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Full Length Research Paper

Drought response of some tropical rice genotypes: Rooting, vegetative traits and grain production

Nassir, Adesola L.* and Adewusi, Kayode M.

Department of Crop Production, College of Agricultural Sciences, Olabisi Onabanjo University, P.M.B. 2002, Ago-Iwoye, Ogun State, Nigeria.

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Sixteen upland rice varieties, comprising of some interspecific New rice for Africa (NERICA) hybrids, established varieties and some breeding lines, were raised in the greenhouse and used to expound drought response under varying moisture conditions, as a guide for breeding genotypes with appreciable drought tolerance and grain yield. Varieties were subjected to different levels of drought stress through different combinations of moisture regime and times of water application at different stages of growth. Varieties, moisture regime and times of water application espoused significant mean squares (MS) for root, vegetative and grain production. Times of water application consistently accounted for the largest percentage of mean squares (PMS) for most characters. Significant interaction was also obtained between variety, moisture regime and times of water application for most of the characters. There were significant correlations between times of water application and all the root, shoot and grain yield character. Fresh shoot weight, dry shoot weight, tiller number and leaf number were also positively correlated to moisture regime. WAB 880 recorded the largest mean value for root volume and thickness and hence better drought adaptation but this failed to translate to superior grain production. ITA 150, an established variety, however recorded the highest panicle number and grain production compared to WAB 880 and the NERICA varieties. The need for further introgression of genes from ITA 150 into newly developed NERICA varieties through an intricate combination of favourable genes for improved drought tolerance and better grain production was canvassed.

Key words: Drought tolerance, interspecific hybrids, root and vegetative traits, grain yield.

INTRODUCTION

The effect of poor soil water content on the performance of rice plant, especially grain yield, has continued to receive attention across cultivation zones and ecologies (Fukai and Cooper, 1995; Boojung and Fukai, 1996; Pantuwan et al., 2002; Kumar et al., 2008; Botwright Acuña, 2008). Rice production in upland ecologies and the typical low grain yield caused by drought-induced sub-optimal expression of rooting, vegetative and reproductive traits, has been a major focus of rice breeding for the ecology. The works of Price et al. (2002), Venuprasad (2008), Wang et al. (2009) and Bernier et al. (2009) have shown the importance of root and shoot traits in improved water uptake and adaptation to moisture stress. The concentration of drought adaptive traits in new genotypes should therefore confer better drought adaptation and necessarily result in higher grain yield. Improvement for drought adaptation and grain yield has been reported for progenies from crosses involving upland-adapted, drought-tolerant and high-yielding, lowland-adapted varieties (Venuprasad et al., 2008). Recent efforts to evolve varieties with improved adaptation to water stress, typical of upland ecologies, has led to the evolution of genotypes from crosses between improved varieties of Asian origin, *Oryza sativa,* and the adapted *Oryza glabberima*, which is of tropical African origin and adaptation. It is expected, that progenies of crosses involving these species should evolve genotypes which combine high grain yield in the former with drought adaptation as in the latter (Africa Rice Center (WARDA)/FAO/SAA, 2008). Expectedly, such interspecific hybridization would reconstitute gene

*Corresponding author. E-mail: solanassir@hotmail.com. Tel: +2348033895773.

complexes and association and create new gamut of trait expressions and responses to varying levels of soil moisture conditions. The New rice for Africa (NERICA) varieties recently developed from the above interspecific crosses should offer such opportunities.

Pantuwan et al. (2002) had noted that variation in performance of genotypes is pronounced, especially for flowering time and potential yield when the characteristics of drought environments differ. Optimum performance at the level of root and vegetative traits play significant roles in the plants reproductive expressions and eventually yield. Although Kumar et al. (2008) however, observed that gains in yield by selecting for secondary traits have not been clearly demonstrated in rice and reported that direct selection for yield under upland and lowland drought conditions improved grain yield. Nonetheless, variation in root volume with increased soil depth and continuous root and shoot development under water stress was linked to drought adaptation by Wang et al. (2009) and Cairns et al. (2009), thus confirming previous reports of Price et al. (2002). However, the findings of Lafitte et al. (2006) have indicated inconsistencies in relationships between traits that correlate with drought adaptation and yield, just as the studies of Botwright Acuña et al. (2008) indicated that with the effect of inconsistencies in rice ecologies, varieties and traits identified as having the potential for drought tolerance in a location may not exhibit consistency over a large area or overtime. A reappraisal of such response among existing genotypes with emphasis on the interspecific NERICA selections could offer more insight into rice adaptation to moisture stress for further manipulation of genotypes for higher grain yield.

