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Growth Physiology of Local Rice Varieties under Moisture Stress Condition

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Authors' contributions

This work was carried out in collaboration between both authors. Author ZAA designed the study, performed the statistical analysis and wrote the protocol. Author KD wrote the first draft of the manuscript. Authors ZAA and KD managed the analyses of the study. Author KD managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

A well-established limiting factor for the survival of plant under normal growth and developmental stages is water stress. Several living (Biotic) and nonliving (abiotic) factors unfavorably affect rice growth and as well yield, and this is connected with the adverse and intense effect of water (Adejare and Unebesse, 2008). In view of this, the present study was carried out during the dry season, between the month of March to April, 2017 which aimed at determining how moisture stress affect the growth physiology of our locally grown rice varieties and to determine the rice variety with drought resistant mechanism between three (3) different local rice varieties: Mai Zabuwa, Maza haji, B.G doguwa. The plant samples were obtained from local farmers from the main city market, a control variety of upland drought resistant rice variety was used as a control (Nerica). There were three different treatments namely, W1 (control-well watered), W2 (mildly watered) and W3 (stressed). A total of 36 pots with a combination of three (3) replications for each treatment including control were been put up for the experiment. The studies revealed that drought adaptation mechanism have shown to be noticeably observed in the Mai Zabuwa variety whereas B.G doguwa and Maza haji performed poorly under drought treatment. Mai Zabuwa, suggestively is observed to have behaved as a drought resistant variety as compared to Nerica.

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1. INTRODUCTION

The most populous continent having the largest number of human population has been seen to be the widely consumer of the cereal crop, rice. Having ranked the 3rd highest produced crop worldwide, rice as an agricultural commodity tops crops like sugarcane and maize, according to FAOSTAT, 2013 data. Not only for human consumption, rice is grown for other agricultural purposes, though rice is seen to be the most highly nutritive grain containing required amounts of calories (having to provide about 1/5 of required calories) and adequate nutritive contents for human [1].

A majority of the whole tissue is composed of water which adequately serves as an essential medium for movement of substances and nutrients within the plant system, it is involved in chemical reactions and it plays an important role in controlling soil-plant water potentials/efficiency by increasing turgor pressure [2]. Water stress results in altering with the physiological processes of growth and at the end, the plant dies. The resultant effect of moisture due to stress within the plant depends on the variety, length and period duration of the stress caused and the stage of growth of the rice plant [3].

Irrigation in agriculture supports plant growth, the growing levels of urbanization demanding fresh water for use in industries, recreation and leisure had cause a serious decrease in available fresh water needed to supplement irrigation [4,5]. A serious threat to plant productivity is water scarcity, as the severity and duration of the drought might cause losses in yield exceeding loses from all other causes [6].

The two-major water stress causative agents are both soil and the atmosphere which account for high decrease in plant productivity worldwide when limiting to plants. Moisture stress negatively decreases the growth and development of the rice plant which is needed for plant survival productivity and it depends on the variety, length and period duration of the stress caused and the stage of growth of the rice plant [3]. Rice yield was observed to decline in the presence of water stress at a stage of growth, called the moisture sensitive periods. These sensitive periods in which the rice plant gets affected by the stress are during flowering and head development. In [7], Philippines an experiment was conducted where it was observed and reported that moisture stress at the premature stage of growth of the rice alters with tillering, which in turn reduces yield. As the stress extends to the reproductive phase, yield loss became significant [8].

The significance of the study cannot be over emphasized, especially looking at the negative effect posed on us by climate change which is stimulated by global warming in this 21st century. This menace has severely affected our season (rainy and dry) in the sense that the amount of rainfall has drastically reduced as result, our local rice varieties cannot yield very well, it is therefore a matter of concern and urgency that a research be carried out as to asses and authenticate the severity of drought on the composition of the local rice varieties and to eventually come up with a feasible antidote to meet up the fast-growing population in the country.

The research aimed to provide an exhaustive information on how water stress affects the growth physiology of local rice varieties by determining the rice variety with resistance mechanism to obtain better performance under stress condition in future.

