

Morphological Response and Yield of Rice Cultivars to Water Deficit Condition at Different Growth Stages on Sandy Loam Soil in Ibadan

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Drought is a major abiotic constraint in upland rice field, causing severe yield loss of more than 50%. Southwestern Nigeria, which covers almost 30% upland rice fields are purely rainfed and rainfed farming is no longer reliable due to fluctuation in rainfall pattern and volume causing drought in rice field. The need to understand response of upland rice cultivars to moisture deficit at different phenological stages is important to device appropriate drought management strategy in upland rice field. Information on response of upland rice cultivar to water deficit condition at different growth stages is scanty. Therefore, response of 12 Rice Cultivars (RC) to water deficit condition at tillering, panicle initiation and grain filling on sandy loam was investigated. The study was a 4×12 factorial, arranged in completely randomized design with six replicates was conducted in a screenhouse during the early and late dry seasons of 2018 in Ibadan. Treatments included twelve RC: OFADA, IGBEMO, FARO-16, FARO-44, FARO-60, IR-64, APO, NERICA-4, NERICA-5, NERICA-7, NERICA-8, water stressed at tillering, Panicle Initiation (PI) and Grain Filling (GF) and Well-Watered Soil (WWS, served as control). Three weeks old rice seedling was transplanted into pot containing 5 kg soil. Data were collected on plant height (cm), leaf area (cm²), number of leaves and tillers, leaf roll and dry, dry matter and yield components. Data were analyzed using analysis of variance (ANOVA) and means separated with LSD ($p < 0.05$). APO had significantly taller plant (99.42 and 113.18) at tillering and GF than other cultivars. However, at PI, OFADA was taller (143.26 cm) than other cultivars. Similarly, IR-64 had significantly higher number of leaves (13.67, 17.38 and 17.54 cm) and tillers (3.17, 3.75 and 4.17) at tillering, PI and GF, respectively than other cultivars. Similarly, IR-64 had highest unfilled grain weight (1.67 g). VANDANA had significantly higher filled grain (3.71 g) and grain weight (3.93 g) over other cultivars. Drought stress retarded growth and reduced yield of upland rice cultivars severely at tillering and panicle initiation stages than at grain filling stage, while VANDANA produced the highest grain relative to other cultivars predisposed to drought.

Key words: Drought, yield components, upland rice cultivars, growth and biomass yield

Globally rice is an important staple food crop for more than 3 billion people in the world (Khush, 2005 and Nguyen, 2010). Rice forms a major part of the Nigerian diet and most populations in developing countries (Sakariyawo *et al.*, 2013). Rice has been reported to generate more income for arable farmers than any other crop (FAO, 2017).

Harfold, (2011) reported that rice consumption in Nigeria is higher than that of any other staple crops due to increase in population, rapid urbanization and changing eating habits. Nigeria relied on importation to meet the increasing rice demand. Rice importation profile of Nigeria stands at approximately 3 MT annually, whereas local production stands at 2 MT (FAO, 2017). Similarly, Uduma *et al.* (2016) noted that the inability of local supply to meet up with rice demand has given rise to the high importation of rice in Nigeria.

Studies have shown that biotic and abiotic stresses are the major constraints affecting rice production (Ismaila *et al.*, 2010). The abiotic factors including flooding, low soil fertility, iron toxicity and particularly drought have been reported to reduce global rice production by 50% (Nwilene *et al.*, 2008; Mostajeran and Rashimi-Eichi, 2009; Pawar *et al.*, 2017). Water deficit is an abiotic factor affecting arable crops particularly, rice production in Nigeria (Dada *et al.*, 2018). It causes stomata closure (Santos and Carlesso, 1998), and other metabolic processes that limit normal growth and development (Amin *et al.*, 2009; Jalal *et al.*, 2012). Substantial reduction in plant growth and yield has been reported to occur because of water deficit (Jalal *et al.*, 2012; Hayatu *et al.*, 2014).

Rice crop have been reported to be susceptible to drought stress which causes yield loss in rice field (Pantuwan *et al.*, 2002). However, some varieties have been reported to be tolerant than others, out-yielding those subjected to the same level of drought (Dada *et al.*, 2018). NERICA- New Rice for Africa has been known for higher yield, tolerant of major stress such as drought; it is higher in protein, with good taste and stable yield under different conditions compared to the traditional rice varieties (Africa Rice Center *et al.*, 2008;

Wopereis *et al.*, 2008; Arouna *et al.*, 2017).

Plant tolerance to drought is generally complex due to interactions between factors causing damage and various physiological responses within the plant (Ashraf and Hafeez, 2004; Manivannan *et al.*, 2008). An adequate understanding of rice response to water deficit is required to select the most appropriate varieties tolerant of this biotic limitation in order to increase rice productivity. Timing, duration, severity, and stage of exposure have roles in determining how plants respond to water deficit. Other factors include stage of plant development (Singh *et al.*, 2012).

Screening for drought tolerant varieties and determining the growth stage(s) at which water deficit is most detrimental to rice plant development is necessary to evolve appropriate drought mitigation approach that could be deployed for improving yield of upland rice. Equally, identification and selection of varieties with high level of tolerance to drought for further breeding programme is expedient for improving upland rice production.

More information is however, needed on morphological response of upland rice cultivars to drought stress at different stages of growth. Therefore, the aim of this study was to investigate the response of twelve upland rice cultivars to water deficit condition at various growth stages in Ibadan, southwestern Nigeria.

MATERIALS AND METHODS

Study site

The study was a pot experiment, carried out between 2018-2019 in the screen house of the Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Nigeria (7°.45'E; 3°.89'N, 227m above sea level). The ambient temperature of the screen house was 32-40 °C while the relative humidity was 66-85% and the average precipitation during the trial was 1260 mm.

Soil collection and analysis

The soil was collected from a field at University of Ibadan Teaching and Research Farm. The field where the soil was collected had been used for cultivation of vegetables such as *Solanum* spp., *Lycopersicum esculentum*, *Abelmoscuhs esculentus*, *Zea mays*, *Vigna*

unguiculata in the previous three planting seasons. Prior to transplanting, routine soil analysis were performed following standard analytical methods described by IITA (1979).

Sources of rice seeds

Twelve upland rice cultivars were investigated to establish their responses to drought. These included nine commonly cultivated lines: OFADA, IGBEMO, FARO-16, FARO-60, FARO-44, NERICA-4, NERICA-5, NERICA-7, NERICA-8, which were collected from rice farmers during preliminary field survey across southwestern, Nigeria. The remaining three cultivars: IR-64, VANDANA and APO were collected from Africa Rice Center (WARDA), Nigeria sub-station, located at the International Institute of Tropical Agriculture (IITA), Ibadan.

Nursery and transplanting

The seeds of the cultivars were raised in nursery beds for two weeks after which they were transplanted to the prepared pots each, filled with 5 kg soil. One vigorous seedling with three fully formed leaves was transplanted per pot.

