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Research Article

Morphological Analysis of Drought Tolerance Traits in Rice (*Oryza Sativa* L.)

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Abstract

Drought stress is the most important constraint to rice production in rainfed systems, affecting 10 million hectares of upland rice and over 13 million ha of rainfed lowland rice in Asia alone. Drought occurs throughout the length and breadth of Nigeria mostly severe in the Sudano-Sahalian states of Kebbi, Sokoto, Zamfara, Katsina, Kano, Jigawa, Yobe, Gombe and Borno. Chronic dry spells of relatively short duration can often result in substantial yield loss, especially if they occur around the flowering stage. In addition, drought risk reduces productivity even during favorable years in drought prone areas because farmers avoid investing in inputs when they fear crop loss. Identifying rice varieties and breeding lines with high levels of drought tolerance for use as donors in breeding and gene discovery is one of the main challenges for rice research. Water stress may occur at different growth stages and be of varying duration and intensities, thereby affecting growth and yield. Information on genetic variation, heritability and correlation among various characters will help breeders in deciding the most appropriate procedure for development of drought-tolerant cultivars. The objectives of these studies were to determine the effect of drought on growth and reproductive traits of rice under drought conditions. Rice (*Oryza sativa* L.) germplasms were evaluated to study the effect of drought on growth and reproductive plant function using a split plot design during 2015/16. Rice germplasms showed appreciable variations in morphological traits (leaf rolling and leaf drying) under different water regimes. The cumulative effect of water stress on growth and reproductive traits resulted in yield reduction. Thus, selection may be possible for these characters for improving yield.

Keywords: Rice Genotypes; Full Irrigation; Vegetative Stage Drought; Reproductive Stage Drought; Drought Stress; Morphological Traits; Breeding Lines.

Abbreviations

T_1 (FI): Full Irrigation; T_2 (VSD): Vegetative Stage Drought; T_3 (RSD): Reproductive Stage Drought; NCRI: National Cereal Research Institute; LSD: Least Significant Difference; GLM: Generalized Linear Model; PH: Plant Height; PL: Panicle Length; TN: Tiller Number; HD: Heading Date; PN: Panicle Number; NPP: Number of Productive Panicle; NHFP: Number of Half-Filled Panicle; PFW: Panicle Fresh Weight; PDW: Panicle Dry Weight; LW: Leaf Width; LL: Leaf Length; GY: Grain Yield.

Introduction

Rice is the world's most important food crop and a primary source of food for more than half the world's population [1]. Worldwide, rice is cultivated on an area of 154 million hectares with an annual production of 700 million tonnes [2] representing the third largest crop behind maize and wheat.

Rice is cultivated under diverse ecologies ranging from irrigated to deep water [3]. Rice is cultivated in virtually all of Nigeria's agro-ecological zones [4], from the mangrove and swampy ecologies of the River Niger in the coastal areas to the dry zones of the Sahel in the North. There are many varieties of rice grown in Nigeria; some of these are traditional varieties while others have been introduced into the country. Nigeria has a land area of 923,768 million square kilometers with a total of 71.2 million hectares of cultivable land, an estimated 4.6 million hectares is suitable for rice production but only about 1.8 million hectares or 39% is currently developed for rice cultivation [5].

In Nigeria, rice has found a place in food security and has become a major staple. Nigeria consumes about five million metric tonnes of rice annually. The local production, however, has not kept pace over the years. The difference is provided for through importation of about 2.1 million metric tonnes at a huge annual import expense of about N356 billion [6]. For rice consuming countries there is a need to produce 40 per cent more rice by 2030 [7]. To achieve this ambitious goal, various rice varieties with greatly improved agronomic traits such as high yield potential, stress tolerance and so on, should be developed (Deshmukh, 2012).

A series of biotic and abiotic stresses limits rice productivity worldwide. Biotic constraints to rice production that cut across countries in West Africa include Weeds, Insect pests, diseases such as blast, nematodes, vertebrate pests [8].

Abiotic stresses alone contribute up to 50 per cent of the total yield losses. Among abiotic stresses, salinity, toxic levels to metals,

extreme temperatures and drought are major barriers that limit rice crop production [9]. Increasing yields essentially means increasing the level of tolerance for these constraints. Plant response to drought stress is one of the most complex biological processes, and it involves numerous changes at the physiological, cellular, and molecular levels [10]. The effect of drought on rice plants considerably varies with germplasm, developmental stages, and the degree and duration of drought stress [11].

Drought is actually a meteorological event which implies the absence of rainfall for a period of time, long enough to cause moisture-depletion in soil and water deficit with a decrease of water potential in plant tissues [12]. Drought limits the agricultural production by preventing the crop plants from expressing their full genetic potential.

Water is the critical and most important factor in rice production. 70 percent of the world's food-growing areas turn increasingly parched [13]. Drought is a major abiotic stress that limits rice productivity in rain-fed and upland ecosystems [14] and worldwide, drought affects approximately 27 million ha of rain-fed ecosystem [15]. Drought reduces yield by 15-50 percent depending on the stress intensity and crop growth period at which the stress occurs in rice [16]. The effect of drought on rice plants considerably varies with germplasm, developmental stages, and the degree and duration of drought stress [17].

Materials and Methods

The experiment was conducted at the screen house of Botanical Garden, Department of Biological Sciences, Kaduna State University. The screen house is located at latitude 100 51' 51'' and longitude 70 44' 93'' at an altitude of 590m above sea level. Average rainfall during the 2015/2016 season was 1.20 mm per year and the temperature was 28.60C.