This study is therefore conducted to evaluate existing and newly developed rice genotypes, under variable soil water conditions, with the hope of further understanding drought response of rice and the character that could be improved to enhance drought tolerance and improved grain yield.

MATERIALS AND METHODS

Genotypes used for experiments

The sixteen rice genotypes used for this study were obtained from the West Africa Rice Development Association (WARDA) unit, (New Africa Rice Center) International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. The genotypes include breeding lines: WAB 880-9-32-1-1-12-HB(abbreviated as WAB 880), WAB 56-50, WAB 224-8-HB, WAB 189-B-B-B-HB(WAB 189), WAB 337-B-B-20-1-129(WAB 337), WAB 181-18; established genotypes: ITA 150, ITA 321, ITA 257, 0S6, IRAT 170, and recent releases NERICA 1 (WAB 450-1-B-38-HB), NERICA 2 (WAB 450-11-1-P31-1-HB), NERICA 3 (WAB 450-1-B-P-28-HB), NERICA 4 (WAB 450-1-B-P-91-HB), and NERICA 5 (WAB 450-11-1-P31-HB).

Plant establishment

Black nursery polythene bags measuring 28 cm in diameter and 28 cm in depth were filled with 5 kg of top soil. The soil is an alluvial loam and was obtained from the upland paddy of the Teaching and Research Farm of the College of Agricultural Sciences, Olabisi Onabanjo University, Ayetoro, Ogun State, Nigeria. The experiment was conducted in the College premise which was located in a derived savannah ecology (6.5°N, 10°E). Three weeks old seedlings of each of the sixteen upland rice genotypes were transplanted into three groups of twenty-seven polythene bags. These were subjected to varying levels of moisture control and were used to collect data on root and vegetative traits at maximum tillering, panicle initiation and grain filling or ripening stage of rice growth. From a preliminary study investigation at the study location, comprising the study genotypes, the average optimum water requirements derived were 1.6 L per plant per week at the maximum tillering, 2.4 L per plant per week at panicle initiation stage and 3.2 L per plant per week at grain filling stage of growth.

The group of the twenty-seven bags used for each genotype at the three stages of investigation was divided into three sub-groups of nine polythene bags. Each of the group of nine was used to investigate the effects of moisture stress when 100, 75 and 50% of average moisture requirement derived from preliminary study was supplied (drought levels). Each of the nine bags for a particular drought level was further sub-divided into three groups of three bags each receiving the allocated moisture at twice-weekly, weekly, and fortnightly intervals. The pots were arranged following the randomized complete block design with four replications. Moisture regime was used as the blocking factor.

All plants received adequate moisture up to two weeks after transplanting. Moisture stress induction started thirty five days after sowing (DAS) and 1.6 L was applied as 100% moisture for three weeks representing the period of maximum tillering and 2.4 L for two weeks at panicle initiation stage while 3.2 L was applied per week at grain filling/ripening stage. For drought levels, pots (plants) received water in amount commensurate with the percent of the average and the number of times for application as described above.

Data collection

At each of the developmental stages, sample plants were carefully uprooted to avoid loss of roots and were washed, air dried used to obtain values for root characters as described below by IRTP (1976) and as used by Ekanayake et al. (1985); Root thickness: 1 = all roots thicker than 2 mm and 9 = all roots thinner than 1 mm; Root branching: 1 = little branching and 4 = extensive branching. The roots of each plant were excised from shoots by cutting with a knife. Root volume was measured as volume of displaced water when soil free root was inserted in distilled water. Root thickness was scored visually as 1 = all thicker than 2 mm and 9 = all the roots thinner than 1 mm. Root branching were also scored as 1 = little branching and 4 = extensive branching (Ekanayake et al., 1985). Data were collected on root and vegetative traits following the methods presented in Table 1. The fresh weight of the roots and shoots were measured in grams with the use of sensitive digital weighing balance. The plant parts were later air dried for many days and weighed for many periods of time till constant weight was achieved. The dry weight was recorded for both roots and shoots.