Treatments and experimental design

There were 48 treatments derived from combination of twelve upland rice cultivars and phenology at which water stress was imposed: tillering, panicle initiation and grain filling while, treatment without imposition of water stress served as the control. The treatments were arranged in completely randomized design and replicated six times. A total of 288 pots used for the experiment were arranged in the screen house at the crop garden of the Department of Crop Protection and Environmental Biology. A repeat trial was carried out following same procedures employed in the first trial. All cultural practices were applied as appropriate.

Imposition of water stress

Prior to imposition of water stress, transplanted seedlings were adequately nurtured for two weeks to ensure that they were well established and had uniform development. Drought was imposed at vegetative stage (active tillering) for 14 days only, while drought was imposed for ten days each at panicle initiation and grain filling stages.

Water stress treatment was imposed twice at tillering at seven days interval. In this treatment, irrigation was withheld for seven consecutive days till the 8th day when plants were irrigated to field capacity with 600 mL water representing 100% of water required to attain field capacity. Field capacity was determined following the method of Saxton and Rawls (2006). At the 9th day, water stress treatment resumed for another seven days. Other plant sets, not subjected to water stress continued to receive water when soil moisture was low with 300 mL water representing 50% of water required to attain field capacity. Drought was imposed at panicle initiation and grain filling stages, each, for ten days at five days intervals. Whenever the stressed plants were to be unstressed after drought treatments, they were irrigated with 600 mL and subsequently with 300 mL based on soil moisture level test carried out, usually every other day till harvest. The moisture level was monitored daily at 9:00 hour and 15:00 hour by probing the moisture sensor at the center of the pots at 8-9 cm depth. Data Logger Em50 series was used to monitor the soil moisture level.

Data collection

Data were collected after the plants had been water stressed for a specific period of time based on the treatment. Morphological parameters such as plant height (cm), numbers of tillers, number of leaves, leaf area and number of tillers formed were assessed at tillering, panicle initiation and grain filling growth stages. Leaf area was evaluated following the method described by Gomez (1972). Dry matter yield was determined at the final harvest, each plant was uprooted carefully and washed thoroughly under running water to remove soil particles to determine dry matter yield at the final harvest. The samples were partitioned into root and shoot, kept in paper bags and oven dried at 80 °C until constant weight was attained after 48 hours. The dried samples were weighed using a measuring scale (Camry 202)

Soil moisture content determination

This was determined using the soil moisture meter (LMS-714) which was done by probing the meter into the soil before and after irrigation.

Assessment of leaf response to water stress

Indicators of water stress such as leaf rolling and leaf drying were assessed using standard procedures described by International Rice Research Institute (IRRI, 2016).

Leaf rolling

The score ranged from 1-9. Where 1 = Slight folding, 3 = Half rolling, 5 = Full to tight rolling, 7 = Tight rolling, 9 = Tube like rolling (no unrolling).

Dried tip

The scores ranged from 1-9. Where 1 = No drying, 3 = Few tips drying (5-10%) basal leaves drying, 5 = 5% leaf tip drying extending to $\frac{1}{4}$ of leaf blade, 5-10% of lower leaves dried, 7 = Most upper leaves $\frac{1}{2}$ – $\frac{3}{4}$ are dried; 60-80% lower leaves are dried, 9 = 100% of all leaves dried, plants generally approach permanent wilting point, some die. The various scores were logarithm transformed before they were analyzed statistically.

Yield and yield components such as numbers of panicles and spikelets, weight of panicles, filled grains, unfilled grains, 100-seed weight and grain yield (g)/plant, were determined following procedures of IRRI (2016).

Data Analysis

Data were analyzed using analysis of variance (ANOVA) of Statistical Analysis System (SAS, 2000) and different means were separated by Least Significant Difference (LSD) at $p \leq 0.05$.

RESULTS

Physical-chemical properties of the soil

The result of physical and chemical analysis of the soil for the study is presented in Table 1. The textural class of the soil is sandy loam and the pH revealed that the soil was slightly acidic (5.9). The soil had low organic carbon, total nitrogen and potassium but had high phosphorus content. Other exchangeable bases and cations were within the optimum mineral range for upland rice growth. The manganese and iron threshold were extremely above the adequate range.

Effect of water deficit condition at different growth stages on height of rice cultivars

Generally, imposition of drought at all the growth

stages had no significant effect on the height of the plants; however the plants were taller at grain filling than any other growth stage. The height of the different rice cultivars differed significantly in response to water limiting conditions. Among the twelve cultivars, APO had significantly taller plant (99.42 and 113.18 cm) but this was not significantly ($p \leq 0.05$) taller than IGBEMO, OFADA and NERICA-7 all through the growing periods except at 9 weeks after transplanting (WAT) when OFADA had the tallest height (143.26 cm) as shown in Table 2.

The interaction between the two factors showed that water deficit condition had no significant influence on height of different rice cultivars at 6 WAT, however, stage of drought occurrence had significant influence on the height of upland rice cultivars at 9 and 12 WAT (Table 2).

Effect of water deficit condition at different growth stages on number of leaves formed by upland rice cultivars

The growth stage at which drought was imposed had no significant effect on number of leaves produced at 6 WAT. However, number of leaves reduced significantly at 9 WAT, in plant water-stressed at grain filling, tillering and at panicle initiation stage while at 12 WAT plants water stressed at grain filling period had the highest number of leaves 11.42 which was significantly higher than plants water stressed at panicle initiation period (9.31) but was not significantly different from other growth stages (Table 3). The response of the different cultivars to water deficit condition was significant. IR-64 had the highest number of leaves (13.67, 17.38 and 17.54) at 6, 9 and 12 WAT but this was not significantly higher than number of leaves formed by FARO-44 and FARO-60.

Number of leaves produced was not significantly influenced by the interaction between growth stages when drought was imposed and different cultivars at 6 and 9 WAT except at 12 WAT when these factors influenced number of leaves significantly.

Effect of drought at different growth stages on leaf area of upland rice cultivars

Water stress imposition across the growth phases

had significant effect on the leaf area of upland rice cultivars. Plants stressed at tillering and panicle initiation had reduced leaf area which was significantly lower than leaf area obtained in plants water stressed at grain filling stage (Table 4).

Different upland rice cultivars responded differently to imposition of drought. Leaf area of APO was significantly higher (68.84 cm²) than other cultivars, but statistically similar to NERICA-7, IGBEMO, OFADA and NERICA-5 at 6 WAT. Also, at 9 WAT, NERICA-7 had highest leaf area (71.53 cm²) but this was comparable to leaf area of APO, OFADA and FARO-60 (Table 46). However, at 12 WAT, NERICA-5 had highest leaf area (63.93 cm²) which was not significantly higher than OFADA, FARO-60, APO, IGBEMO and FARO-44 at 12 WAT.

The interaction between varieties and growth stages had no significant influence on leaf area of upland rice cultivars at 6 WAT. However, these factors affected the leaf area significantly at 9 and 12 WAT (Table 4).