Ten (10) rice germplasm (Table 1) were obtained from National Cereal Research Institute (NCRI) Badeggi, Niger State.

Field evaluation and data collection

The experiment was laid out in a split plot design with three replications; with irrigation treatments as main plot and varieties as subplots. Randomization was carried out using the SAS [18] software. Seeds of 10 rice germplasms were transplanted in polyethylene pots (30 cm diameter) containing loamy soil. Pre-germination was done according to the method described by [1,19]. After uniform pre-germination, one plant was transplanted into each pot. Pots were laid out at least 100 cm apart. Dead rice seedlings were replaced on the 7th day after transplanting. 4g of 20:20:20 NPK fertilizer was applied basal per pot in slit application at 2 weeks and 12 weeks after transplanting. Weeding and other cultural practices were carried out as and when needed [1,20,21].

Germplasm	Species	Sources
ARICA 4	*Oryza sativa*	NCRI-Badegi
ART 15-13-2-2-2-1-1-B-1-1	*O. sativa*	NCRI-Badegi
ART 15-16-45-1-B-1-1-B-1-2	*O. sativa*	NCRI-Badegi
ART 16-13-11-1-2-B-2-B-2-2	*O. sativa*	NCRI-Badegi
ART 16-16-11-25-1-B-1-B-1-1	*O. sativa*	NCRI-Badegi
ART 16-21-5-12-3-1-2-B-1-2	*O. sativa*	NCRI-Badegi
ART 16-9-28-21-3-2-1-B-2-1	*O. sativa*	NCRI-Badegi
ART 16-9-122-33-2-1-1-B-1-1	*O. sativa*	NCRI-Badegi
ART 16-9-1-32-1-1-1-B-1-2	*O. sativa*	NCRI-Badegi
ART 16-9-26-21-3-2-1-B-2-1	*O. sativa*	NCRI-Badegi

Table 1: Rice germplasm utilized for the research.

The treatment combinations consisted of three levels of water regimes, viz

T_1 (Full Irrigation) well-watered in which the plants were watered with one litre of water after every two days throughout the life cycle. T_2 (Vegetative stage Drought) water deficit at vegetative stage in which water was withheld by irrigating the plants using one litre of water after every six days from 21-50 days after transplanting. T_3 (Reproductive stage Drought) Water deficit at reproductive stage in which water was withheld by irrigating the plants using one litre of water after thirteen days, re-watered after every two days for six days and withholding irrigation for another six days from 51-71 days after transplanting.

One litre of water was used to irrigate all the pots after every two days for 20 days to maintain optimum moisture before initiating experimental treatments. After the water deficit period, plants were irrigated after every two days.

Data was collected on the measured traits as described by Sikuku., *et al.* [21]. Plant height (cm) was determined at 28, 42, 56, 70 and 84 days after transplanting. Measurements were made using a meter rule (cm) from the stem base to shoot apex in plants. Leaf length (cm) was determined on the last three fully developed leaves at maturity with a meter rule from the leaf base to the tip of the leaf. Leaf width (cm) was measured from the middle of the leaf using meter rule at maturity. The average number of tillers was recorded at 28, 42, 56, 70 and 84 days after transplanting for each genotype and at harvest [19,20]. At the end of the experiment, the plants were uprooted, soil particles were washed off the roots and roots blotted dry using paper towels. The length of the roots were determined using a meter rule from the stem base to the longest root tip of the main root and measured in centimeter (cm) [19,21]. Heading date was determined by counting the percentage of panicles in each plot when the first panicle is observed. Panicle length was determined using a meter rule. The length was measured as the distance from the panicle neck to the tip of the last grain in centimeters (cm) [21,22]. When each line reached maturity, Panicle number was determined. At maturity, the number of productive panicles was determined from randomly sampled plants. At maturity, the number of half-filled panicles was determined from randomly sampled plants. Fresh and dry weight of panicles were mea-

sured at harvest. Measurement was done in grams (g). The grain yield was determined at harvest from each plot and extrapolated using the equation below in kilograms per hectare.

$$GY(kg/ha) = \frac{(GYP/0.8)}{10000} * 1000$$

Where GY is grain yield (kg/ha), GYP is grain yield per plot (kg/m^2) [23].

The Standard Evaluation System (SES), methods adopted for evaluation of rice IRRI [13] was used to score for leaf rolling and leaf drying by observing visually using 0-9 scale. The plants were scored at full irrigation (FI), vegetative stage drought (VSD) and reproductive stage drought (RSD).

Statistical data analysis

Data were analysed using statistical software [18]. Generalized Linear Model (GLM) procedure of SAS was used. Fisher's Least Significant Difference (LSD) test was used to test the difference between plant tolerance levels.

Results

The mean performance for each traits are presented in Tables 2 to 9.

Effect of drought on growth traits

Leaf drying

Under full irrigated conditions, the germplasm did not show leaf drying. Under vegetative stage drought, ART 16-9-122-33-2-1-1-B-1-1 had tip drying extended to one-fourth length in most leaves (3) with all the remaining germplasm having tip almost drying to one-fourth length in most leaves (2) with the exception of ART 15-13-2-2-2-1-1-B-1-1 and ART 16-16-11-25-1-B-1-B-1-1 which had slight tip drying (1). Similarly, under reproductive stage drought ART 16-9-122-33-2-1-1-B-1-1 had all plants apparently dead (9) closely followed by ART 16-9-28-21-3-2-1-B-2-1 and ART 16-9-26-21-3-2-1-B-2-1 with more than two third of all leaves fully dried (8). On the other hand, ART 15-16-45-1-B-1-1-B-1-2 and ARICA 4 had tip drying extended to one-fourth length in most leaves (3).