1.1 Varieties of the Rice Plant

Information from reliable sources has it that, there are about 40,000 to 80,000 rice varieties consisting of local ancient varieties, semi-dwarf varieties, and hybrids from crosses. Through the years, ancient rice varieties have changed from been tall and slender with dropping leaves, subtle and insensitive to photoperiod, high grain dormancy, resistance to waterlogging and greater positive response to nitrogen fertilizers. These local varieties, through the years have been collected, assembled, regenerated, and distributed by both private and public institutions such as the IRRI [9,10,11] and the USDA-ARS (United States Department of Agriculture-Agricultural Research Stations) Small Grains Lab. Public breeding programs have now developed newer conventional varieties adapted to shortened growing seasons, tolerant to various a-biotic conditions such as salinity, acidic or alkaline soils, water scarcity (drought), water logging (deep water or flooded soils), variable ambient temperatures, and biotic stress conditions due to disease or insects. Improved hybrid rice varieties developed by the private and public breeding programs have been on the increase as breeders sought to in the shortest period match the best traits of two parents as well as increase yields to meet up with the consumer demands. Examples are of the improved nutritional content of rice by added genes to increase nutrients such as pro-vitamin A (such as in the GMO Golden Rice program), to increase iron content, and phytic acid. The incorporation of other traits such as higher yield and tolerance to harsh environment was the generation of successful crossing of the two species of cultivated rice which are the African rice (*Oryza glaberrima* steud) and the Asian rice (*Oryza sativa*) to produce progeny known as interspecific that combine the traits of both parents. The interspecific progeny were dubbed new rice for Africa (NERICA) and name trademarked two years later [12].

1.2 Rice Production and Consumption

The International Rice Research Institute (IRRI) studied the food problem in relation to world population, and they predict that 800 million tons of rice will be required in 2025 [13].

For 52 years now, rice production worldwide is in the increment from the year 1965 to 2017.

In Nigeria, for instance rice production has escalated from 5.8 million tonnes in the year 2017 [14]. “The boost in consumption rate now is reported to be 7.9 million tonnes’’ [14].

The Global rice production statistics show that the top five importers of Nigeria are the USA, Vietnam, India, Thailand, and Brazil. These countries help Nigeria to overcome the shortfall of over 4.3 million metric tons. This shortfall is valued over N365 billion. This great sum of money is needed to meet Nigerian demand of over 7 million metric tons (Fig. 1). Although, one of the large importers of rice is China yet it is not amongst the large importers of rice. FAO has reported China to have imported about 0.6 million tonnes of rice ranking it as the 18th largest importer in the year, 2011. Which is a mere 0.3% of its national rice output.

Indonesia, Nigeria and Bangladesh with 2.8 million tonnes, 2.2 million tonnes and 1.3 million tonnes makes them the top largest importers of rice in the world respectively. Whereas, Thailand (10.7 million tonnes), Vietnam (7.1 million tonnes) and India (5.0 million tonnes) are the