Number of tillers of twelve rice cultivars at different growth stages under water deficit condition

Water stress imposition had no significant effect on tiller formation at the phenological stages when drought was imposed. However, drought had significant effect on numbers of tillers produced by different upland rice cultivars. IR-64 cultivar formed higher number of tillers than other cultivars. Nevertheless, the number of tiller produced by FARO-44 and FARO-60 were similar to that of IR-64. NERICA-4 formed the lowest number of tillers across the growth phases (Table 5).

The interaction showed that growth period and cultivars had no significant influence on number of tillers at 6 and 12 WAT except at 9 WAT when these factors significantly influenced number of tillers formed (Table 5).

Leaf rolling scores of twelve rice cultivars at different growth stages under water deficit condition

Imposition of drought caused the leaves of upland rice cultivars to roll significantly at all the phenological stages (Table 6). Leaf of upland rice cultivar rolled up (1.73) in response to drought mostly when drought was imposed at tillering at 6 WAT. At 9 WAT, leaf roll score was highest when drought was imposed at panicle

initiation (1.84), while imposition of drought at grain filling resulted in higher leaf roll (1.52) at 12 WAT.

The interaction between growth stages and varieties caused significant leaf roll at 6 and 12 WAT (Table 6).

Leaf drying as an indicator of response to drought by rice cultivars at different growth stages

The response of different upland rice cultivars to drought as indicated by leaf drying differed significantly. At 6 WAT, FARO-16 had the highest leaf roll score (1.52) which was not significantly higher than the leaf roll score observed in IR-64, FARO-44, FARO-60 and APO cultivars. At 9 and 12 WAT there was no significant difference among the cultivars regarding leaf roll score (Table 7).

The interaction between growth stages and cultivars had no significant influence on leaf drying of rice cultivars at 9 and 12 WAT (Table 7).

Effect of Water-stress Imposed at Different Growth Stages on Yield Components of Upland Rice Cultivars

Imposition of drought at different growth stages reduced number of panicles, weight of panicles and number of spikelets per panicle formed significantly, relative to the yield components recorded in well-watered plants. Highest number of panicles (2.34), weight of panicle (2.40 g) as well as number of spikelets (11.75) was recorded in irrigated plants relative to plants water-stressed at various stages of growth (Table 4.10). Generally, yield components such as number of panicles (1.63), weight of panicle (1.78 g) and number of spikelets per panicle were lowest when the plants were water-stressed at panicle initiation (Table 6).

Drought imposition had significant effect on yield components of upland rice cultivars. VANDANA produced the highest number of panicles (2.88 g) which was significantly similar to number of panicles recorded in IR-64 and FARO-44 but statistically higher than number of panicles obtained in the other cultivars. Likewise, FARO-60 had highest weight of panicle (2.84 g) that was significantly similar to weight of panicle observed in IR-64, NERICA-4 and NERICA-5. Similarly, IR-64 had highest number of spikelets (13.30) per panicle and the lowest (6.58) was recorded in OFADA.

Table 1: Pre-cropping chemical properties of soil use for the study

Particle size (g/kg)		Textural Class		pH (H ₂ O)	Minerals (g/kg)		Exchangeable bases (cmol./kg)						Exchangeable cation (mg/kg)			
Sand	Silt	Clay	Clay		Org. Carbon	Total N	Avail. P	Ca	Mg	K	Na	Mn	Fe	Cu	Zn	
81.4	6.8	11.8	Loam	5.90	11.86	1.10	6.80	2.77	1.21	0.03	1.00	203.00	139.00	2.41	1.47	
*Soil sample was collected at 0-15 cm depth																

Table 2: Plant height (cm) of upland rice cultivars under water deficit condition at different growth stages

	Weeks after transplanting												
	6				9				12				
	Year 1	Year 2	Mean		Year 1	Year 2	Mean		Year 1	Year 2	Mean		
Stage of drought imposition (GS)													
Tillering	77.93a	92.19a	83.69a		81.51a	100.45a	92.41a		94.71ab	90.01a	91.43a		
Panicle initiation	73.91a	94.40a	83.32a		85.07a	98.28a	90.94a		87.24b	94.38a	90.31a		
Grain filling	78.92a	99.89a	88.44a		91.69a	134.21a	110.94a		96.04a	98.37a	96.82a		
Control	73.68a	97.26a	89.90a		87.51a	100.09a	92.55a		91.73ab	101.39a	95.31a		
LSD (p<0.05)	6.35	7.62	5.56		7.58	43.72	20.56		8.54	11.82	10.94		
Cultivar (CL)													
NERICA-4	75.53b-d	81.04e	78.29cd		81.08bc	89.08b	85.08b		83.27cd	81.62d	82.44ef		
NERICA-5	67.13d	86.78de	76.95cd		83.34bc	96.31b	89.83b		90.28b-d	94.67a-d	92.47b-e		
NERICA-7	89.58a	99.88a-d	94.73ab		103.60a	111.14b	107.37ab		106.57a	94.06b-d	100.31ab		
NERICA-8	67.56d	77.04e	67.56d		74.86c	80.01b	74.86b		77.58d	79.61d	77.58f		
FARO-16	66.03d	87.12de	76.57cd		71.54c	93.87b	82.70b		79.11d	89.84b-d	84.48d-f		
FARO-44	64.75d	88.01de	76.38cd		75.97c	92.98b	84.47b		77.93d	94.90a-d	86.42c-f		
FARO-60	73.15cd	99.33b-e	84.24bc		93.12ab	101.48b	97.34b		99.90ab	97.48a-d	98.69bc		
APO	88.77a	110.07a	99.42a		103.98a	114.73b	109.35ab		112.13a	114.22a	113.18a		
IGBEMO	88.63a	109.03a	98.83a		100.86a	111.98b	106.42ab		105.66a	101.50a-c	103.58a		
IR-64	65.28d	90.08c-e	77.68cd		76.27c	92.68b	84.48b		78.82d	84.00cd	81.43ef		
OFADA	82.63a-c	106.12ab	94.37ab		92.48ab	194.04a	143.26a		100.56ab	108.86ab	104.71ab		
VANDANA	84.29ab	101.82a-c	93.05ab		98.17a	92.57b	95.37b		97.40a-c	95.23a-d	96.31b-d		
LSD (p<0.05)	11.28	13.51	9.63		13.87	72.36	31.61		15.23	19.60	12.01		
Interaction													
GS x CL	ns	ns	ns		ns	*	*		ns	*	*		
GS=	Drought	imposition	stage,	CL	=	Cultivars,	LSD	=	Least	Significant	Difference	at	p<0.05

Table 3: Number leaves of upland rice cultivars under water deficit condition at different growth stages