Leaf rolling

Under full irrigated conditions, the germplasm did not show leaf rolling. Under vegetative stage drought, ART 15-16-45-1-B-1-1-B-1-2, ARICA 4 and ART 16-9-1-32-1-1-1-B-1-2 had leaves tightly rolled, with the highest score of (9) closely followed by ART 16-21-5-12-3-1-2-B-1-2, ART 16-9-26-21-3-2-1-B-2-1 and ART 16-9-122-33-2-1-1-B-1-1 which have rolled leaves (8) with all the remaining germplasm having rolled leaves (7) with the exception of ART 15-13-2-2-2-1-1-B-1-1 which had leaves margins touching (6). Similarly, under reproductive stage drought ART 15-16-45-1-B-1-1-B-1-2 has leaves starting to fold (1) for all the germplasm except ART 15-16-45-1-B-1-1-B-1-2 which had healthy leaves (0).

Plant height (cm)

The mean plant height for the rice is 54.95 cm under full irrigated conditions and ranged from 49.77 cm for ART 15-16-45-1-B-1-1-B-1-2 to 60.17 cm for ART 15-13-2-2-2-1-1-B-1-1. The genotype with highest was ART 15-13-2-2-2-1-1-B-1-1 (60.17 cm), closely followed by ART 16-16-11-25-1-B-1-B-1-1 (57.25), and the least being ART 15-16-45-1-B-1-1-B-1-2 (49.77 cm). Under the vegetative stage drought, the mean plant height is 66.75cm, with the highest being ART 16-9-28-21-3-2-1-B-2-1 (74.17 cm) and the least, ART 15-16-45-1-B-1-1-B-1-2 (58.17 cm). The mean plant height for the rice germplasm is 62.85 cm under reproductive stage drought, with the highest being ART 16-16-11-25-1-B-1-B-1-1 (68.17 cm) and the least, ARICA 4 (53.50 cm).

Genotype	Leaf Drying			Leaf Rolling		
	FI	VSD	RSD	FI	VSD	RSD
ART 15-16-45-1-B-1-1-B-1-2	0	2	3	0	9	0
ART 16-21-5-12-3-1-2-B-1-2	0	2	6	0	8	1
ART	0	2	8	0	7	1
ARICA 4	0	2	3	0	9	1
ART 15-13-2-2-2-1-1-B-1-1	0	1	5	0	6	1
ART 16-9-26-21-3-2-1-B-2-1	0	2	8	0	8	1
ART 16-9-1-32-1-1-1-B-1-2	0	2	6	0	9	1
ART 16-9-122-33-2-1-1-B-1-1	0	3	9	0	8	1
ART 16-16-11-25-1-B-1-B-1-1	0	1	5	0	7	1
ART 16-13-11-1-2-B-2-B-2-2	0	2	4	0	7	1
Mean	0	1.93	5.60	0	7.70	0.90
SE	0	0.40	0.40	0	0.18	0.18
CV %	0	33.3	36.6	0.00	15.0	25.0

Table 2: Performance of rice germplasm for leaf drying and leaf rolling evaluated under full irrigation (F1), vegetative stage drought (VSD) and reproductive stage drought (RSD) in Kaduna, 2016.

SE: Standard Error; CV: Coefficient of Variation (%).

Tiller number

The mean tiller number per plant for the germplasm is approximately 18 under full irrigated conditions and it ranged from 9 tillers for ART 16-9-28-21-3-2-1-B-2-1 to 23 tillers for ART 15-13-2-2-2-1-1-B-1-1. The rice germplasm with the highest number of tillers were ART 15-16-45-1-B-1-1-B-1-2 and ART 15-13-2-2-2-1-1-B-1-1 (23 each), closely followed by ART 16-9-1-32-1-1-1-B-1-2 (20), and the least being ART 16-9-28-21-3-2-1-B-2-1 (9). Under the vegetative stage drought, the mean tiller number is 20, with the highest being ART 15-16-45-1-B-1-1-B-1-2 (26) and the least, ART 16-21-5-12-3-1-2-B-1-2 (13). The mean tiller number for germplasm under the reproductive stage drought is 17, with the highest being ART 16-9-122-33-2-1-1-B-1-1 (22) and the least, ART 16-13-11-1-2-B-2-B-2-2 (10). The high coefficient of variation in tiller number of FI might be due to the low tillers number in ART 16-9-28-21-3-2-1-B-2-1.

Leaf width (cm)

The mean leaf width for the germplasm is 1.21cm under full irrigated conditions and it ranged from 0.9cm for ART 15-16-45-1-B-1-1-B-1-2 to 1.5 cm for ART 16-21-5-12-3-1-2-B-1-2. The germplasm with the widest leaf was ART 16-21-5-12-3-1-2-B-1-2 (1.5 cm), closely followed by ART 16-9-28-21-3-2-1-B-2-1 (1.4 cm), and the least being ART 15-16-45-1-B-1-1-B-1-2 (0.9 cm). Under the

