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Full Length Research Paper

Response of some rice cultivars to Abiotic stress

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It is a global challenge of sustainable rice cultivation to find or develop rice varieties that have tolerance to limited water and nutrients while at the same time maintaining or improving grain yields. The aim of this research was investigate NPK fertilizer and water use efficiency of three rice cultivars namely; Faro 55 (Nerica 1), Srilanka, Faro 44 (Sippi) and three different phenotypic cultivars of Faro 44 viz. Faro 44 (SD drought), Faro 44 (SD tall) and Faro 44 (SD short). The rice cultivars were subjected to droughted (water deficit) and irrigated treatments with 180kg/ha NPK fertilizer and 90kg/ha NPK in each case. Tiller numbers, shoot biomass and root biomass of each of the rice cultivars were determined. The results showed that, while all the rice cultivars had tolerance (NPK use efficiency) to low NPK fertilizer, they had no resilience to limited water. Faro 44 (SD short) had the highest tolerance toward low NPK having higher tiller numbers, shoot mass and root mass. This could suggest a drastic reduce in the input of NPK fertilizer, saving cost of cultivation and the environment (soil ecosystem) from unnecessary accumulation. This could enhance the production of rice toward attainment of food security in developing countries.

Key words: Rice cultivars, NPK fertilizer, food security, Irrigated treatment, Drought treatment.

INTRODUCTION

Most rice farmers in the developing countries are faced with the challenge of climate change which affects rice production. Decreased rain fall coupled with intermittent drought is a common feature in the tropical and sub tropical savannas. It has been estimated that 25% of the fields used for upland crop production are prone to yield reductions as a consequence of drought (Jeong *et al.*, 2010). Drought may happen at any time during the growing season and may occur every year in some areas. Drought tolerant varieties developed through plant breeding are more accessible to farmers than costly agronomic practices or irrigation enhancements that might require large investments by farmers (Hu *et al.*, 2006, 2008; Zheng *et al.*, 2009; Jeong *et al.*, 2010).

Drought and depleted soil nutrients such as NPK are among the limiting abiotic factors affecting rice production. Nitrogen is the most deficient essential element in most tropical soils followed by potassium, which is why NPK fertilizer is required in order to obtain good yield (Abe *et al.* 2009). The systematic increase in the price of inorganic fertilizer especially NPK is now out of reach of most farmers in developing world. This has caused decline in rice production over the years. This problem is exacerbated by the ever increasing population in Africa and the number of mouth to feed. A number of steps have been taken to burst rice production in Africa. Prominent was the introduction of NERICA (New Rice for Africa) a cultivar developed in West Africa by the crossing between African rice, *Oryza glaberrima* Steud and Asian rice, *Oryza sativa* L. (WARDA 1999; Futakuchi *et al*. 2003). *O. sativa* L is known for its tolerance to drought and have the attribute of superior ability to obtain soil water, a trait that is related to their root architecture (Lilley and Ludlow, 2006, Kobata *et al*., 1996, Fujii and Horie 2004). This resistance to drought have not been fully investigated in NERICA and most rice cultivars.

Drought is the major abiotic constraint on upland rice production and affects half of rain fed lowland rice. Molecular marker technology has located genes of agronomic importance in rice, including root growth and drought resistance. There are some lines in NERICA that

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show high growth with low uptake of water and they seem to be appropriate for long periods of cultivation in drought condition **(**Michihiko *et al*., 2004).The cultivation of rice in marginal areas with low soil fertility and threatened by severe abiotic stresses, such as periods of drought during the cropping season, has a significant impact on rice production (Pinheiro *et al.,* 2006 and Heinemann *et al.,* 2007). The determination of the mechanisms directly involved in drought tolerance and nutrient use efficiency remain a challenge (Price *et al.,* 2002). The identification of cultivars with potentials to limiting water and nutrient tolerance and the isolation of genes associated with these traits are of major importance in order to better understand this trait and increase the efficiency in developing nutrient use efficiency and drought tolerant varieties (Tuberosa and Salvi 2006, Lafitte *et al*., 2007 and Sreenivasulu *et al.,* 2007). Rice farmers are aware of the importance of inorganic fertilizers in providing consistent benefit from farming activity. But subsistence farming consisting of sub-optimal use of fertilizers and other soil management practices leaves little opportunity for farmers to afford fertilizers to replace nutrients removed from their soils through harvested crops. Quantities applied are below upland rice nutrient requirements in the area. Manyong *et al.,* 2001 reported an average application of only 40 kg N/ha in northern Nigeria. For rice production, average applications of nutrients are in the ranges of 26.75–30.5 kg N, 1.64–3.28 kg P and 3.12–6.25 kg K/ha. These values are low considering that for the production of 1 tonne of upland rice paddy, rice needs to take up 15–40 kg N, 0.8–3.5 kg P and 14.3–40 kg K per hectare (Koopmans, 1990), which correspond to the application of 51–133 kg N, 8–35kg P and 48–133 kg K/ha for a recovery fraction of 30 % N, 10 % P and 30 % K applied. They are also far below the generalized recommendation of 76 kg N, 13kg P and 25 kg K/ha, regardless of soil type. Many reasons may explain the lack of adoption of full-dose fertilization, including poor response under certain circumstances, the cost of the fertilizer at recommended rate being beyond the reach of farmers, and farmers' lack of proper fertilizer-management skills. As a result, low average paddy yields are recorded: 0.7 t/ha on uplands (Ahmed *et al.,* 2009), compared to the national average of about 1.5 t/ha (Fashola *et al.,* 2006). What is important therefore, is finding rice cultivars that have resource and drought use efficiency. The aim of this research is to investigate the tolerance of tree rice cultivars to limiting water and NPK fertilizer.