	Weeks after transplanting									
	6			9			12			
	Year 1	Year 2	Mean	Year 1	Year 2	Mean	Year 1	Year 2	Mean	
Stage of drought imposition (GS)										
Tillering	8.56a	9.82a	8.94a	9.61a	10.27ab	9.83b	12.53ab	8.67a	10.42ab	
Panicle initiation	8.06a	8.73a	8.21a	10.14a	10.55ab	10.33ab	9.67b	9.03a	9.31b	
Grain filling	8.92a	9.03a	8.90a	11.67a	9.82b	9.75b	13.92a	8.91a	11.42a	
Control	8.91a	9.91a	8.81a	10.67a	11.94a	11.31a	12.39ab	10.03	11.07ab	
LSD (p≤0.05)	1.46	1.73	1.07	2.20	1.83	1.40	2.91	1.89	1.83	
Cultivar (CL)										
NERICA-4	5.20ef	6.25d	5.75g	6.67de	5.92d	6.29d	7.50e	4.83d	6.17e	
NERICA-5	4.58f	6.17d	5.38g	6.67de	7.42b-d	7.04d	7.92e	6.25cd	7.08de	
NERICA-7	7.33de	8.67cd	8.00de	9.08cde	7.92b-d	8.50cd	9.75de	6.25cd	8.00de	
NERICA-8	4.92ef	5.25d	4.92g	6.58de	4.92d	6.58d	7.67e	3.83d	7.67de	
FARO-16	10.67bc	10.67bc	10.67bc	14.17b	13.67a	13.92b	15.00bc	12.50ab	13.75bc	
FARO-44	12.08ab	12.58ab	12.33ab	14.08b	14.58a	14.33b	16.50b	15.58a	16.04ab	
FARO-60	11.25ab	12.92ab	12.08ab	14.50b	15.00a	14.75b	17.33b	12.25b	14.79ab	
APO	10.67bc	8.42cd	9.54cd	11.83bc	10.17b	11.00c	14.08b-d	7.33cd	10.71cd	
IGBEMO	6.80def	8.25cd	7.54def	7.83de	10.08b	8.96cd	9.30de	8.83c	9.08de	
IR-64	13.75a	13.58a	13.67a	18.58a	16.17a	17.38a	23.08a	12.00b	17.54a	
OFADA	5.33ef	7.83cd	6.58def	6.17e	9.33bc	2.75d	7.25e	8.25c	7.75de	
VANDANA	8.50cd	7.75d	8.13de	10.08cd	6.83cd	8.46cd	10.08cde	6.67cd	8.38de	
LSD (p≤0.05)	2.76	2.87	1.86	4.05	3.04	2.42	5.05	3.13	3.17	
Interaction										
GS x CL	ns	ns	ns	ns	*	ns	*	*	ns	
GS=	Drought	imposition	stage,	CL	=	Cultivars,	LSD	=	Least	Significant
									Difference	at
										p≤0.05

Table 4: Leaf area (cm²) of upland rice cultivars under water deficit condition at different growth stages

	Weeks after transplanting						
	6		9		12		Mean
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	
Stage of drought imposition (GS)							
Tillering	44.68a	58.50ab	53.37ab	57.89b	56.79ab	41.29b	48.39ab
Panicle initiation	40.02a	53.92b	48.36b	56.29b	48.78b	43.48ab	46.50b
Grain filling	47.28a	67.29a	59.92a	53.86a	69.16a	48.14ab	54.72a
Control	45.31a	68.78a	54.61ab	60.55b	54.87ab	50.48a	52.46ab
LSD (p≤0.05)	6.92a	10.57	8.95	7.69	11.37	8.67	7.27
Cultivar (CL)							
NERICA-4	40.59cd	0.67e	48.51cd	0.92d	44.38de	0.67e	40.78c
NERICA-5	46.28a-d	0.83ed	55.68bcd	0.83d	70.29ab	0.83ed	63.93a
NERICA-7	57.94a	2.17bc	73.88a	2.25abc	73.72a	1.42cde	44.86bc
NERICA-8	38.04d	0.60e	52.82bcd	0.82d	43.23de	0.57e	43.23c
FARO-16	36.11d	2.58ab	42.63de	2.67abc	45.17cde	2.42abc	44.86bc
FARO-44	40.59bd	3.58a	50.49bcd	3.25a	53.78bcd	3.42a	56.89ab
FARO-60	44.03bcd	2.42bc	60.93abc	2.75abc	64.08abc	2.83ab	58.18ab
APO	57.43a	1.83bcd	73.35a	1.75cd	68.68ab	1.83bcd	57.70ab
IGBEMO	56.30ab	1.75bcd	64.65ab	2.00bc	69.07ab	1.83bcd	57.48ab
IR-64	35.73d	2.42bc	40.51de	2.92ab	43.16de	2.83ab	39.51cd
OFADA	52.23abc	2.42bc	54.53bcd	1.83cd	59.06a-d	1.83bcd	58.78ab
VANDANA	40.40cd	1.50cde	30.75e	2.42abc	30.18e	1.25ed	27.40d
LSD (p≤0.05)	12.3	1.07	15.59	1.02	19.85	1.01	12.59
Interaction							
GS x CL	ns	ns	*	*	*	*	*

GS= Drought imposition stage, CL = Cultivars, LSD = Least Significant Difference at p≤0.05

	Weeks after transplanting							
	6			9			12	
	Year 1	Year 2	Mean	Year 1	Year 2	Mean	Year 1	Year 2
Stage of drought imposition (GS)								
Tillering	1.11a	1.91a	1.43a	1.16a	1.94a	1.55a	2.86ab	1.94a
Panicle initiation	1.42a	1.82a	1.54a	2.17a	2.33a	2.25a	2.25b	2.12a
Grain filling	1.56a	1.88a	1.68a	2.25a	1.91a	2.08a	3.22a	1.82a
Control	1.25a	2.45a	1.75a	2.08a	2.39a	2.24a	2.89ab	2.16a
LSD (p≤0.05)	0.59	0.64	1.97	0.76	0.62	0.47	0.92	0.61
Cultivar (CL)								
NERICA-4	0.17e	0.67e	0.42d	0.92ef	0.92d	0.92de	1.50e	0.67e
NERICA-5	0.33e	0.83ed	0.58d	1.00def	0.83d	0.92de	1.33e	0.83ed
NERICA-7	1.67de	2.17bc	1.67bc	1.58c-f	2.25abc	1.92c	2.25cde	1.42cde
NERICA-8	0.25e	0.60e	0.25d	0.58f	0.81d	0.58e	1.92de	0.60e
FARO-16	1.4dc	2.58ab	2.00bc	2.25bcd	2.67abc	2.46bc	3.56bc	2.42abc
FARO-44	2.5ab	2.42bc	2.46ab	3.42ab	2.92ab	3.17ab	4.17ab	3.42a
FARO-60	2.45abc	2.42bc	2.42ab	3.42ab	2.75abc	3.08ab	4.17ab	2.83ab
APO	1.50bcd	1.83bcd	1.67bc	2.5bc	1.75cd	2.13c	3.17bcd	1.83bcd
IGBEMO	1.50bcd	1.75bcd	1.63bc	1.50c-f	2.00bc	1.75cd	1.78ed	1.83bcd
IR-64	2.75a	3.58a	3.17a	4.25a	3.25a	3.75a	5.50a	2.83ab
OFADA	0.50de	2.42bc	1.46c	1.75c-f	1.83cd	1.79cd	1.17e	1.83bcd
VANDANA	1.50bcd	1.50cde	1.50c	1.92cde	2.42abc	2.17c	3.17bcd	1.25ed
LSD (p≤0.05)	1.06	1.07	0.74	1.39	1.02	0.82	1.65	1.01
Interaction								
GS x VR	ns	ns	ns	ns	*	*	*	ns
GS= Drought imposition stage, CL = Cultivars, LSD = Least Significant Difference at p≤0.05								