Germplasm	Plant height			Tiller number		
	FI	VSD	RSD	FI	VSD	RSD
ART 15-16-45-1-B-1-1-B-1-2	49.77	58.17	55.17	23.00	18.67	17.00
ART 16-21-5-12-3-1-2-B-1-2	52.80	71.63	63.67	16.00	19.00	19.00
ART 16-9-28-21-3-2-1-B-2-1	52.93	74.17	67.83	9.00	15.17	21.33
ARICA 4	54.00	62.33	53.50	12.00	17.17	21.00
ART 15-13-2-2-2-1-1-B-1-1	60.17	65.23	66.83	23.00	20.00	17.00
ART 16-9-26-21-3-2-1-B-2-1	56.40	70.80	66.90	19.00	17.67	17.00
ART 16-9-1-32-1-1-1-B-1-2	57.00	65.83	62.83	20.00	18.50	20.00
ART 16-9-122-33-2-1-1-B-1-1	55.00	69.97	63.77	18.00	16.33	16.00
ART 16-16-11-25-1-B-1-B-1-1	57.25	68.93	68.17	18.00	18.50	17.00
ART 16-13-11-1-2-B-2-B-2-2	54.17	58.67	59.83	17.00	15.33	15.50
Mean	54.95	66.57	62.85	17.50	17.63	18.08
SE	1.26	1.26	1.23	1.39	0.11	0.11
CV %	5.28	8.25	8.26	25.1	9.13	11.6

Table 3: Performance of rice germplasm for plant height (cm) and tiller number evaluated under full irrigation (F1), vegetative stage drought (VSD) and reproductive stage drought (RSD) in Kaduna, 2016.

SE: Standard Error; CV: Coefficient of Variation (%).

Germplasm	Leaf width			Leaf length		
	FI	VSD	RSD	FI	VSD	RSD
ART 15-16-45-1-B-1-1-B-1-2	0.90	0.77	1.47	40.33	31.80	38.80
ART 16-21-5-12-3-1-2-B-1-2	1.50	1.07	1.47	46.60	30.50	33.50
ART 16-9-28-21-3-2-1-B-2-1	1.40	1.07	1.47	58.00	30.00	51.50
ARICA 4	1.10	1.27	1.17	31.17	43.70	40.50
ART 15-13-2-2-2-1-1-B-1-1	1.20	0.97	1.37	40.33	42.50	37.00
ART 16-9-26-21-3-2-1-B-2-1	1.30	1.17	1.27	29.00	35.70	32.20
ART 16-9-1-32-1-1-1-B-1-2	1.30	1.07	1.27	40.00	34.00	41.80
ART 16-9-122-33-2-1-1-B-1-1	1.20	1.37	1.07	31.93	36.00	35.10
ART 16-16-11-25-1-B-1-B-1-1	1.20	1.17	1.27	33.00	39.50	36.00
ART 16-13-11-1-2-B-2-B-2-2	1.00	1.17	1.17	40.60	33.50	46.50
Mean	1.21	1.11	1.30	39.10	35.72	39.29
SE	0.05	0.05	0.04	0.06	0.06	0.06
CV %	14.8	14.9	10.9	22.1	13.4	15.3

Table 4: Performance of rice germplasm for Leaf width (cm) and Leaf length (cm) evaluated under full irrigation (F1), vegetative stage drought (VSD) and reproductive stage drought (RSD) in Kaduna, 2016.

SE: Standard Error; CV: Coefficient of Variation (%).

vegetative stage drought, the mean leaf width is 1.11cm, with the widest being ART 15-16-45-1-B-1-1-B-1-2 (1.47 cm) and the least, ART 16-9-122-33-2-1-1-B-1-1 (1.07 cm). The mean leaf width for germplasm under the reproductive stage drought is 1.30cm, with the widest being ART 15-16-45-1-B-1-1-B-1-2, ART 16-21-5-12-3-1-2-B-1-2 and ART 16-9-28-21-3-2-1-B-2-1 (1.47 cm) and the least for ART 16-9-122-33-2-1-1-B-1-1 (1.07 cm).

Leaf length (cm)

The mean leaf length for the rice is 39.10cm under full irrigated conditions and it ranged from 29 cm for ART 16-9-26-21-3-2-1-B-2-1 to 58 cm for ART 16-9-28-21-3-2-1-B-2-1. The genotype with the longest leaf was ART 16-9-28-21-3-2-1-B-2-1 (58 cm), closely followed by ART 16-21-5-12-3-1-2-B-1-2 (46.6 cm), and the least being ART 16-9-26-21-3-2-1-B-2-1 (29.0 cm). Under the vegetative stage drought, the mean leaf length is 35.7cm, with the longest being ARICA 4 (43.7 cm) and the least, ART 16-21-5-12-3-1-2-B-1-2 (30 cm). The mean leaf length for germplasm under the reproductive stage drought is 39.29cm, with the longest being ART 16-9-28-21-3-2-1-B-2-1 (51.5 cm) and the least, ART 16-9-26-21-3-2-1-B-2-1 (32.2 cm). Leaf length showed more variability in length under FI, which resulted in higher coefficient of variation.

Root length (cm)

The mean root length for the germplasm is 33.72cm under full irrigated conditions and it ranged from 27.7 cm for ART 16-9-122-33-2-1-1-B-1-1 to 37.7 cm for ART 16-9-1-32-1-1-1-B-1-2. The germplasm with the longest root was ART 16-9-1-32-1-1-1-B-1-2 (37.67 cm), closely followed by ART 16-21-5-12-3-1-2-B-1-2 (37.17 cm), and the least being ART 16-9-122-33-2-1-1-B-1-1 (27.67m). Under the vegetative stage drought, the mean root length is 35.72 cm, with the longest being ART 16-16-11-25-1-B-1-B-1-1 (42.3 cm) and the least, ARICA 4 (25.83 cm). The mean root length for germplasm under the reproductive stage drought is 34.02 cm, with the longest being ART 16-21-5-12-3-1-2-B-1-2 (36.67 cm) and the least, ART 16-9-26-21-3-2-1-B-2-1 (27.17 cm). The germplasms were phenotypically more diverse in root length under VSD which lead to its high coefficient of variation.

