [+]g, grams; cm, centimetre.

Table 6. Mean squares and percentage mean square for panicle traits of sixteen varieties of field-planted upland rice.

Character	Days to 50% flowering		Panicle number		Panicle length (cm)[+]		Primary branching (no)		Secondary branching (s)	
Source of variation	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)
Replicate	208.51	0.43	13.188	0.1	31.463	0.4	13.816	1	0.103	0.2
Variety (VT)	1713.878**	3.6	34.156**	0.4	131.886**	1.7	29.466**	2.0	0.512**	1.1
Season (SS)	12926.042**	89.4	9129.900**	99.2	7381.534**	95.9	1383.202**	95.5	43.336**	96.7
VT × SS	2972.464**	6.2	12.738	0.1	136.439**	1.8	19.480**	1.4	0.791**	1.8
Error	216.833	0.45	11.581	0.1	11.926	0.2	2.325	0.2	0.091	0.2
Total	48037.727		9201.573		7693.25		1448.29		44.833	
Adjusted R^2	0.838		0.896		0.907		0.903		0.874	

*,**, Means square value significant at 5% and 1% probability level, respectively; [+]cm, centimetre; s, score.

variation, it still suggests that the varieties used harbour reasonable amount of variability for the root characters that can still be exploited for selection, hybridization and further selection for improvement of root characters and possibly drought tolerance. Also, the major significant effect of season MSs for root characters implies marked influence of seasonal indices on rooting ability over the seasons. The attendant instability

Table 7. Mean square and percentage mean square for grain yield character of sixteen varieties of field-planted upland rice.

Character	Grain weight per panicle (g)+		Grain weight per plant (g)		Hundred-grain weight (g)		Grain length (mm)		Grain width (mm)		Spikelets per panicle		Spikelets fertility (s)	
Source of variation	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)	MS	PMS (%)
Replicate	16.604	1.7	262.83	60.1	0.294	0.4	0.017	0.4	0	0	196.587	0.0	1.792	0.5
Variety (VT)	13.32	1.4	1525.05**	0.4	4.175**	5	0.211**	4.6	0.005**	3.7	2360.390**	0.3	5.289**	1.4
Season (SS)	897.93**	94	408386.77**	99.2	75.793**	90.5	4.084**	89.7	0.124**	91.9	813280.167	99.4	368.167	95.8
VT × SS	14.927	1.6	1315.369**	0.3	3.197**	3.8	0.219**	4.8	0.006**	4.4	1234.92	0.2	7.989**	2.1
Error MS	12.430	1.3	148.357	0.0	0.297	0.4	0.021	0.5	0	0	759.619	0.1	1.103	0.3
Total	955.223		411638.36		83.756		4.552		0.135		817831.66		384.340	
Adjusted R^2	0.444		0.969		0.863		0.833		0.855		0.921			

*,**, Means square value significant at 5% and 1% probability level, respectively; +g, grams; mm, millimetre; s, score.

of root development and plant performance, over upland environments is underscored. However, the significant VT x SS interaction gives indication that the varieties exhibited differential responses to seasonal indices for rooting. Lafitte et al. (2006) had reported instability in the manner of interaction between rice genotypes and cultivation environments. The consequence of this is that the performance of the varieties as measured by root characters would be expected to show inconsistencies over cultivation (field) conditions. It further suggests the need for further studies response of rice and rooting dynamics to variable field moisture status, especially under tropical upland drought condition in order to reveal more information on the rice reaction to water deficit. This was clearly confirmed elsewhere by Lafitte et al. (2006) and Botwright et al. (2008). Hence, exposure existing varieties to differing seasonal (growing) conditions with natural or imposed differences in soil moisture, which in this case, appeared to be the major cause of the VT × SS variation, should continue offer opportunity for understanding response of ecology based selections to drought. Indeed, the high variation accounted for by the season component further attests for this.