Table 6: Leaf roll response of twelve rice cultivars to water deficit condition at different growth stages

	Weeks after transplanting							
	6				9			
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
Stage of drought imposition (GS)								
Tillering	1.44a	1.78a	1.61a		0.71b	0.71b	0.71b	
Panicle initiation	0.71b	0.71b	0.71b		1.89a	1.74a	1.82a	
Grain filling	0.71b	0.71b	0.71b		0.71b	0.71b	0.71b	
Control	0.71b	0.71b	0.71b		0.71b	0.71b	0.71b	
LSD (p≤0.05)	0.12	0.25	0.19		0.15	0.19	0.15	
Cultivars (CL)								
NERICA-4	0.85a	0.80d	0.82d		0.89a	0.75b	0.82a	
NERICA-5	1.04a	0.88d	0.96cd		0.99a	0.71b	0.85a	
NERICA-7	0.85a	1.07cd	0.96cd		1.00a	0.89ab	0.94a	
NERICA-8	0.84a	0.84d	0.84d		0.87a	0.89ab	0.89a	
FARO-16	0.93a	2.11a	1.52a		0.98a	1.12a	1.05a	
FARO-44	0.99a	1.51bc	1.25abc		0.80a	0.98ab	0.89a	
FARO-60	0.94a	1.76ab	1.35ab		0.75a	1.15a	0.95a	
APO	0.85a	2.01a	1.43a		0.94a	1.15a	1.05a	
IGBEMO	0.90a	1.77ab	1.33ab		0.84a	1.11a	0.96a	
IR-64	0.90a	2.07a	1.49a		1.00a	1.15a	1.07a	
OFADA	0.90a	1.22cd	1.06bcd		0.85a	1.02ab	0.94a	
VANDANA	0.90a	0.88d	0.89d		0.79a	0.85ab	0.82a	
LSD (p≤0.05)	0.33	0.44	0.33		0.26	0.32	0.26	
Interaction								
GS x CL	ns	**	*		*	**	*	

GS= Drought imposition stage, CL = Cultivars, LSD = Least Significant Difference at p≤0.05

Table 7: Leaf drying of twelve upland rice cultivars at different growth stages under water deficit condition

	Weeks after transplanting									
	6			9			12			
	Year 1	Year 2	Mean	Year 1	Year 2	Mean	Year 1	Year 2	Mean	
Stage of drought imposition (GS)										
Tillering	1.57a	1.73a	1.65a	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b
Panicle initiation	0.71b	0.71b	0.71b	1.78a	1.89a	1.84a	0.71b	0.71b	0.71b	0.71b
Grain filling	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b	1.73a	1.85a	1.52a	1.52a
Control	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b	0.71b
LSD (p<0.05)	0.13	0.20	0.17	0.16	0.18	0.17	0.13	0.18	0.17	0.17
Cultivar (CL)										
NERICA-4	0.94abc	1.07b	1.0dc	0.98ab	0.90ab	0.94a	1.04a	0.80d	0.92a	0.92a
NERICA-5	1.04ab	1.13b	1.08bcd	1.25a	0.79b	1.02a	0.90ab	0.10a-d	0.95a	0.95a
NERICA-7	0.84b	1.00b	0.92d	0.89b	0.98ab	0.94a	1.11a	0.94a-d	1.03a	1.03a
NERICA-8	1.04ab	1.04b	1.04bcd	1.08ab	1.08ab	1.08a	0.89ab	0.89bcd	0.89a	0.89a
FARO-16	1.10a	1.81a	1.45a	1.03ab	1.08ab	1.05a	0.93ab	1.12abc	1.02a	1.02a
FARO-44	1.03ab	1.62a	1.32ab	1.13ab	0.94ab	1.04a	0.80b	0.89bcd	0.85a	0.85a
FARO-60	1.00abc	1.89a	1.44a	1.04ab	1.15a	1.09a	0.89ab	1.12abc	1.00a	1.00a
APO	0.98abc	1.86a	1.42a	1.00ab	1.18a	1.09a	1.04a	1.22a	1.13a	1.13a
IGBEMO	0.79b	1.71a	1.25abc	0.94b	1.11a	1.03a	1.08a	1.12abc	1.10a	1.10a
IR-64	0.90abc	1.89a	1.40a	0.94b	1.12a	1.03a	1.04a	1.18ab	1.11a	1.11a
OFADA	0.85b	1.07b	0.96d	0.98ab	1.08ab	1.03a	1.00ab	0.10a-d	0.10a	0.10a
VANDANA	0.89abc	0.98b	0.93d	0.89b	0.10ab	0.94a	0.94ab	0.85cd	0.90a	0.90a
LSD (p<0.05)	0.22	0.34	0.29	0.28	0.31	0.30	0.23	0.31	0.29	0.29
Interaction										
GS x CL	*	**	*	*	**	ns	*	**	ns	ns
GS=	Drought	stage,	CL	Cultivars,	LSD	=	Least	Difference	at	p<0.05
	imposition		=							

Table 8: Yield Components of Twelve Upland Rice Cultivars in Response to Water-stress Condition at Different Growth Stages