Drought effect on reproductive traits

Heading date

The mean heading date for the germplasm is 109.8 days under full irrigated conditions and it ranged from 107.1 days for ART 15-16-45-1-B-1-1-B-1-2 to 114.33 days for ART 16-21-5-12-3-1-2-B-1-2. The genotype with highest days was ART 16-21-5-12-3-1-2-B-1-2 (114.3 days), closely followed by ART 16-9-1-32-1-1-1-B-1-2 (111 days), and the least being ART 15-16-45-1-B-1-1-B-1-2 (107.1 days). Under vegetative stage drought, the mean heading date is 112.13days with the highest being ART 16-9-28-21-3-2-1-B-2-1 (117.5 days) and the least, ART 16-16-11-25-1-B-1-B-1-1 (105.8 days). The mean heading date for the germplasm is 111.4 days under reproductive stage drought, with the highest being ART 16-9-28-21-3-2-1-B-2-1 (117 days) and the least. ART 15-16-45-1-B-1-1-B-1-2 (107.3 days).

Germplasm	Root length		
	FI	VSD	RSD
ART 15-16-45-1-B-1-1-B-1-2	36.67	30.33	28.17
ART 16-21-5-12-3-1-2-B-1-2	37.17	34.83	36.67
ART 16-9-28-21-3-2-1-B-2-1	32.67	38.83	36.17
ARICA 4	32.17	25.83	33.17
ART 15-13-2-2-2-1-1-B-1-1	30.67	29.83	36.17
ART 16-9-26-21-3-2-1-B-2-1	36.67	35.83	27.17
ART 16-9-1-32-1-1-1-B-1-2	37.67	26.83	36.17
ART 16-9-122-33-2-1-1-B-1-1	27.67	29.83	34.17
ART 16-16-11-25-1-B-1-B-1-1	33.17	42.83	36.17
ART 16-13-11-1-2-B-2-B-2-2	32.67	27.83	36.17
Mean	33.72	32.28	34.02
SE	1.03	1.76	1.11
CV %	9.67	17.3	10.4

Table 5: Performance of rice germplasm for root length (cm) evaluated under full irrigation (F1), vegetative stage drought (VSD) and reproductive stage drought (RSD) in Kaduna, 2016.
SE: Standard Error; CV: Coefficient of Variation (%).

Panicle length (cm)

The mean panicle length for the germplasm is 16.7cm under full irrigated conditions and it ranged from 12.9cm for ART 16-13-11-1-2-B-2-B-2-2 to 20.5 cm for 2ART 16-21-5-12-3-1-2-B-12. The genotype with the longest panicle was 2ART 16-21-5-12-3-1-2-B-12 (20.5 cm), closely followed by ART 16-9-1-32-1-1-1-B-1-2 (18.2 cm), and the least being ART 16-13-11-1-2-B-2-B-2-2 (12.9 cm). Under the vegetative stage drought, the mean panicle length is 17.6 cm, with the highest being ART 15-13-2-2-2-1-1-B-1-1 (20.0 cm) and the least, ART 16-9-28-21-3-2-1-B-2-1 (15.2 cm). The mean panicle length for germplasm under the reproductive stage drought is (18.1 cm), with the highest being ART 16-9-28-21-3-2-1-B-2-1 (21.3 cm) and the least, ART 16-13-11-1-2-B-2-B-2-2 (15.5 cm).

Panicle number

The mean panicle number per plant for the germplasm is 12 under full irrigated conditions and it ranged from 5 for ART 16-9-28-21-3-2-1-B-2-1 to 18 for ART 16-9-1-32-1-1-1-B-1-2. The germplasm with the highest number was ART 16-9-1-32-1-1-1-B-1-2 (18), closely followed by ART 16-9-122-33-2-1-1-B-1-1 (17), and the least being ART 16-9-28-21-3-2-1-B-2-1 (5). Under the vegetative stage drought, the mean panicle number is 13, with the highest being ART 16-13-11-1-2-B-2-B-2-2 (28) and the least, ART 16-21-5-12-3-1-2-B-1-2 (6). The mean panicle number for germplasm under the reproductive stage drought is 11, with the highest being ART 16-9-26-21-3-2-1-B-2-1 (19) and the least, ART 16-9-1-32-1-1-1-B-1-2 (6). The germplasms panicle number were phenotypically very diverse under drought and FI conditions.

Number of productive panicle

The mean number of productive panicle per plant for the germplasm was 5 under full irrigated conditions and it ranged from 1 for ART 16-9-26-21-3-2-1-B-2-1 and ART 16-9-1-32-1-1-1-B-1-2 to 8 for ART 15-13-2-2-2-1-1-B-1-1 and ART 16-13-11-1-2-B-2-B-2-2. The germplasm with the highest number were ART 15-13-2-2-2-1-1-B-1-1 and ART 16-13-11-1-2-B-2-B-2-2 (8), closely followed by ART 15-16-45-1-B-1-1-B-1-2 (7), and the least being ART 16-9-26-21-3-2-1-B-2-1 and ART 16-9-1-32-1-1-1-B-1-2 (1). Under the vegetative stage drought, the mean number of productive panicle is 4, with the highest being ART 16-13-11-1-2-B-2-B-2-2 (8) and the least, ART 16-9-1-32-1-1-1-B-1-2 (0). The mean number of productive panicle for germplasm under the reproductive stage drought is 11, with the highest being ART 15-16-45-1-B-1-1-B-1-2 (9) and the least, ART 16-9-122-33-2-1-1-B-1-1 (0). The germplasms in the number of productive panicle were phenotypically very diverse under drought and FI conditions which lead to high coefficient of variation.