MATERIALS AND METHODS

Experimental site (10° 16' 52'' N, 9° 47' 19'' E)

The experiment was conducted at green house of Abubakar Tafawa Balewa University (ATBU) Bauchi State, Nigeria in the months of March and April, 2013 when the average temperature was about 32°C.

Plant Samples

Cultivars used for the experiment were Faro 55 (Nerica 1), Srilanka, Faro 44 (Sippi), and, three different phenotypic cultivars of Faro 44, designated as: Faro 44 (SD drought, which showed drought resistance), Faro 44 (SD tall, which are taller than average) and Faro 44 (SD short, which are shorter than average).

Experimental Measurements

The recommended agricultural dose of NPK fertilizer in Bauchi the experimental location is in the ratio 120:30:30 kg/ha respectively (180kg/ha). Some farmers though, go up to 200kg/ha.

Treatments

The experiment as arranged in a completely randomised block design with four treatments. Each treatment had three replications. The treatments were, irrigation for 63 days with full dose (FD) of NPK (180kg/ha)=WD63, Irrigation for 63 days with half dose (HD) of NPK (90kg/ha) = WD63, Alternate wetting and drying after 28 days of watering with full dose (FD) of NPK (180kg/ha) = WD28 and alternate wetting and drying after 28 days with half dose (HD) of NPK (90kg/ha) = WD28 . The irrigated treatment WD63 was the control for water, while the FD (180kg/ha) was the control for NPK.

Procedure

Seeds of Faro 55 (Nerica 1), Srilanka, Faro 44(Sippi), Faro 44 (SD drought), Faro 44 (S.D tall) and Faro 44 (S.D short) were obtained from Bauchi State Agricultural Development Program (BSADP) and were used for the experiment. The seeds were sown in plastic pots, filled with 3.6kg of soil and saturated with water and kept in the Green House of Abubakar Tafawa Balewa University Bauchi in a complete randomised block design using Microsoft excel©. All treatments were irrigated for 28 days before the commencement of drought treatment. The experiment was set up thus: Two sets of experiments were given same droughted treatment (WD28) with different levels of NPK. This sets had water deficit at day 28 i.e. irrigation started at day 1 and ended at day 28 there after the treatment was subjected to one week of drought and one week of irrigation till day 63 with 180kg/ha NPK (FD) while the second set had 90kg/ha NPK which is half dose (HD).

In the second irrigated treatment (WD63), there were two sets as well having same irrigated treatments with two different levels of NPK. Water was given from day 1 till day 63 with 180kg/ha (FD) and 90kg/ha (HD) of NPK. Tiller numbers, biomass of the shoot and root were recorded.

Determination of Biomass

The plants were harvested from the pots gently, and the soil was washed off from the roots with water. The shoots were separated from the roots using a sharp knife. Shoots and roots of each cultivar were placed in a labelled brown envelope separately and are spread in the green house to dry. After two weeks of drying, all the envelopes containing shoots and root were moved to the laboratory where the weight of each shoot and root was recorded (Degenkolbe *et al.,* 2009).

Data Analyses

Data collected were analysed statistically with the General Linear Model (GLM) of Analysis of variance (ANOVA) using Minitab version 16$^{©}$ and graphs plotted using Sigma Plot v.12 (Systat Software Inc., CA).