Stage of Drought	Number of Panicles			Weight of Panicle (g)			Number of Spikelets/Panicle		
	Season 1		Mean	Season 1		Mean	Season 1		Mean
	Season 1	Season 2	Mean	Season 1	Season 2	Mean	Season 1	Season 2	Mean
Imposition									
Tillering	1.67	1.88b	1.75b	1.93	1.73bc	1.83b	6.36	9.30cb	7.69b
Panicle Initiation	1.86	1.42b	1.63b	2.21	1.34c	1.78b	6.78	7.83c	7.19b
Grain Filling	1.78	1.91b	1.86b	1.76	2.31ab	2.02ab	6.00	12.70b	9.35ab
Control (Irrigated)	1.92	2.67a	2.34a	2.45	2.73a	2.40a	7.67	16.94a	11.75a
LSD (p<0.05)	0.45	0.50	0.33	0.61	0.70	0.46	2.56	3.58	2.37
Cultivars									
NERICA-4	1.58cd	1.5ed	1.54c	2.06a-e	1.32d	1.69b	8.17bc	10.92ab	9.54abc
NERICA-5	1.33d	1.5ed	1.42c	2.78a	1.59bcd	2.18ab	8.53bc	11.33ab	9.96abc
NERICA-7	2.17bc	1.25e	1.71bc	2.71ab	1.46d	2.08ab	5.58dc	8.42b	7.00c
NERICA-8	1.50cd	1.00e	1.50c	1.65cde	0.59dc	1.61b	6.83dc	4.00b	6.83c
FARO-16	1.67cd	2.08bcd	1.88bc	1.43de	2.72ab	2.07ab	6.42dc	12.67ab	9.54abc
FARO-44	1.75bcd	2.83ab	2.29ab	1.70b-e	2.65abc	2.18ab	2.58d	16.75a	9.67abc
FARO-60	1.92bcd	2.00cde	1.96bc	2.40a-d	3.29a	2.84a	4.92dc	11.42ab	8.17bc
APO	1.25d	2.00cde	1.63c	1.01e	2.00bcd	1.51b	2.67d	11.50ab	7.08c
IGBEMO	1.33d	1.67ed	1.50c	2.07a-e	1.67bcd	1.87b	3.67d	11.92ab	7.79bc
IR-64	1.75bcd	2.50abc	2.71a	2.57abc	2.31a-d	2.55ab	11.50ab	15.12a	13.30a
OFADA	1.42cd	1.42ed	1.42c	2.02a-e	1.54dc	1.78b	5.75dc	7.42b	6.58c
VANDANA	3.25a	2.92a	2.88a	1.78a-e	1.75bcd	1.76b	13.75a	11.17ab	12.46ab
LSD (p<0.05)	0.78	0.82	0.58	1.05	1.16	0.80	4.42	5.94	4.11
Interaction									
GS x CUL	ns	*	ns	ns	*	*	*	*	ns

LSD = Least Significant Difference at p<0.05. Values with similar letters on the same column are not significantly different at p>0.05 of LSD, * Significant, ns= not significant, CUL= Cultivars, GS= Growth stages.

Table 9: Yield and Yield Components of Twelve Upland Rice Cultivars in Response to Water-stress Condition at Different Growth Stages

Stage of Drought Imposition	Weight of Filled Grain /Plant (g)			Weight of Unfilled Grain /Plant (g)			Weight of Grain /Plant (g)			Weight of 100 Seeds/Plant (g)		
	Season n1	Season 2	Mean	Season 1	Season 2	Mean	Season 1	Season n2	Mean	Season 1	Season 2	Mean
LSD (ps0.05)	0.57	0.66	0.45	0.52	0.31	0.32	0.82	0.92	0.64	0.33	0.57	0.64
Cultivars												
NERICA-4	2.62b	1.78ab	2.11cb	0.92abc	0.21cd	0.56cd	3.20bc	1.88ab	2.55bcd	1.38bc	1.29abc	1.34ab
NERICA-5	2.67b	1.92ab	2.29b	1.30abc	0.32cd	0.81bcd	3.58b	1.77b	2.68bc	1.60b	1.20abc	1.13bcd
NERICA-7	1.23cd	1.55ab	1.39cd	1.67abc	0.23cd	0.70bcd	2.28b-e	1.76b	2.02bcd	0.85cde	1.03abc	0.94b-e
NERICA-8	1.48c	0.70b	1.48b-e	1.23abc	0.85ab	1.23ab	1.00e	2.40ab	2.68bc	1.04bcd	0.40c	1.04b-e
FARO-16	0.65cd	1.59ab	1.21de	1.67abc	0.65bc	0.91bcd	1.78de	2.24ab	2.01bcd	0.56de	0.66abc	0.48de
FARO-44	0.68cd	1.63ab	1.16de	1.27abc	0.83ab	1.05bc	1.95cde	2.45ab	2.00bcd	0.47de	0.60bc	0.53de
FARO-60	0.70cd	1.28ab	0.99de	1.51ab	0.59bcd	1.05bc	2.21c-e	1.88ab	2.04bcd	0.5de	0.38c	0.44e
APO	0.67d	0.83b	0.65e	0.98abc	0.83b	0.90bcd	1.44e	1.66b	1.55d	0.33e	1.38ab	0.85b-e
IGBEMO	0.58cd	1.95ab	1.11ed	0.85bc	0.46bcd	0.65bcd	1.18e	2.21ab	1.69cd	0.36e	1.07abc	0.71b-e
IR-64	0.48c	0.65b	1.56bc	2.76a	2.58a	1.67a	2.91bcd	2.77ab	2.84ab	0.64de	0.39c	0.65cde
OFADA	1.42cd	1.32b	1.37cd	0.66bc	0.26cd	0.46cd	1.99cde	3.38a	2.68bc	1.01cd	1.58a	1.29abc
VANDANA	4.88a	2.53a	3.71a	0.53c	0.13d	0.33d	5.33a	2.53ab	3.93a	2.58a	1.11abc	1.85a
LSD (ps0.05)	0.89	1.10	0.77	0.91	0.51	0.56	1.36	1.54	1.11	0.58	0.94	0.56
Interaction												
GS x CUL	*	*	*	*	ns	*	*	*	*	*	ns	ns

LSD = Least Significant Difference at ps0.05. Values with similar letters on the same column are not significantly different at p>0.05 of LSD. * Significant, ns= not significant, CUL= Cultivars, GS= Growth stages

Table 10: Root Parameters of Twelve Upland Rice Cultivars in Response to Water-stress Condition at Different Growth Stages

Stage of Drought Imposition	Root Length/Plant (cm)			Number of Roots/Plant		
	Year 1	Year 2	Mean	Year 1	Year 2	Mean
Tillering	26.78	35.06	30.92	36.06	35.36	34.83
Panicle Initiation	25.51	36.17	30.84	36.47	39.06	37.68
Grain Filling	25.95	34.93	30.44	35.69	39.88	37.50
Control (Irrigated)	24.08	35.78	29.93	34.14	41.39	36.96
LSD ($p\leq0.05$)	4.23	4.17	3.23	7.87	6.28	4.94
	ns	ns	ns	ns	Ns	ns
Cultivars						
NERICA-4	27.43	36.02a	31.72a	30.25c-e	23.33f	26.79f
NERICA-5	25.41	39.05a	32.23a	36.75a-e	35.00c-e	35.88c-f
NERICA-7	25.42	37.07a	31.24a	33.17b-e	29.75d-f	31.46d-f
NERICA-8	24.64	33.40a	24.64b	26.58de	22.34f	26.53f
FARO-16	20.87	28.28b	24.57b	36.92a-e	46.75ab	41.83a-c
FARO-44	27.30	33.04ab	30.17ab	39.50a-d	42.50bc	41.00a-d
FARO-60	27.90	37.97a	32.93a	47.50a	53.92a	50.71a
APO	27.73	35.06ab	31.39a	42.08a-c	39.92b-d	41.00a-d
IGBEMO	25.90	36.85a	31.38a	34.67a-e	45abc	39.83b-e
IR-64	25.86	34.83ab	30.35ab	46.67ab	45.83ab	46.25ab
OFADA	23.56	39.44a	31.50a	24.25e	37.17b-e	30.71ef
VANDANA	24.93	32.60ab	28.81ab	28.75c-e	29.00ef	28.88f
LSD ($p\leq0.05$)	7.33	6.92	5.60	13.63	10.41	8.55
Interaction						
GS x CUL	*	*	*	*	*	*

LSD = Least Significant Difference at $p\leq0.05$. Values with similar letters on the same column are not significantly different at $p>0.05$ of LSD, * Significant, ns= not significant, CUL= Cultivars, GS= Growth stages.