Germplasms	Panicle length			Heading dates		
	FI	VSD	RSD	FI	VSD	RSD
ART 15-16-45-1-B-1-1-B-1-2	14.50	18.67	17.00	107.06	108.67	107.33
ART 16-21-5-12-3-1-2-B-1-2	20.50	19.00	19.00	114.33	114.33	113.67
ART 16-9-28-21-3-2-1-B-2-1	17.80	15.17	21.33	110.33	117.51	117.00
ARICA 4	16.50	17.17	21.00	109.33	111.33	113.33
ART 15-13-2-2-2-1-1-B-1-1	16.50	20.00	17.00	109.67	114.67	112.33
ART 16-9-26-21-3-2-1-B-2-1	17.50	17.67	17.00	109.00	113.33	108.67
ART 16-9-1-32-1-1-1-B-1-2	18.20	18.50	20.00	111.00	112.67	115.00
ART 16-9-122-33-2-1-1-B-1-1	15.00	16.33	16.00	108.67	114.33	108.00
ART 16-16-11-25-1-B-1-B-1-1	17.50	18.50	17.00	108.33	105.75	110.00
ART 16-13-11-1-2-B-2-B-2-2	12.90	15.33	15.50	110.33	108.67	108.67
Mean	16.69	17.63	18.08	109.81	112.13	111.40
SE	0.11	0.11	0.11	0.65	0.67	0.64
CV %	12.9	9.13	11.6	1.78	3.15	2.98

Table 6: Performance of rice germplasms for panicle length (cm) and Heading dates evaluated under full irrigation (F1), vegetative stage drought (VSD) and reproductive stage drought (RSD) in Kaduna, 2016.
SE: Standard Error; CV: Coefficient of Variation (%).

Number of half-filled panicle

The mean number of half-filled panicle per plant for the germplasm is 2.8 under full irrigated conditions and it ranged from 0.33 for ART 16-9-28-21-3-2-1-B-2-1 to 4.67 for ART 16-9-26-21-3-2-1-B-2-1. The germplasm with the highest number was ART 16-9-26-21-3-2-1-B-2-1 (4.67), closely followed by ART 15-16-45-1-B-1-1-B-1-2 and ART 15-13-2-2-2-1-1-B-1-1 (4), and the least being ART 16-9-28-21-3-2-1-B-2-1 (0.33). Under the vegetative stage drought, the mean number of half-filled panicle is 2.7, with the highest being ART 15-16-45-1-B-1-1-B-1-2 (6) and the least been ART 16-9-122-33-2-1-1-B-1-1 (0.67). The mean number of half-

filled panicle for germplasm under the reproductive stage drought is 0.43, with the highest been ART 16-16-11-25-1-B-1-B-1-1 (2) and the least been ART 16-21-5-12-3-1-2-B-1-2, ARICA 4, ART 16-9-1-32-1-1-1-B-1-2, ART 16-9-122-33-2-1-1-B-1-1 and ART 16-13-11-1-2-B-2-B-2-2 (0). The germplasms were phenotypically very diverse in number of half-filled panicle with some of the germplasms not having half-filled panicles at all. This resulted in a high coefficient of variation.

Germplasm	Panicle number			Number of productive panicle		
	FI	VSD	RSD	FI	VSD	RSD
ART 15-16-45-1-B-1-1-B-1-2	14.00	15.00	10.00	7.00	8.00	9.00
ART 16-21-5-12-3-1-2-B-1-2	11.00	6.00	12.00	3.00	2.00	4.00
ART 16-9-28-21-3-2-1-B-2-1	5.00	10.00	6.00	5.00	2.00	5.00
ARICA 4	6.00	10.00	13.00	5.00	2.00	7.00
ART 15-13-2-2-2-1-1-B-1-1	13.00	11.00	8.00	8.00	3.00	7.00
ART 16-9-26-21-3-2-1-B-2-1	12.00	16.00	19.00	1.00	3.00	5.00
ART 16-9-1-32-1-1-1-B-1-2	18.00	9.00	6.00	1.00	0.33	1.00
ART 16-9-122-33-2-1-1-B-1-1	17.00	15.00	13.00	2.00	4.00	0.00
ART 16-16-11-25-1-B-1-B-1-1	11.00	13.00	18.00	5.00	4.00	6.00
ART 16-13-11-1-2-B-2-B-2-2	13.00	28.00	9.00	8.00	8.00	7.00
Mean	12.00	13.30	11.40	4.50	3.63	5.10
SE	1.3	1.9	1.43	0.04	0.04	0.04
CV %	34.5	45.4	39.7	59.5	69.9	55.0

Table 7: Performance of rice germplasm for Panicle number and Number of productive panicle evaluated under full irrigation (F1), vegetative stage drought (VSD) and reproductive stage drought (RSD) in Kaduna, 2016.