Statistical analysis

Computer analysis of variance (ANOVA) was done using the SAS package following simple factorial procedure. Means were separated following the Duncan Multiple Range Test (DMRT) procedure. Percentage of mean squares (PMS) for the main effect and interaction was calculated to estimate the amount of variation harboured by each component. Correlation of times of water application with the root shoot and reproductive characters was done with the SPSS package (version 15). The effects of

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

S/NO	Character	Measurement/Score (s)
1	Tillering ability (no)	Counted
2	Leaf number (cm)	Counted
3	Panicle number	Counted
4.	Grain weight per panicle (g)	Weighed
5	Grain weight per plant (g)	Weighed

Source: Standard evaluation system for rice (RTP/IRRI, 1988).

Table 2. Mean square and percentage mean square for root characters of sixteen varieties of upland rice with moisture control.

Sources of variation	Root volume (ml)		Root thickness (mm)		Root branching		Fresh root Wt (g)		Dry root Wt (g)	
	MS	PMS	MS	PMS	MS	PMS	MS	PMS	MS	PMS
Variety (VT)	48.256**	2.0	361.114**	32.5	86.327**	61.3	420.311**	1.5	32.709**	0.82
Moisture Regime (MR)	515.463**	21.3	5.843	0.5	9.306**	6.6	5897.175**	21.4	991.156**	24.91
Stage (ST)	624.172**	25.8	402.062**	36.2	8.633**	6.1	7225.118**	26.2	1096.568**	27.55
Time of water application (TWA)	1091.605**	45.2	156.530**	14.1	15.056**	10.7	12480.250**	45.3	1622.237**	40.6
VT×MR	4.205**	0.2	14.340*	1.3	3.843**	2.7	42.200**	0.2	18.677**	0.47
VT×ST	5.095**	0.2	14.147	1.3	2.071*	1.5	49.496**	0.2	18.582**	0.47
VT × TWA	5.837**	0.2	37.067**	3.3	1.872	1.3	59.541**	0.2	16.870**	0.42
VT×MR×ST	1.129**	0.1	12.245	1.1	1.666	1.2	16.984**	0.06	10.871**	0.27
VT×MR×TWA	1.725**	0.1	16.244**	1.5	1.66	1.2	23.250**	0.08	9.096**	0.23
MR×ST×TWA	116.577**	4.8	81.455**	7.3	9.166**	6.5	13560.086**	4.92	158.086**	3.97
Error MS	0.567	0.0	9.641	0.9	1.289	0.9	10.612	0.04	4.821	0.12
Total	2414.631		1110.694		140.889		27581.023		3979.666	

*, ** Mean square significant at 5% and 1% probability level respectively.

replications and other interaction values that were consistently not significant and also failed to expound structural information were pooled with the residual to improve the analysis.

RESULTS

Root characters

The mean squares (MS) and PMS for the root characters are presented in Table 2. The MS for the main effects and their interactions were significant for all the root characters except root thickness and root branching. For root thickness, all the main effects were significant except for moisture regime. The interactions were also significant with the exception of variety-by-stage interaction (VT × ST), and the variety-by-moisture regime-by-stage interactions (V × MR × ST). For root branching, all the main effects were significant (P<0.05). Similarly, the variety-by-moisture regime (VT × MR), VT × ST and moisture regime-by-times of water application interactions (MR × TWA), moisture regime-by stage--times of water application (MR × ST × TWA) interactions were significant. The time of water application (TWA) accounted for the highest PMS values of 45.2, 45.3 and 40.6 for root volume and fresh root weight and dry root weight respectively. For root branching, variety had the

Table 3. Mean value for root traits of sixteen varieties of upland rice with total moisture control.