With specific emphasis on varietal improvement, the identified variability among the varieties for root characters is indicative of the need for several crosses in order to concentrate important genes for root characters in a few varieties. As emphasized by O' Toole and Somartomo (1981), root morphology and root patterns influence directly the amount of water available to crop just as increased width, depth and branching of root system is linked to decrease plant water stress. The assertion of Price (2002) on diffused nature of genes and traits for drought tolerance further corroborates this. Expectedly, this would translate to higher productivity. IRAT 170, for instance, has high root volume and also high fresh and dry root weight but would benefit from improved root thickness and branching through introgression of genes from ITA 257 and WAB 880-9-32-1-1-12-HB, respectively. This may assist in overcoming, to some extent, the problem of lack of adequate concentration of drought adaptive traits in cultivars as emphasized by Fukai and Cooper (1995).

The significant MS for variety, season and stage of growth for vegetative traits showed variation among the varieties, marked differences of the seasons and also differential expression of the characters at different stages of rice growth. This cannot be isolated from the rooting ability of the varieties as most root characters exhibited positive correlation with vegetativeness, as measured by plant height, tiller number and leaf number. By inference, moderate to high tillering varieties like WAB 56-50, ITA 150, WAB 181-18, IRAT 170 and recently released NERICAS have better ability to tolerate drought stress better than WAB 224-8-HB and 0S6 varieties with least tiller number. The previous deduction of Cutler et al. (1980) which emphasized reduction in tiller number consequent upon drought that occur at the vegetative stage does not necessarily imply development of low tillering varieties for drought tolerance. The reverse may indeed be true.

The relatively higher value for tallness in NERICA 1 is a desirable trait in upland rice and

Table 8. Mean value for panicle traits of sixteen varieties of upland rice from the field studies under varying moisture condition.

Variety	Day to 50% flowering	Panicle number	Panicle length (cm)$^+$	Primary branching (no)	Secondary branching (s)$^+$
WAB 880-9-32--1-1-12-HB	79.67^a	10.52^{be}	25.08^a	10.5^a	1.50^{ab}
NERICA 1	82.00^a	12.83^{be}	22.77^a	9.55^a	1.67^a
ITA 150	82.00	14.65^b	23.2^a	9.13^{ab}	1.50^{ab}
WAB 56-50	82.00^a	19.15^a	24.77^a	10.40^a	1.50^{ab}
NERICA 2	75.83^a	10.68^{be}	23.15^a	10.7^a	1.67^a
NERICA 3	75.83^a	11.68^{be}	23.02^a	10.8^a	1.67^a
WAB 224-8-HB	45.00^a	8.93^c	13.72^b	5.92^{cd}	1.00^d
NERICA 4	55.33^b	10.93^{bc}	16.23^b	6.40^{cd}	1.17^{cd}
ITA 321	45.5^b	11.88^{be}	13.87^b	5.68^{cd}	1.00^d
NERICA 5	38.33^b	10.55^{be}	13.83^b	6.27^{cd}	0.97^d
WAB 189-B-B-HB	82.17^a	11.82^{be}	22.58^b	10.00^a	1.62^a
OS6	48.00^b	10.05^{be}	14.2^b	5.72^{cd}	0.97^d
ITA 257	50.17^b	11.23^{be}	16.3^b	6.83^{cd}	1.43^{bc}
WAB 337-B-B-20-1-12	43.3^b	10.27^{be}	14.18^b	5.10^d	1.00^d
IRAT 170	53.33^b	10.43^{be}	12.71^b	5.13^d	1.00^d
WAB 181-18	55.00^b	10.55^{be}	17.37^b	7.67^{bc}	1.10^d

Means with similar alphabets are not significantly different at $p \leq 0.05$, using Duncan multiple range test (DMRT). $^+$cm, centimetre; s, score.

Table 9. Mean Value for grain character of sixteen varieties of upland rice form the field studies under varying moisture condition.