SE: Standard Error; CV: Coefficient of Variation (%).a

Grain yield (kg/ha)

The mean grain yield for the germplasm is 59.65kg/ha under full irrigated conditions and it ranged from 29kg/ha for ART 16-9-26-21-3-2-1-B-2-1 to 80.33kg/ha for ART 16-9-28-21-3-2-1-B-2-1. The germplasm with the highest yield was ART 16-9-28-21-3-2-1-B-2-1 (80.33kg/ha), closely followed by ARICA 4 (78kg/ha), and the least being ART 16-9-26-21-3-2-1-B-2-1 (29kg/ha). Under the vegetative stage drought, the mean grain yield is 56.68kg/ha, with the highest being ART 16-16-11-25-1-B-1-B-1-1 (85.17kg/ha) and the least, ART 16-9-1-32-1-1-1-B-1-2 (35kg/ha). The mean grain yield for germplasm under the reproductive stage drought is 56.68kg/ha, with the highest being ART 16-9-28-21-3-2-1-B-2-1 (84kg/ha) and the least, ART 16-9-122-33-2-1-1-B-1-1 (34.67kg/ha). The germplasms were phenotypically diverse in grain yield (kg/ha) under all the treatments which lead to their high coefficient of variation.

Germplasm	Number of half-filled panicle			Grain yield		
	FI	VSD	RSD	FI	VSD	RSD
ART 15-16-45-1-B-1-1-B-1-2	4.00	6.00	0.33	50.50	50.00	51.33
ART 16-21-5-12-3-1-2-B-1-2	3.00	3.00	0.00	69.00	70.83	52.83
ART 16-9-28-21-3-2-1-B-2-1	0.33	1.00	0.67	80.33	52.33	84.00
ARICA 4	1.00	2.00	1.00	78.00	67.67	58.33
ART 15-13-2-2-2-1-1-B-1-1	4.00	2.00	0.00	75.50	64.50	68.50
ART 16-9-26-21-3-2-1-B-2-1	4.67	2.33	0.33	29.00	68.00	50.33
ART 16-9-1-32-1-1-1-B-1-2	2.00	3.33	0.00	54.83	35.00	54.83
ART 16-9-122-33-2-1-1-B-1-1	3.00	0.67	0.00	51.83	48.33	34.67
ART 16-16-11-25-1-B-1-B-1-1	3.00	3.33	2.00	60.00	85.17	63.00
ART 16-13-11-1-2-B-2-B-2-2	3.00	3.33	0.00	62.67	54.67	49.00
Mean	2.80	2.70	0.43	59.65	56.68	56.68
SE	0.12	0.12	0.12	0.88	0.88	0.88
CV %	48.3	55.7	149.7	26.2	25.2	23.2

Table 8: Performance of rice germplasm for Number of half-filled panicle and Grain yield (kg/ha) evaluated under full irrigation (F1), vegetative stage drought (VSD) and reproductive stage drought (RSD) in Kaduna, 2016.

SE: Standard Error; CV: Coefficient of Variation (%).

Panicle fresh weight (g)

The mean panicle fresh weight per plant for the germplasm is 1.39g under full irrigated conditions and it ranged from 0.65g for ART 16-9-26-21-3-2-1-B-2-1 to 1.88g for ART 16-9-28-21-3-2-1-B-2-1. The genotype with the heaviest panicle is ART 16-9-28-21-3-2-1-B-2-1 (1.88), closely followed by ARICA 4 (1.76), and the least being ART 16-9-26-21-3-2-1-B-2-1 (0.65g). Under the vegetative stage drought, the mean panicle fresh weight is 1.39g, with the heaviest being ART 16-16-11-25-1-B-1-B-1-1 (1.9g) and the least, ART 16-9-1-32-1-1-1-B-1-2 (0.85g). The mean tiller number for germplasm under the reproductive stage drought is 1.27g, with the highest been ART 16-9-28-21-3-2-1-B-2-1 (1.89g) and the least been ART 16-9-122-33-2-1-1-B-1-1 (0.74g).

Panicle dry weight (g)

The mean panicle dry weight per plant for the germplasm is 1.22g under full irrigated conditions and it ranged from 0.58g for ART 16-9-26-21-3-2-1-B-2-1 to 1.61g for ART 16-9-28-21-3-2-1-B-2-1. The genotype with the heaviest panicle is ART 16-9-28-21-3-2-1-B-2-1 (1.61g), closely followed by ARICA 4 (1.56), and the least being ART 16-9-26-21-3-2-1-B-2-1 (0.58g). Under the vegetative stage drought, the mean panicle dry weight is 1.99g, with the heaviest being ART 16-16-11-25-1-B-1-B-1-1 (1.7g) and the least, ART 16-9-1-32-1-1-1-B-1-2 (0.7g). The mean panicle dry weight

Germplasm	Panicle fresh weight			Panicle dry weight		
	FI	VSD	RSD	FI	VSD	RSD
ART 15-16-45-1-B-1-1-B-1-2	1.16	1.32	1.04	1.01	1.00	1.03
ART 16-21-5-12-3-1-2-B-1-2	1.73	1.75	1.29	1.38	1.42	1.06
ART 16-9-28-21-3-2-1-B-2-1	1.88	1.13	1.89	1.61	1.05	1.68
ARICA 4	1.76	1.47	1.39	1.56	1.35	1.17
ART 15-13-2-2-2-1-1-B-1-1	1.72	1.39	1.38	1.51	1.29	1.37
ART 16-9-26-21-3-2-1-B-2-1	0.65	1.42	1.27	0.58	1.36	1.01
ART 16-9-1-32-1-1-1-B-1-2	1.09	0.85	1.04	1.10	0.70	1.10
ART 16-9-122-33-2-1-1-B-1-1	1.09	1.15	0.74	1.04	0.97	0.69
ART 16-16-11-25-1-B-1-B-1-1	1.17	1.90	1.50	1.20	1.70	1.26
ART 16-13-11-1-2-B-2-B-2-2	1.66	1.47	1.17	1.25	1.09	0.98
Mean	1.39	1.39	1.27	1.22	1.19	1.13
SE	0.12	0.09	0.09	0.09	0.09	0.08
CV %	29.4	21.9	24.5	25.5	24.0	23.2

Table 9: Performance of rice germplasm for Panicle fresh weight (g) and Panicle dry weight (g) evaluated under full irrigation (F1), vegetative stage drought (VSD) and reproductive stage drought (RSD) in Kaduna, 2016.