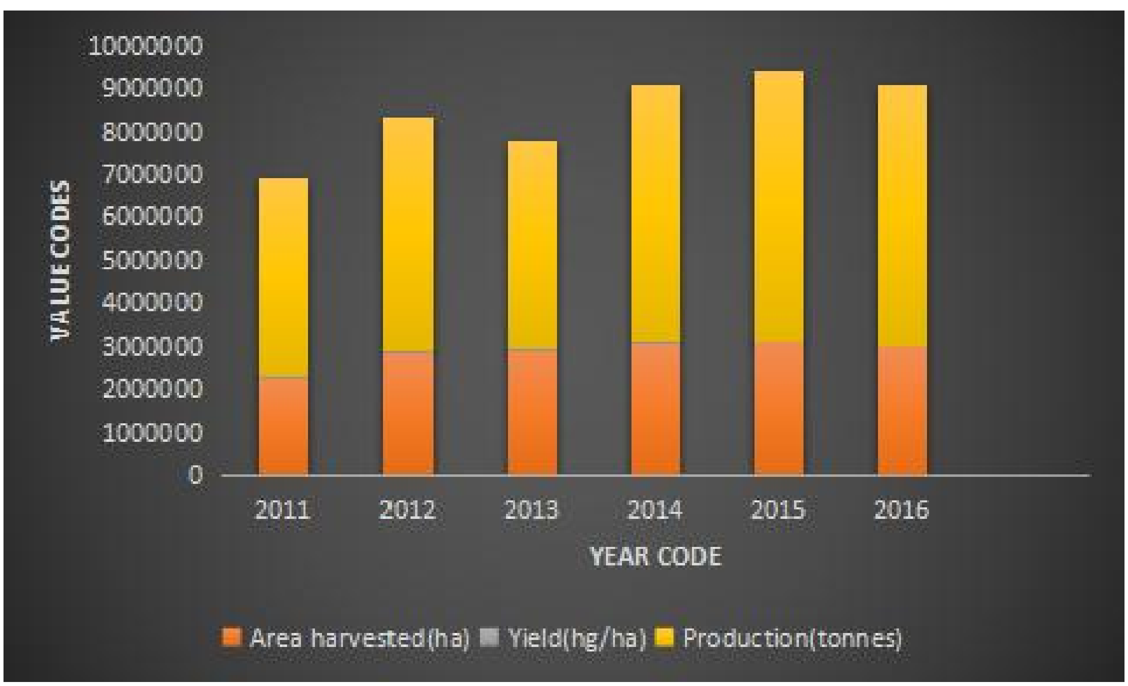


Fig. 1. Nigeria paddy rice agronomic index from 2011 to 2016
(Source: FAOSTAT, 2015)

World's top three exporters– collectively comparable to about 11% of China's yearly rice production [1].

1.3 Rice Morphology Based on Water Scarcity Resistance

In plants, a better criterion for understanding the fundamentals behind morpho-anatomical and physiological basis of variations in water scarcity resistance could be utilised to hand-pick or generate newer varieties of crops with better yield under drought conditions. Plants react differently in relation to various structural stages liable upon the degree of intensity and period of stress as well as plant species and growing stage [15,16]. However, in this regard some genotypes showed better adaptation to the stress than the others. Shoot dry weight was observed to be affected by mild water stress, while in another scenario under severe water stress, shoot dry weight loss was greater than root dry weight loss in sugar beet genotypes [17]. Biomass was seen to be reduced in water stressed soya bean [18].

An adaptation to various drought conditions by plants depends on the physiological and biochemical changes.

Plants physiological response to drought is a highly complex mechanism which involves harmful and/or adaptive changes. This complexity depends on some factors such as the plant species and variety, the changing aspects, period and severity water depleted soils, change in atmospheric water demand, environmental conditions, and equally morphological growth and the phenological condition in which water deficit developed [19].

2. MATERIALS AND METHODOLOGY

2.1 Plant Samples

The plant samples were obtained from local farmers in Gombe main market, Gombe State and a control variety of upland drought resistant rice variety was used as a control (Nerica). The varieties include; B.G. Doguwa, Maza haji, Mai Zabuwa. All plants were subjected to stressed, mild and controlled water treatments as designed in the experimental setup.

2.2 Experimental Site and Set-up

Pot experiment were conducted in dry season from March to April at the University Botanic garden. Three (3) different local rice varieties and Nerica (Control) were used in this experiment. There were a total number of 36 pots with a combination of 3 replications for each treatment including control. The experiment was conducted in pots. Three different water treatment, namely W1 (continuous watering everyday) W2 water given every 2 days and W3 water given after every 3 days. For comparison a well-watered controlled treatment was given water everyday as control or check.

2.3 Soil Mixture/ Poly Pots Arrangement and Planting

Top soil and river sand were mixed in the ratio of 8:2; the purpose of the river sand is to allow easy water percolation and to reduce the rate of water logging. The soil mixture was filled into a poly pots for continuous watering for 3-5 days to make ready for planting. Three poly pots were used for every replication for all the treatment. Four seeds were sown in each poly pots, 2 seeds per hole. After germination the young seedlings were watered using 50 ml beaker based on the scheduled treatment i.e. the control, mild and severe. The seedlings were thinned out to reduce competition. Two (2) seedlings were left out in each pot.

2.4 Experimental Design

Each pot was filled with soil mixture leaving 3 cm at the top to facilitate water treatment. The mixture contained loamy soil, organic and river sand in the ratio 8:2. Seeds were also tested for viability before planting. Viability varies indirectly when the rice floats. Weeding of unwanted grasses and weeds was done manually using hand until harvest.

The experiment was terminated at six weeks after sowing for further post-harvest measurements.

2.5 Data Collection

At two (2) weeks after germination, all plants were subjected to measurements of growth characters, such as plant height (cm) and number of tillers/leaves. For six (6) weeks, at harvest the plants were harvested and root lengths (cm), root to shoot ratios and plant biomass (g) were taken.