Variety	Grain wt per panicle (g)$^+$	Grain wt. Per plant (g)	Hundred grain wt (g)	Grain length (mm)	Grainwidth (mm)	Spikelets no panicle	Spikelets fertility
WAB 880-9-32--1-1-12-HB	4.25^b	61.47^{def}	3.32^b	0.81^a	0.10^{def}	136.58^{bed}	3.67^d
NERICA 1	3.95^b	80.98^{be}	2.97^b	0.76^a	0.10^{bed}	143.07^{ab}	3.67^d
ITA 150	4.32^b	93.83^{ab}	4.08^a	0.82^a	0.13^b	111.83^{bcde}	3.67^d
WAB 56-50	4.83^b	97.68^a	3.37^b	0.83^a	0.12^b	162.87^a	4.00^{cd}
NERICA 2	3.05^b	48.48^{bgf}	2.85^b	0.76^a	0.11^{bc}	119.32^{cdef}	4.33^{bed}
NERICA 3	3.25^b	54.12^{gf}	2.95^b	0.84^a	0.12^b	119.58^{bed}	4.33^{bed}
WAB 224-8-HB	2.80^b	49.85^{gf}	1.37^d	0.39^b	0.05^d	124.9^{bed}	5.67^{ab}
NERICA 4	2.30^b	46.15^g	2.02^{cd}	0.53^b	0.07^{de}	105.77^{bcde}	5.33^{abc}
ITA 321	8.68^a	73.65^{cd}	1.75^{cd}	0.40^b	0.08^{cde}	96.92^{ef}	6.00^a
NERICA 5	2.72^b	55.28^{efg}	1.5^{cd}	0.39^b	0.07^{cd}	90.72^{ef}	6.00^a
WAB 189-B-B-HB	4.10^b	76.68^{cd}	3.56^{ab}	0.82^a	0.15^a	110.38^{bcde}	4.00^{cd}
OS6	2.63^b	51.35^{gf}	1.67^{cd}	0.40^b	0.06^{ef}	84.78^e	5.66^{ab}
ITA 257	2.85^b	64.37^{def}	2.08^{cd}	0.56^b	0.08^{def}	105.93^{bcde}	5.00^{abcd}
WAB 337-B-B-20-1-12	3.70^b	76.37^{cd}	1.77^{cd}	0.44^b	0.08^{def}	105.93^{bcde}	6.00^a
IRAT 170	3.37^b	70.15^{cde}	1.87^{cd}	0.43^b	0.08^{cde}	102.86^{cde}	5.33^{abc}
WAB 181-18	4.03^b	74.45^{cd}	2.22^c	0.55^b	0.08^{cde}	118.67^{bcde}	6.00^a

Means with similar alphabets are not significantly different at $p \leq 0.05$, using Duncan multiple range test (DMRT). $^+$g, grams; mm, millimetre.

according to Nassir and Ariyo (2006), can confer better competitive ability against weeds. NERICA 1 also had moderate tillering ability and can be improved for drought tolerance by carrying out crosses with the established lines such as IRAT 170 and ITA 257 to concentrate the genes for drought adaptive root characters, specifically.

The marked variability in stages of growth for vegetative characters was supported by the findings of Boojung and Fukai (1996), and is consistent with phenological manifestation expected of the plants. Drought condition influences vegetative rice growth just as the effect of such on root development would be expectedly implicated.

Table 10. Correlation coefficient among vegetative and root characters of sixteen field-planted upland rice.