SE: Standard Error; CV: Coefficient of Variation (%).

for germplasm under the reproductive stage drought is 1.27g, with the highest being ART 16-9-28-21-3-2-1-B-2-1 (1.68g) and the least, ART 16-9-122-33-2-1-1-B-1-1 (0.69g).

Discussion

In drought studies, leaf rolling and leaf drying are used as an indication of tolerance. Leaf rolling and drying at vegetative stage drought showed that only few varieties were resistant. Leaf rolling has been found to correspond to leaf water potential [24]. Hence, a plant that maintains high leaf water potential will show less leaf rolling. Leaf drying score can be used to determine drought resistance at all stages of rice growth and has moderate to high heritability under stress [25]. Degree of leaf rolling determines the germplasm response to drought [26]. The results indicate that plant height decreased with increasing soil moisture stress. It might be due to inhibition of cell division or cell enlargement under water stress. Variation in plant height among the germplasm also indicates that different germplasm had different water requirements. Plant height and grain yield were reduced under drought. Under drought, plant development is reduced as a consequence of poor root development; reduced leaf-surface traits, which affect the radiation load on the leaf canopy; delay in or reduced rate of normal plant senescence as it approaches maturity; and inhibition of stem reserves [27]. The negative effect of drought on plant height and grain yield were also reported in previous studies [20-22,28,29]. Plant height was also affected by drought but was not correlated with grain yield in all irrigation treatments. This is in accordance with the findings of Lanceras., *et al.* [30]. Plant height was found to be highest at the vegetative stage drought, and least at full irrigation. This could be due to rapid elongation of plants after recovery from drought; but it was reduced at both drought stages during drought imposition. The high number of tiller under vegetative stage drought compared to reproductive stage drought could be due to rapid growth of plant after recovery from vegetative stage drought. However the results showed that the number of tiller per hill was decreased with decreased soil moisture level. Tillering capacity is one of the most important characters determining yield potential under irrigated condition as it is closely related with the number of panicles per unit area [31]. Reduced tiller production under lower soil moisture levels might be due to water stress and plants were not able to produce enough assimilates for inhibited photosynthesis. It might also be due to less amount of water uptake to prepare sufficient food and inhibition of cell division of meristematic tissue. The results agree with Zubaer., *et al.* [20]. The germplasm did not produce much tillers in FI relative to the stressed conditions. Root length was higher under reproductive stage drought than full irrigation and vegetative stage drought. In responding to drought, germplasm with a higher deep-root system showed more resistance to drought [19]. This might contribute greatly to its drought resistance through enhanced water uptake [32]. Under drought, plant development is reduced as a consequence of poor root development; reduced leaf-surface traits, which affect the radiation load on the leaf canopy; delay in or reduced rate of normal plant senescence as it approaches maturity; and inhibition of stem reserves [27].

Heading days were found to be reduced under full irrigation compared to vegetative and reproductive stage drought. This is a good characteristic in terms of drought avoidance in case of late season drought. It was reported that many lines flower earlier under stress than under non-stress conditions, some by up to 14 days [33]. Mean panicle length across the germplasm was higher under reproductive stage drought than under vegetative stage drought or full irrigation. This is also as reported by Deshmukh (2012). Panicle number was found to be the highest at vegetative stage drought than full irrigation and reproductive stage drought. This might be due to rapid growth after a period of drought; although, some of the tillers were not productive. Number of productive panicles was higher under reproductive stage drought than full irrigation and vegetative stage drought. Drought stress during the vegetative growth, flowering, and terminal stages of rice cultivation can cause spikelet sterility and unfilled grains [34]. Number of half-filled panicle is higher under full irrigation than vegetative and reproductive stage drought. Panicle fresh and dry weight was higher under full irrigation than vegetative and reproductive stage drought. This resulted in higher yield at full irrigation. This is in accordance with the findings of Akram., et al. [35]. Greater plant fresh and dry weights under water deficit conditions are desirable characters [21].

Grain yield was higher under full irrigation than vegetative and reproductive stage drought. The low yield might be due to decreased filled grains per panicle caused by inhibition of sufficient translocation of assimilates to the grains as the plants competed for moisture. This is in accordance with the findings of Sikuku., *et al.* [21]. Lower soil moisture might inhibit photosynthesis and decrease translocation of assimilates to the grain which lowered grain weight [36]. Grain yield in different irrigation treatments showed

negative correlations with percent spikelet sterility indicating that drought stress occurring during the reproductive stage increased the percent spikelet sterility and consequently decreased the grain yield [30].

Conclusion

The study shows appreciable variations among the rice germplasm with respect to their response to morphological traits (leaf rolling and leaf drying) under different water regimes. ART 15-16-45-1-B-1-1-B-1-2, ART 16-9-26-21-3-2-1-B-2-1 and ART 16-16-11-25-1-B-1-B-1-1 were tolerant to water deficit occurring at vegetative stage or reproductive stage as compared to the other germplasms because of little or no effect of drought on their growth and yield.

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