Variety	Root volume (ml)	Root thickness (mm)	Root branching	Wt of fresh root (g)	Wt of dry root (g)
WAB 880	5.83^{a}	2.31^{i}	1.11^{f}	18.18^{a}	7.02^{a}
NERICA 1	4.71^{c}	8.51^{a}	3.44^{ab}	15.82^{b}	5.89^{cd}
ITA 150	3.72^{efg}	8.11^{ab}	3.19^{b}	12.58^{cd}	4.67^{ef}
WAB 56-50	3.17^{h}	6.22^{de}	1.26^{def}	10.74^{e}	4.13^{f}
NERICA 2	3.22^{h}	5.30^{f}	1.19^{ef}	10.74^{e}	4.13^{f}
NERICA 3	5.20^{h}	2.68^{hi}	3.37^{ab}	17.40^{a}	6.64^{b}
WAB 224-8-HB	3.87^{def}	7.21^{bcd}	1.63^{cd}	12.95^{c}	4.89^{ef}
NERICA 4	3.67^{g}	2.68^{hi}	3.51^{ab}	12.62^{cd}	4.78^{ef}
ITA 321	4.81^{c}	5.63^{f}	1.56^{bcd}	16.08^{b}	6.32^{c}
NERICA 5	3.99^{d}	3.07^{ghi}	3.33^{ab}	13.40^{c}	5.23^{de}
WAB 189	3.94^{de}	6.06^{ef}	1.23^{ef}	12.94^{c}	5.12^{de}
OS6	3.49^{g}	6.91^{cde}	1.63^{cd}	11.70^{de}	4.61^{ef}
ITA 257	3.21^{h}	3.67^{gh}	3.63^{a}	10.73^{c}	4.20^{f}
WAB 337	3.97^{de}	4.06^{g}	3.48^{ab}	13.46^{c}	5.29^{de}
IRAT 170	3.53^{g}	7.42^{bc}	1.64^{cd}	12.980^{c}	5.28^{de}
WAB 181-18	3.90^{def}	7.53^{abc}	1.78^{c}	13.076^{c}	5.15^{de}

Mean with similar alphabets are not significantly different at P<0.05 using Duncan Multiple Range Test (DMRT).

largest PMS of 61.3. Moisture regime (MR) recorded relatively high PMS for all the root characters except for the root thickness. Stage of growth also had appreciable PMS for the root characters with the exception of root branching.

Table 3 presents the mean values of the root characters for the genotypes. WAB 880 recorded the largest mean value of 5.83 for root volume though this was not significantly different from that of NERICA 3 which had a mean of 5.20 ml. WAB 880 also had relatively thicker roots which is to that of NERICA 3 but compared to other varieties it also had the least root branching. ITA 257 had the most branched root of mean score 3.63 which is similar to those of WAB 337 and NERICA 1, 3, 4 and 5. WAB 880 also recorded highest mean value for fresh and dry root weights of 18.18 and 7.02 g respectively.

Vegetative characters

Table 4 shows the analysis of variance of rice for the vegetative. All the main effect and interactions were significant except the VT × MR × TWA for leaf number. Time of water application (TWA) consistently recorded the largest PMS for all the characters while error mean square had the least PMS for all the traits.

The mean separations for the vegetative traits are reported in Table 5. WAB 880 had the most number of leaves though not significantly more than those of WAB 189-B-B-6, ITA 150 and NERICA 5. NERICA 2 had the least number of leaves. For tiller numbers, ITA 150 recorded the highest value. This was however not significantly different from those of NERICA 1, ITA 321, NERICA 5, and IRAT 170. With a mean value of 96.93 cm, NERICA 3 had the tallest plants though comparable to the 96.20 and 93.26 cm for ITA 150 and NERICA 5 respectively. ITA 321 had the largest mean of 74.2 and 22.6 g respectively for weight of fresh and dry shoot respectively but these were not significantly different from those of WAB 181 and WAB 880 in terms of weight of fresh shoot. Generally, ITA 150 appeared to be the most vegetatively endowed, having one of the best combinations of tiller number, plant height and leaf number.