Character	RT	RB	FRW	FSW	DRW	DSW	TN	PH	LN
Root volume (RV)	0.046	0.172**	0.920**	0.854**	0.847**	0.825**	0.756**	0.415**	0.770**
Root thickness (RT)	-	0.028	0.068	0.073	0.092	0.085	0.033	-0.005	0.077
Root branching (RB)		-	0.160**	0.127	0.168**	0.086	0.131*	0.095	0.114
Fresh root weight (FRW)			-	0.930**	0.919**	0.899**	0.831**	0.456**	0.844**
Fresh shoot weight (FSW)				-	0.833**	0.960**	0.866**	0.477**	0.889**
Dry root weight (DRW)					-	0.827**	0.733**	0.395**	0.752**
Dry shoot weight (DSW)						-	0.837**	0.448**	0.858**
Tiller number (TN)							-	0.543**	0.962**
Plant height (PH)								-	0.550*

Most of the variation in panicle characters was however explained by the season and by extension, soil moisture differences. This should underscore the importance of drought tolerance in developing genotypes for increased grain production. Nonetheless, the appreciable variability for panicle and grain yield characters among the genotypes constitutes a gene pool that can be applied for the improvement of the yield and grain characters, along with improved root development for drought tolerance of the varieties. Specifically, the variability indicates the need for crosses to concentrate important genes for panicle and grain yield characters in recent releases like NERICA 2 and NERICA 3 with the breeding lines WAB 880-9-32-1-1-12-HB, WAB 56-50 and WAB 189-B-B-HB which exhibited profuse primary and secondary panicle branching. This should lead, for instance, to increase in spikelets number per panicle and grain yield. A similar position was emphasized by Kozan et al. (2007). Similarly, ITA 321 would benefit from such upgrading that would improve it for spikelets fertility as well as primary and secondary branching of panicles.

By extension, IRAT 170, ITA 257 with good drought adaptive root characters but with lower panicle and yield components would also gain from introgression of genes from the genotypes that have good yield and grain characters. The significant positive correlation observed from vegetative and rooting characters among the varieties indicates that they can be jointly selected for in breeding programmes. Advantageously, therefore, most of the root characters can be concomitantly improved along with vegetative and yield characters through carefully planned selection. The non correlation of root thickness with the other root and shoot characters raises concern on the importance of root thickness *per se* to drought adaptation. Possibly, certain other components of root weight and volume, not excluding length and other anatomical features may be of major consideration for further studies.

In conclusion, the variability among the sixteen genotypes studied present opportunities for further improvement of existing and recently released varieties. The NERICAS, which constitute recent releases for cultivation in drought prone environments, still require upgrading to further improve them for drought tolerance and yield. Results obtained further attests to the necessity for continuous plant breeding for the development of high performing and fairly stable varieties for the upland ecology. The results from these studies have proved useful in advising on the choice of parents for selection, hybridization and introgression purposes, especially for drought tolerance and yield increases. IRAT 170 for instance has good rooting characters which could be used to upgrade NERICA 1, ITA 150 and WAB 56-50 which recorded good grain yield attributes. Other crosses could also be made to improve genotypes for grain length, width and panicle production However, the differential reaction of root characters to dissimilar environments would require a more in depth study involving many genotypes and levels of drought in order to generate more knowledge of rice response to drought condition.

REFERENCES

Anonymous (1988). Standard evaluation system for rice IRRI 3rd edition Philippine pp. 54.

Araus JL, Slafer GA, Reynolds MP, Royo C (2002). Plant Breeding and Drought in C3 Cereals: What Should we breed for? Ann. Bot., 89: 925-940.

Atlin GN, Lafitte HR, Taob D, Laza M, Amante M, Courtois M (2006). Developing rice cultivars for high-fertility upland systems in the Asian tropics. Field Crops Res., 97: 43-52.

Banziger M, Setimela PS, Hodson D, Vivek B (2006). Breeding for improved abiotic, stress tolerance in maize adapted to Southern Africa. Agric. Water Manage., 80: 212-224.

Bernier J, Serraj R, Kumar A, Venuprasad R, Impa S, Veeresh Gowda RP, Oane R, Spaner D, Atlin G (2009). The large-effect drought-resistance QTL qtl12.1 increases water uptake in upland rice. Field Crops Res., 110: 139-146.