2.5.1 Measurement of growth characteristics

At two weeks after planting, all the thirty-six plants in every replication were selected for the measurement of growth characteristics at 2, 3, 4, 5 and 6weeks after planting respectively.

2.5.1.1 Plant height (cm)

This was taken as the height of the rice plant measured to the nearest centimeter from the base to top at 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} weeks after planting. The mean heights from the thirty-six plants were measured from longest leaf tip to the stem base.

2.5.1.2 Root length (cm)

The length of the roots was also measured after harvest from the longest root tip to the stem base.

2.5.1.3 Biomass (dry matter) yield per plant (g)

The plant vegetative parts at harvest were carefully removed and washed off to remove soil in the roots. Biomass was determined by harvesting the whole plant including the leaf, root and stem materials at five (5) and six (6) weeks after planting and drying in the autoclave for one week after harvesting.

2.5.1.4 Root: Shoot ratio

The ratio of the length of the shoot and roots were compared.

Data that were collected were statistically analyzed using the analysis of variance (ANOVA). Computer software used was Minitab(c) V. 17 (State College PA). A probability value of 0.05 was used as bench mark for significant differences between parameters.

3. RESULTS

From observations made during the experiment, plant heights (cm) were noticed to be relatively higher under all treatments for Mai Zabuwa and Nerica (Control) followed by B.G Doguwa compared to Maza haji been the lowest (Fig. 2).

Root length (cm) observed for the variety, Mai Zabuwa under the three treatments showed to be higher compared to the other two local varieties. Whereas, Nerica was next in plant growth or same at times with Mai Zabuwa for all the treatments and as well under the control condition (Fig. 3).

The variety, Mai Zabuwa in the below root length interaction plot has shown a relational interaction effect as a result of the control and mild stress treatments but not for the severe stress treatment where root length under the control and severe stressed treatments were reduced than under the mild stressed treatment (Fig. 4).

Table 1 shows the mean and standard deviation for all the measured parameters which were observed to be significantly different with their p-value (< 0.01) under the three treatment conditions for the plant height from week 4 to week 6 (this is exclusive of plant heights(cm) for weeks one (1) to three (3) because no variation was observed for the parameters measured during these experimental periods) whereas root length (cm), biomass (g) and root to shoot ratio shown no significantly different.

Table 1. Table showing means ± Standard deviation of all parameters for all the treatments of control, mild drought and severe drought from week 4 till week 6 of harvest

Parameters	Treatments			P values
	Control	Mild	Severe	
Plant height (cm) week 4	29.9^a ±3.35	25.8^a ±4.51	19.4^b±4.72	<0.001
Plant height (cm) week 5	33.16^a± 3.43	28.79^b ± 3.91	21.8 ^{c}±5.06	<0.001
Plant height (cm) week 6	42.51^a± 6.11	38.27^a± 2.76	30.41^b± 5.37	<0.001
Root length (cm)	30.69^a±3.01	28.78^a±1.64	23.95^b±1.20	0.004
Biomass (g)	2.19^a±0.35	1.32^b±0.47	0.75^b±0.24	<0.001
Root to shoot ratios	0.27^a±0.09	0.41^b±0.17	1.03^b±1.00	0.008