Grain production

The mean squares and percentage mean squares of the varieties are presented in Table 6. Significant mean squares were recorded for the moisture regime and times of water application for panicle number and grain weight per panicle. For grain weight per plant, all the main squares and interaction were significant with the exception of the variety mean square and the MR × TWA component. From the mean value for panicle and grain production of the varieties presented in Table 7, ITA 150 recorded the most number of panicles and grain weight per panicle which also translated to the largest grain weight per plant.

Correlation coefficient

The correlation coefficient of moisture regime and time of

Table 4. Mean square (MS) and percentage of mean square (PMS) for vegetative traits of sixteen varieties of upland rice with moisture control.

Source of variation	Fresh shoot weight (g)		Dried shoot weight (g)		Tiller number		Plant height (cm)		Leaf number	
	MS	PMS	MS	PMS	MS	PMS	MS	PMS	MS	PMS
Variety (VT)	5827.735**	0.71	709.843**	1.0	115.522	5.0	2963.414**	1.7	1002.093**	3.6
Moisture regime (MR)	115673.466**	14.10	9889.736**	13.9	588.174**	25.5	43756.383**	25.1	8400.268**	30.2
Stage (ST)	225908.116**	27.53	20035.682**	28.1	215.433**	9.3	12435.427**	7.1	3240.571**	11.7
Times of water application (TWA)	421923.043**	51.4	36330.383**	50.9	1152.113**	50.0	88291.346**	50.7	12603.116**	45.3
VT×MR	646.650**	0.08	59.094**	0.08	6.329**	0.3	433.287**	0.3	57.273**	0.2
VT×ST	328.916**	0.04	46.285**	0.06	15.041**	0.7	2059.618**	1.2	110.426**	0.4
VT × TWA	835.164**	0.10	101.825*	0.14	20.430**	0.9	2651.396**	1.5	216.027**	0.8
VT×MR×ST	198.991**	0.02	26.757**	0.03	2.823**	0.1	277.520**	0.2	24.263**	0.1
VT × MR× TWA	390.732**	0.05	52.318**	0.07	5.424**	0.2	261.047**	0.2	50.630	0.2
MR×ST×TWA	48761.265**	5.94	4102.644**	5.75	180.488**	7.8	20758.431**	11.9	2097.380**	7.5
Error	143.722	0.02	17.739	0.02	4.178	0.2	160.734	0.1	19.377	0.1
Total	820637.76		71372.306	0.901	2305.955		174048.57		27821.424	

*,** Means square significant at 5% and at 1% probability levels respectively.

Table 5. Mean value for vegetative traits of sixteen varieties of upland rice with moisture control.

Varieties	No of leaves	No of tillers	Plant height (cm)	Shoot fresh weight (g)	Shoot dry weight (g)
WAB 880	26.98^{a}	7.96^{abc}	81.83^{de}	67.40^{b}	21.06^{b}
NERICA 1	25.28^{cd}	8.44^{a}	80.07^{e}	63.00^{e}	18.31^{ef}
ITA 150	26.28^{ab}	8.65^{a}	96.20^{a}	52.92^{ef}	15.56^{g}
WAB 56-50	20.89^{e}	6.38^{efg}	83.21^{de}	52.51^{ef}	15.01^{gh}
NERICA 2	14.83^{g}	4.52^{h}	79.84^{e}	49.85^{fg}	14.40^{gh}
NERICA 3	24.09^{cd}	7.53^{cd}	96.93^{a}	62.82^{e}	18.44^{ef}
WAB 224-8HB	18.37^{f}	5.74^{g}	81.27^{de}	54.96^{de}	15.51^{g}
NERICA 4	19.86^{e}	6.16^{fg}	90.52^{b}	50.05^{fg}	14.14^{ef}
ITA 321	26.15^{ab}	8.28^{abc}	81.85^{bc}	74.19^{a}	22.62^{a}
NERICA 5	26.10^{ab}	8.15^{abc}	93.26^{ab}	58.11^{d}	17.56^{f}
WAB 189	26.74^{ab}	5.79^{g}	85.95^{cd}	66.42^{bc}	20.32^{bc}
OS6	20.14^{e}	8.44^{a}	81.68^{de}	47.04^{g}	13.71^{h}
ITA 257	20.98e	6.73^{ef}	89.85^{bc}	50.21^{fg}	14.36^{gh}
WAB 337	23.47^{d}	7.61^{bcd}	82.04^{de}	62.93^{e}	18.82^{def}
IRAT 170	24.44^{cd}	8.15^{abc}	80.32^{e}	65.37^{bc}	19.53^{cde}
WAB 181-18	20.95^{e}	6.98^{dc}	79.58^{e}	71.53^{a}	20.15^{bcd}