Table 11: Dry matter accumulation by upland rice cultivars at different growth stages under water deficit condition

	Dry root weight (g)			Dry shoot (g)			Total biomass weight (g)		
	Year 1	Year 2	Mean	Year 1	Year 2	Mean	Year 1	Year 2	Mean
Stage of drought imposition (GS)									
Tillering	1.09a	1.98a	1.46a	4.68a	3.89a	4.29a	5.84a	5.70b	5.84a
Panicle initiation	1.15a	1.82a	1.45a	4.63a	3.88a	4.26a	5.90a	5.13b	5.36a
Grain filling	1.10a	2.14a	1.56a	5.01a	4.31a	4.62a	5.94a	6.21ab	5.99a
Control	1.08a	2.32a	1.62a	4.29a	4.50a	4.28a	5.53a	7.80a	6.43a
LSD ($p \leq 0.05$)	0.42	0.62	0.40	1.46	1.17	0.92	1.75	2.02	1.28
Cultivars (CL)									
NERICA-4	0.61c	0.90de	0.75b	2.43e	1.78d	2.10d	3.23de	2.56d	2.89d
NERICA-5	1.13bc	1.83dc	1.48a	4.00b-e	2.69dc	3.34cd	4.88c-e	6.41bcd	4.65cd
NERICA-7	1.87a	1.87dc	1.87a	6.28ab	3.53bcd	4.90abc	8.12ab	7.43ab	7.77ab
NERICA-8	0.57c	1.84dc	0.57b	2.58e	3.46bcd	2.58d	3.15e	2.54d	3.15d
FARO-16	1.08bc	2.98ab	2.03a	4.84a-e	5.46ab	5.15ab	6.10a-e	8.06a	7.08abc
FARO-44	1.08bc	2.39abc	1.74a	5.18a-d	5.82a	5.50ab	6.26a-d	8.26a	7.26ab
FARO-60	1.56ab	2.96ab	2.26a	6.89a	5.83a	6.33a	8.98a	9.13a	9.05a
APO	1.48ab	1.62cde	1.55a	6.28ab	4.59abc	5.44ab	8.23ab	5.95abc	7.08abc
IGBEMO	1.23abc	2.06bc	1.65a	5.16a-d	4.78abc	4.67abc	5.81b-e	6.40ab	6.10bc
IR-64	1.43ab	2.06bc	1.75a	5.80abc	4.68ab	5.23ab	6.95a-c	6.83ab	6.89abc
OFADA	0.63c	3.37a	2.00a	3.10ed	4.51abc	3.80bcd	4.05c-e	6.56ab	5.30bcd
VANDANA	0.58c	0.67e	0.63b	3.31cde	1.73d	2.52d	3.88de	2.74cd	3.31d
LSD ($p \leq 0.05$)	0.72	1.02	0.69	2.53	1.94	1.59	3.03	3.35	2.22
Interaction									
GS x CL	ns	*	ns	*	*	*	*	ns	*

GS= Drought imposition stage, CL = Cultivars, LSD = Least Significant Difference at $p \leq 0.05$

The number of panicles and spikelets per panicle were not significantly influenced by interaction between

growth stages when drought was imposed and upland rice cultivars. However, weight of panicle of different upland rice cultivars was significantly influenced by

growth stage at which drought was imposed (Table 8).

Filled grain, unfilled grain and grain weight of the different rice cultivars differed significantly in response to water limiting conditions (Table 9). Plants that were well watered (Control) had highest weight of filled grains (3.32 g) which was significantly higher than weight of filled grains obtained from plants subjected to drought at tillering, panicle initiation and grain filling stages. Similarly, well watered plants had lowest weight of unfilled grains (0.08 g) relative to plants subjected to drought at different growth stages. Highest weight of grains and 100 seeds was recorded in plants that were well watered compared to plants subjected to water-stress at different growth stages.

VANDANA had the highest weight of filled grain (3.71 g) which was statistically higher than other cultivars. Cultivar, IR-64 cultivar had highest weight of unfilled grain (1.67 g) which was significantly different from other cultivars but not significantly different from NERICA-8. VANDANA had the highest weight of grain (3.93 g) which was significantly similar to weight of grain recorded in IR-64. Similarly, weight of 100 seeds (1.85 g) was significantly higher in VANDANA than in any other cultivar.

The interaction between different upland rice cultivars and growth stages when drought was imposed had significant effect on all the yield components such as weight of filled grain, unfilled grain weight. However water-stress had no significant effect on weight of 100 seeds as indicated in Table 9.

Effect of Water-stress on Root Parameters of Upland Rice Cultivars at Different Growth Stages

The length and number of roots of upland rice cultivars were not significantly influenced by drought imposed at different growth stages. However, among the cultivars, FARO-60 had the highest number of secondary roots (32.93) and main root length (50.71 cm), while FARO-16 recorded the lowest roots length (24.57 cm) and lowest number of roots was recorded in NERICA- 8 cultivar (26.53).

The interaction between growth stages when drought was imposed and different cultivars had significant influence on length and numbers of roots of upland rice

cultivars (Table 10).

Dry Matter Accumulation by Upland Rice Cultivars Water-stress at Different Growth Stages

There was no variation in dry matter partitioning into shoot or root of upland rice cultivars exposed to water deficit condition at different growth stages. However, accumulation and partitioning of dry matter into shoot and root of different upland rice cultivars were significantly influenced by drought condition. NERICA-8, NERICA-4 and VANDANA had comparable weight of dry roots and shoot but these were significantly lower than dry matter into accumulated by shoot and root of the other cultivars (Table 11). Weight of shoot (6.33 g) and total biomass (9.05 g) of FARO-60 were significantly higher than that of NERICA-8, NERICA-4, OFADA, NERICA-5 and VANDANA.

The interaction between growth stages when drought was imposed and different upland cultivars had significant influence on dry matter accumulation into shoot and total biomass except weight of dry root which was not significantly influenced by interaction as presented in (Table 11).