** Means that do not share a letter are significantly different*

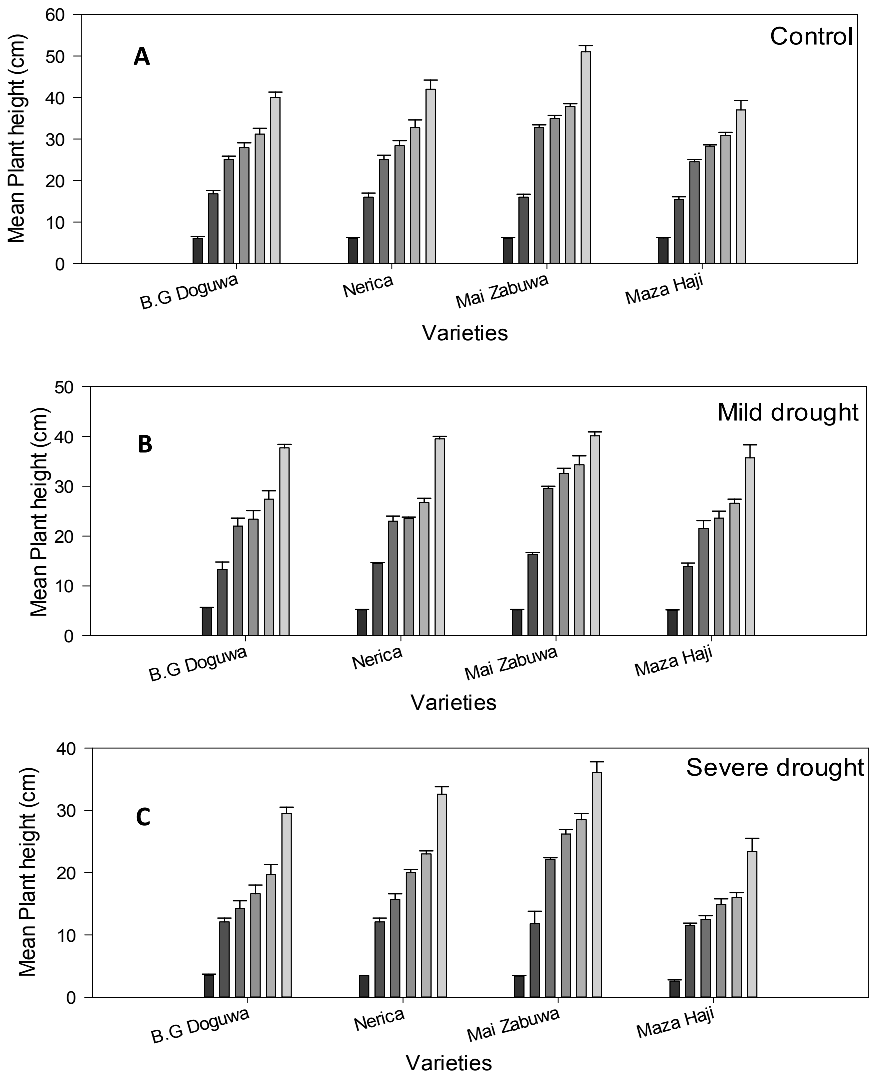


Fig. 2. Chart showing mean of plant height(cm) for all varieties including control under the three (3) different water stress treatments (A-Control, B-Mild stress and C-Severe stress) from week 1 (germination) to week 6 (harvest)

From the table below, the varieties plant heights at weeks 4, 5 and week 6 showed significant differences between the plant varieties and their p-values are 0.002, 0.007 and 0.01 respectively. Whereas root length (cm), biomass (g) and root to shoot ratios showed no significant differences for all the varieties (Table 2).

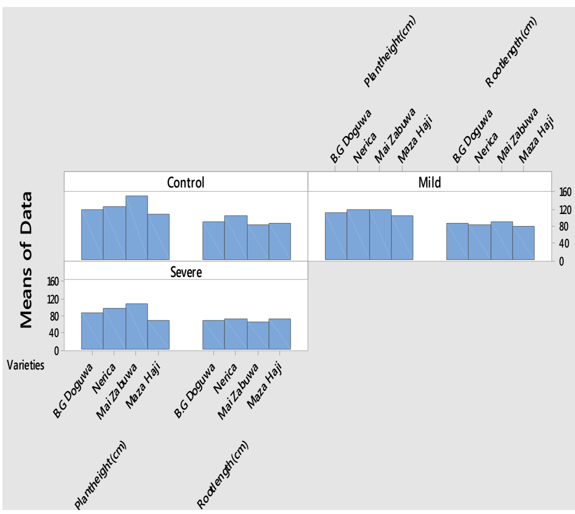
4. DISCUSSION

According to the experiment conducted, mean of plant height (cm) for all the varieties including control under the three different treatment for week one (germination) to weeks six (harvest), showed the plants growing at uniform height in all the treatment for week one to three, though, there was no variation between the plant height. This was consistent with the works of [20], who show rice responding to drought as expressed by leaves, shoot and root was due to the period when the plants were exposed to the stress during plant growth. The plants started showing differences in height at weeks four to six in all the treatment with Mai Zabuwa having the highest height followed by Nerica, BG Doguwa and Maza haji. Plant height (cm) of rice varieties along-side root-length (cm) at weeks six under the control for Mai Zabuwa