Mean with similar alphabet are not significantly differently at P<0.05 using Duncan multiple range tool (DMRT).

Table 6. Mean square (MS) and percentage mean square (PMS) for panicle, and grain production of sixteen varieties of upland rice with moisture control.

Source of variation	Panicle number		Grain weight per panicle (g)		Grain weight per plant (g)	
	MS	PMS	MS	PMS	MS	PMS
Variety (VT)	24.155**	1.59	2.153**	2.72	449.13	4.75
Moisture Regime (MR)	309.174*	20.30	14.559**	18.40	2813.871**	29.76
Time of Water Application	1141.85*	74.96	59.618**	75.40	511.866**	54.08
VT×MR	3.902**	0.26	0.146**	0.18	181.042**	1.92
VT × TWA	14.117**	0.93	1.386**	1.75	177.209*	1.87
MR × TWA	28.036**	1.84	1.102**	1.39	477.25	5.05
VT×MR×TWA	1.530**	0.10	0.093**	0.12	129.098**	1.37
Error	0.558	0.04	0.012	0.02	114	1.21
Total	1523.31		79.0698		9454.5	

*,** Mean square value significant at 5% and at 1% probability level respectively.

Table 7. Mean value for panicle and grain production of sixteen varieties of upland rice with moisture control.

Variety	Panicle number	Grain weight per panicle (g)	Grain weight per plant (g)
WAB 880	5.48^{c}	1.38^{f}	11.84^{b}
NERICA 1	5.78^{bc}	1.69^{b}	10.56^{b}
ITA 150	6.56^{a}	2.03^{a}	22.52^{a}
WAB 56-50	3.70^{e}	1.05^{i}	6.20^{b}
NERICA 2	3.63^{ef}	1.06^{i}	5.76^{b}
NERICA 3	5.00^{d}	1.39^{ef}	7.54^{b}
WAB 224-B-HB	3.85^{e}	0.98^{j}	5.73^{b}
NERICA 4	5.00^{d}	1.33^{gf}	8.00^{b}
ITA 321	3.26^{f}	1.05^{i}	5.32^{b}
NERICA 5	5.93^{b}	1.41^{e}	8.93^{b}
WAB 189	3.74^{e}	1.30^{f}	6.70^{b}
OS6	4.59^{d}	1.03^{ij}	7.60^{b}
ITA 257	4.89^{d}	1.59^{c}	8.37^{b}
WAB 337	5.52^{bc}	1.53^{d}	9.35^{b}
IRAT 170	4.96^{d}	1.37^{ef}	10.55^{b}
WAB 181-18	4.89^{d}	1.20^{hi}	9.14^{b}

Mean with similar alphabet are not significantly different at P≤0.05 using, Duncan multiple range test (DMRT).

water application with root, shoot and reproductive characters are presented in Table 8. TWA correlated positively with all root, shoot and reproductive characters. In addition, MR was positively related to fresh shoot weight, dry shoot weight, tiller number and leaf number.