Boonjung H, Fukai S (1996). Effects of soil water deficit at different growth stages on rice growth and yield under upland conditions. 2. Phenology, biomass production and yield. Field Crops Res., 48: 47-55.

Botwright Acuña TL, Lafitte HR, Wade LJ, (2008). Genotype x environment interactions for grain yield of upland rice backcross lines in diverse hydrological environments. Field Crops Res., 108: 117-125.

Cutler JM, Steponkus PL, Wach MJ, Shaban KW (1980). Dynamic aspects and enhancement of leaf elongation in rice. Plant Physiol., 66: 147-152.

Degenkolbe T, Do PT, Zuther E, Repsilber D, Walther D, Hincha DK, Kohl KI (2009). Expression profiling of rice cultivars differing in their tolerance to long-term drought stress. Plant Mol. Biol., 69: 133-153.

Ekanayake IJ, Garvity DP, Masajo TM, O'Toole JC (1985). A root pulling resistance of rice. Euphytica, 34 (3): 905-913.

Fukai S, Cooper M (1995). Development of drought - resistance cultivars using physiomorphological traits in rice. Field Crops Res., 40: 67- 86.

IRTP (1976). Standard evaluation system for rice. Internacional rice testing program. Second Printing. May, 1976. International Rice Research Institute, Los Banos, Philippines. p. 52.

Kozam M, Pankai K, Singh PK, Verma MR, Hore DK (2007). Causal mechanism for determination of grain yield and milling quality of lowland rice. Field Crops Res., 102: 178-184.

Kumar A, Bernier J, Verulkar S, Lafitte HR, Atlin GN (2008). Breeding for drought tolerance: Direct selection for yield, response to selection and use of and lowland-adapted populations drought-tolerant donors in upland. Field Crops Res., 107: 221 - 231

Lafitte HR, Yongsheng G, Yan S, Li Z-K (2006). Whole plant responses, key processes, and adaptation to drought stress: the case of rice. J. of Exp. Bot., 58 (2): 169 -175.

MacMillan K, Emrich K, Peipho HP, Mullins CE, Price AH (2006). Assessing the importance of genotype 9 environment interaction for root traits in rice using a mapping population II: conventional QTL analysis. Theor. Appl. Genet., 113: 953-964.

Nassir AL and Ariyo OJ (2011). Genotype x Environment Interaction and Yield-Stability Analyses of Rice Grown in Tropical Inland Swamp. Not. Bot. Hort. Agrobot. Cluj. 39(1): 220-225.

Nassir AL, Ariyo OJ (2005). Genotype x Environment stability analysis of grain yield of rice *Oryza sativa* (L.) Tropical Agriculture (Trinidad) In Press.

Nassir AL, Ariyo OJ (2006). Plant character correlations and path analysis of grain yield in rice *(Oryza sativa)*. J. Genet. Breed., 60: 161-172.

Price AH (2002). QTLs, for root growth and drought resistance in rice. In: Mohan Jain DS, Ahloowalia BS (eds.) Molecular techniques in crop improvement, Kulwer Academic Publisher, Norwell, MA, USA, pp 563-584.

Price AH, Courtois B (1999). Mapping QTLs associated with drought resistance in rice: progress, problems, and prospects. Plant Growth Regul., 29: 123-133.

Price AH, Steele KA, Moore BJ, Jones RGW (2002). Upland rice grown in soil-filled chambers and exposed to contrasting water deficit regimes II. Mapping quantitative trait loci for root morphology and distribution. Field Crops Res., 76: 25-43.

Samonte SOPB, Wilson LT, McClung AM, and Medley JC (2005). Targeting Cultivars onto Rice Growing Environments Using AMMI and SREG GGE Biplot Analyses. Crop Sci., 45: 2414-2424.

Wang H, Siopongcob J, Wadec LJ, Yamauchi A (2009). Fractal analysis on root systems of rice plants in response to drought stress. Environ. Exp. Bot. 65: 338-344.