Table 2. Table showing means ± Standard deviation of all the varieties for the vegetative and harvest parameters measured during the experimental period

Parameters	Varieties				P values
	Nerica	BG Doguwa	Mai Zabuwa	Maza Haji	
Plant height (cm) week 4	24.01^{b}±3.83	22.64^{b}±5.41	31.24^{a}±4.15	22.27^{b}±6.10	0.002
Plant height (cm) week 5	27.49^{ab}±4.65	26.14^{b}±5.58	33.56^{a}±4.46	24.49±6.76	0.007
Plant height (cm) week 6	38.02^{ab}±4.78	35.74^{ab}±5.01	42.42^{a}±6.99	32.07^{b}±7.38	0.010
Root length (cm)	29.26^{a}±5.31	27.88^{a}±5.42	26.89^{a}±4.50	27.21^{a}±4.71	0.757
Biomass (g)	1.28^{a}±0.73	1.62^{a}±0.90	1.70^{a}±0.85	1.07^{a}±0.79	0.352
Root to shoot ratio	0.42^{a}±0.28	0.53^{a}±0.49	0.37^{a}±0.14	0.94^{a}±1.16	0.254

** Means that do not share a letter are significantly different*



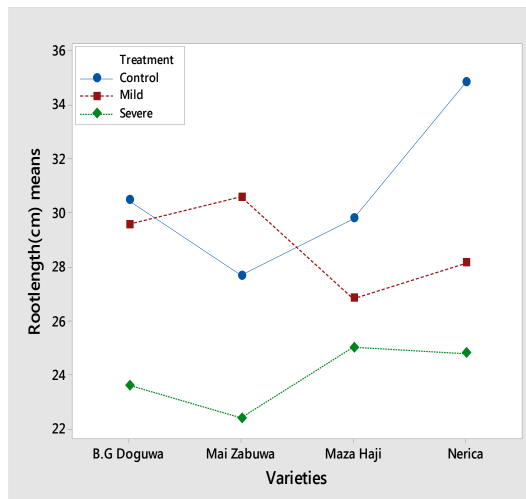


Fig. 3. Bar charts showing plant heights (cm) of rice varieties alongside root lengths (cm) at week 6 of harvest and Fig. 4. Interaction plots of root lengths (cm) showing relationship between the varieties under the three (3) different treatments

has the highest shoot height compared to all varieties and Nerica has the highest root length compared to all the varieties, indicating the ability of Nerica root to have the mechanism of storing much water and giving less to the shoot for growth and storing much water against future drought. This could imply that Nerica have mechanism for drought avoidance which is in accordance with [21], who showed that the penetration and width of the root as well as the mechanism of efficient water use, has a major impact in the plant physiology evading water stress. The root is trying to be saturated with water because there is the availability of water in the soil against the future drought. The variety, Mai Zabuwa exhibited same mechanism where the plant height of Mai Zabuwa is having the highest height compared to the other varieties while Nerica had the highest root length. It is assumed that, the root of Nerica goes deep in search of water underground and is not giving much to the shoot while the Mai Zabuwa gives much of the water support the growth of the shoot, rice has a significant genetic variation in traits related to drought tolerance such as root architecture, water use efficiency as reported by [22].

Root length observed for the variety has shown a relationship effect for the control and mild drought treatment but not for severe drought where interaction occurred at the BG Doguwa and Mai Zabuwa, the root length of Mai Zabuwa under the mild stress is higher than the root of the same Mai Zabuwa under the control, the reason was ascertained to the control having abundant availability of water so the root doesn't have to go deep in search of water while compared to the less available water in the mild stress condition where the water is assumed sinks down and that influence the root to extend it root length to search for water, at the severe no interaction was observed as the water is not sufficiently available.

5. CONCLUSION

One of the major abiotic stresses that restrains high rice production and yield stability is drought [23].

Drought adaptation mechanism have shown to be relatively efficient on the tested variety Mai Zabuwa, as compared to the other local varieties of BG Doguwa and lastly Maza haji based on the result of the capability of the root, shoot and leaf system to conduct and utilize available water and nutrient resources to the different parts of the plants.

Water shortage threatens rice production, as the future predicts drought to increase, efforts must be made to progress in developing drought adapted local rice varieties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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