DISCUSSION

The significant mean squares obtained for varieties, moisture regime and times of water application is an indication that the imposed differences in moisture condition created appreciable variation which concomitantly translated into differential varietal performance for root and vegetative characters. It additionally implies significant variation for vegetative, root and grain production characters which could still be exploited for plant breeding purposes. The significant interaction of the main effects for the root, vegetative and grain characters however underscores the inconsistencies in response of varieties to differential moisture availability and is worthy of consideration in the development of cultivars even for upland ecologies where soil moisture would expectedly be variable across seasons and regions. Deduction made by Botwright Acuña (2008) alludes to the need to ensure that new varieties have appreciable adaptation for fairly wide cultivation regions. Time of water application consistently accounted for the highest percentage mean square for root volume, fresh and dry weights for shoot, panicle and grain characters, in addition to having significant positive correlation with the root, shoot and grain characters. By

Table 8. Correlation of times of water application (TWA) and moisture regime (MR) with some root, shoot and reproductive characters.

Correlation	MR	TWA
Root volume	0.56	0.597**
Root thickness	-0.073	0.312**
Root branching	0.019	0.181**
Fresh root weight	0.059	0.593**
Fresh shoot weight	0.125*	0.663**
Dry root weight	0.017	0.363**
Dry shoot weight	0.156*	0.673**
Tiller number	0.132*	0.559**
Plant height	0.053	0.533**
Leaf number	0.141*	0.580**
Panicle number	0.000	0.606**
Grain weight per panicle	-0.031	0.543**
Grain weight per plant	-0.046	0.212**

*,** Mean square value significant at 5 and 1% probability level respectively.

implication, it is clear that the difference in the amount of moisture, as dictated by the water regime, is not as important as the time of water application. Jongedee et al. (2002) had noted the importance of timing and duration of drought stress to phenological processes and performance of plants. It would therefore be important to be mindful of this in developing varieties that would be considered as drought tolerant. The largest PMS exhibited by varieties for root branching is an indication that the varieties harbour significant variation for the character. Root branching results in proliferation of roots and has profound influence in soil water uptake and drought condition reduce significantly root mass (Price et al., 2002; Wang et al., 2009).

Generally, the root characters that have the potential for improving drought tolerance are scattered amongst the varieties. For instance, WAB 880-9-32 which had the largest root volume, thicker roots and weight of fresh and dry roots weight can still be further improved for better rooting branching through carefully planned introgression of genes from ITA 257. Perhaps thin would translate into better grain production by the variety.

The high values recorded by ITA 150 for the shoot characters appeared to translate into relatively higher grain production. Large vegetativeness as reflected in leaf and tiller production is an indication of large surface area and ability to produce more photosynthates. Nonetheless, ITA 150 is an established variety but would still benefit from improvement in root thickness and volume through direct introgression of the traits or through selection for drought tolerance from progenies derived between it and WAB 880-9-32. The low grain yield by WAB 880-9-32 was obviously due to low grain weight per panicle. The variety and indeed the newly developed NERICA varieties would benefit from breeding for improved grain weight per panicle either through increase in spikelet number or weight or both.

The improvement of grain production of rice through adaptation or tolerance to limited soil water condition which is the major force behind the evolution of interspecific NERICA hybrids (Africa Rice Center (WARDA)/FAO/SAA, 2008) would obviously require the contribution of other established varieties for improvement in grain production. The NERICA varieties generally performed lower in grain yield compared to ITA 150. Although rice exhibits intense compensatory relationships among many traits (Kato and Takeda, 1996; Nassir and Ariyo, 2006), there is no evidence to suggest pleiotropic genetic control of root and grain characters. In line with the above and riding on the submission of Venuprasad et al. (2008) on the possibility of selection of drought tolerant varieties under drought condition, for improved performance under conditions of moisture availability, it would therefore be safe to conclude that painstaking introgression can still be done to achieve a better combination of drought adaptive traits for better grain yield. Going by the positive correlation obtained between moisture availability indices and the characters studied, the immediate conclusion favours developing higher values for the root, shoot and vegetative characters. However, reduction in days to flowering and plant height due to selection for higher grain yield under moisture stress have been reported (Pantuwan et al., 2002; Kumar et al., 2006; Venuprasad et al., 2008). This would imply the need to strike a balance between genotype response to water availability and selection for yield and yield related characters. Early flowering and reduced plant height may not favour optimal plant performance in the upland especially where soil water is not limiting since varieties that exhibit delayed flowering produce more tillers just as taller plants compete favourably with weeds under upland condition.

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