DISCUSSION

Obviously, occurrence of water deficit condition at various growth stages adversely affected morphological development and yield of rice plant. However, the duration of stress, the stage of plant growth and development at which the plant was exposed to drought and severity contributed to plant response to abiotic stress. Similar reports by Salam *et al.* (2001) showed that rice is highly susceptible to drought across growth stages. In our study, majority of the cultivars were susceptible to drought as implicated by poor growth performance at tillering and panicle initiation as well as reduced yield at grain filling. This is in consonance with the report of Singh *et al.* (2012) on wheat and Adejumo *et al.* (2018) on okra.

The better growth performance displayed by the following cultivars APO, OFADA, NERICA-7, FARO-44, FARO-60 and IR-64 in terms of plant height, number of leaves, leaf area and tiller formation suggests these cultivars may have the potential to tolerate drought irrespective of the growth stages. These cultivars should

therefore be considered for further breeding program. Bouman and Toungh (2001) reported that different cultivars might have different responses to the same drought stress, timing and intensity. It is therefore pertinent to consider water economy and its use efficiency by different rice cultivars in order to improve rice production in rice growing ecologies. Similar view had been shared by Datta *et al.* (2017) on the need to integrate rice biology with water economy, while considering rice designing program.

The stage of plant growth and development at which rice plant was exposed to drought contributed greatly to the observed effects. Drought affected morphological development at tillering, while grain formation was adversely affected when moisture stress was imposed at panicle initiation. Yield was greatly reduced when drought occurred at grain filling. The variation in response attested to the fact that water plays different roles in plant at varying stages of growth. Hence water deficit at any of the stage, will spell doom for the metabolic pathways responsible for the expected physiological characteristics. This could be attributed to plant metabolic activities, at the stage of active reproductive development, that are highly sensitive to changes in environmental factors more than at the vegetative stage (Saikumar *et al.*, 2016). Water deficit at these stages might have interfered with metabolic activities involved in these key processes necessary for plant development (Samarah, 2005; Adejumo *et al.*, 2018). Our view agrees with that of Sah *et al.* (2020) on impact of drought at pre-flowering and grain filling stages in maize growth and yield. Moisture deficit at panicle initiation was more critical with damaging effects on yield of the crops. It was observed that rice showed appreciable level of tolerance to water shortage at grain filling stage than when imposed at tillering and panicle initiation stages. This observation contradicts the report of Sah *et al.* (2020) who reported that water deficit affected maize similarly at all phenological stages.

Number of tillers reduced greatly, especially at tillering and panicle initiation stages relative to the well-watered plants and drought imposition at grain filling stage. Drought occurrence at the vegetative phase of rice plant may lead to reduced tiller (Sikuku *et al.*, 2010)

as well as the number of leaves which is less detrimental to assimilate partitioning compared to water shortage at both anthesis and post anthesis (Hanum, 2017). Similarly the high number of tillers that was more in plants subjected to water deficit condition at grain filling phase than the control plants suggests that rice plant was more tolerant to water deficit at grain filling stage than other growth phases. Rahman *et al.* (2002) reported similar experience that tiller numbers of rice plant was reduced tremendously under moisture deficit condition at different growth stages. When water shortage occurs at the tillering stage, the cell division and expansion processes are impaired resulting in poor growth and development according to Dada *et al.* (2018) and Wicaksono *et al.* (2022). The high number of tillers and leaves displayed by IR-64 cultivars, a susceptible cultivar shows that the cultivar has potential for early growth or may display those attribute in response to moisture stress as an escape mechanism. Mattioli *et al.* (2020) and Wicaksono *et al.* (2022) reported that plant may accelerate completion of their life cycle under water stress situation. The ability of the plant under drought to maintain internal water content is crucial for plant survival. These help in maintaining cell turgor by conserving the internal water content and scavenging reactive oxygen species (ROS) produced in response to environmental challenge as opined by Mattioli *et al.* (2020).

Main root number and length were higher in plants under water stress at tillering and panicle initiation phases than those subjected to water deficit condition at grain filling. This implies that moisture stress was more severe at these phases as proliferation of root mass indicates massive production of roots necessary for scavenging for moisture within the rhizosphere. The massive root production may encourage quick recovery after the drought imposition. Similarly, production of long and numerous roots by FARO-60 and IR-64 suggests that the cultivars were highly susceptible to water deficit condition and hence develop numerous roots as a drought adaptation strategy to survive the harsh environmental condition. This is similar to the findings of Salam (2001) on rice genotypes and Morales *et al.* (2013) on raspberry. High root numbers under water

deficit condition has been reported to enhance nutrient uptake better than plants with poorly developed roots (Blum, 1996; Barnabas *et al.*, 2008).

Dry matter accumulation was reduced by moisture stress mostly at tillering and panicle initiation stage possibly due to impaired nutrient uptake, which limits photosynthate formation and partitioning into biological and economic yield. The observed increased partitioning of dry matter into root is an indication of drought avoidance in a bid to maximize uptake of available water (Barnabas *et al.*, 2008). Also water stress at tillering effectively reduced total biomass; this may be due to decrease in photosynthesis rate and dry matter accumulation. However, high dry matter was partitioned in FARO'S cultivars than any other cultivars.

Among the cultivars, VANDANA was more prolific with huge grain yield. This suggests that the cultivar is likely to be tolerant to moisture stress, while IR-64 and APO had lowest grain yield suggests the likelihood of these cultivars susceptibility to drought. The differences in grain yield may be directly linked to the recovery rate after stress imposition at different stages. Recovery from water stress is a function of growth stage and severity of the stress (Kato *et al.* 2007). However, panicle number and grain yield was reduced drastically at panicle initiation stage compare to other growth phases. Drought has been found to reduce yield in upland rice field up to 50% according to Dada *et al.* (2018). Cereal crops showed similar response to drought at all phases but became more intense or severe at grain filling stage (Barnabas *et al.*, 2008).

Plants respond to drought at physiological stages and this is indicated by alteration in morphological responses such as leaf rolling, dry tips and dead heart. This could be the possible reasons why upland rice cultivars that were subjected to drought stress at panicle initiation period had the highest leaf roll and dry score all through the growth period. Alteration of leaf morphology under drought included the direct effect on photosynthetically active radiation and net photosynthetic rate (Syuhada and Jahan, 2016; Khairi *et al.*, 2016). Similarly among the various cultivars used for the study, cultivar IR-64 had highest leaf rolling and drying score which suggests that the cultivar was highly

susceptible to drought stress and this study is in line with previous research carried out by Bouman and Toung (2001) who reported that different cultivars might have different responses to the same drought stress, timing and intensity.

CONCLUSION

Oryza species is more sensitive to water deficit condition at tillering and panicle initiation growth stages than at grain filling phase. Drought at panicle initiation stage reduced grain yield than at tillering phase in rice cultivars. Also VANDANA cultivar had the yield performance compared to other cultivars. The studies conclude that moisture deficit condition should be avoided at the critical growing period like panicle initiation as irrigation schedule should be incorporated into rice growing system.

CONFLICTS OF INTEREST

The authors declare that they have no potential conflicts of interest.

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