RESULTS AND DISCUSSION

Drought tolerance in crops is an increasingly relevant trait, as water availability is the limiting factor for rice production in Asia and Africa. It is a quantitative agricultural trait that is though difficult and labor-intensive to determine (Moumeni, *et al.*, 2011) but equally important since drought tolerance could be influence by environmental factors that is now unpredictable with the consequence of decline in rice production (Lafitte, *et al* 2007). One of these traits is the ability to maintain a high biomass under drought stress at the juvenile stage which enhances plant survival after transplanting as well as rapid recovery after drought (Reddy, *et al.*, 2002, Wang, *et al.,* 2007). Both features increase yield. Our study was conducted to determine the resilience of each of the cultivars under investigation to water deficit and low NPK i.e. 90kg/ha NPK was chosen for this study being half the recommended agricultural dose (RAD) in the most rice producing areas. Tables 1A & B, 2 -- 3 and Figure 1 showed the effects limiting water and NPK fertilizer on the biomass of rice cultivars under investigation.

Water Deficits

There was general reduction in plant biomass with increase in water deficit in all the cultivars.

There was significantly ($p<0.05$) higher root biomass and shoot biomass in the irrigated treatments than the droughted. Drought thus affected the whole cultivars with no sign of resilience. Drought is one of the major factors that limit rice productivity worldwide (Price, *et al.,* 1999 and 2002, Gorantla,*et al.,*2007). This is still a major challenge in rice plants (Valliyodan and Nguyen, 2006).

Physiological and biochemical changes at the cellular level that are associated with drought stress include turgor loss, changes in membrane fluidity and composition, changes in solute concentration, and protein–protein and protein–lipid interactions . Plant tissues can maintain turgor during drought by avoiding dehydration, tolerating dehydration or both. These forms of stress resistance are controlled by developmental and morphological traits such as root mass. Others include root thickness, the ability of roots to penetrate compacted soil layers, and root depth (Fu, *et al*., 2007, Fujii, *et al*., 2004, Degenkolbe, 2009). Constitutive phenotypic traits (e.g. root thickness) are present even in the absence of stress conditions. By contrast, adaptive traits, such as osmotic adjustment and dehydration tolerance, arise in response to water deficit (Chaves and Oliveira, 2004). Reduction of photosynthetic activity, accumulation of organic acids and osmolytes, and changes in carbohydrate metabolism, are typical physiological and biochemical responses to stress. The reduction in photosynthetic activity is due to several coordinated events, such as stomatal closure and the reduced activity of photosynthetic enzymes (Dalal, 2013)). The inability of all the rice cultivars under investigation to synthesize osmolytes or osmoprotectants which serve as adaptive trait to water deficit could be the possible reason for the lack tolerance to water stress and subsequent low biomass.Similar results were reported by Willumsen 1993, Price *et al*, 2002 and Jeong *et al*., 2010.

NPK Treatment

In terms of the response to low NPK dose (90kg/ha NPK) within the WD63 treatment, all the cultivars were tolerant to the low NPK applications. Even though, differences in the levels of tolerance (90kg/ha NPK) were observed in the cultivars as indicated by their number of tillers, root mass and shoot mass. There was however, no statistical difference between the rice cultivars treated with the higher (180kg/ha) dose and lower dose (90kg/ha) of NPK. In terms of low NPK tolerance Faro 44 (SD short), was the most resilient. This was followed by Faro 44 (SD drought) and then Faro 44 (Sippi) .These cultivars were able to accumulate more plant biomass and higher tiller numbers than the others (Figures 1 - 6). These cultivars could be potential candidates for low NPK tolerance. Similar other works on nutrient use efficiency of rice were conducted (Sun *et al*., 2014). Faro 44 (SD short and SD drought) belong to Faro 44(Sippi) that showed phenotypic traits of shortness and seemingly drought resistance respectively. The variability of this plant’s response to low

Table 1. Comparisons of effect of water deficit on root and shoot biomass of the rice cultivars
A. Comparisons for factor: **Water Vs Root mass**

Comparison	Diff of Means	t	P	P<0.050
Irrigated vs. droughted	**3.036**	**7.813**	**<0.001**	**Yes**

B. Comparisons for factor: **Water Vs Shoot mass**

Comparison	Diff of Means	t	P	P<0.050	
Irrigated vs. droughted	4.266	9.017		**<0.001**	**Yes**

Diff of Means= difference of means, t = t value; P = Probability level

Table 2. Effect of water deficit and NPK on tiller number of the rice cultivars

Cultivars/Water	DF	SS	MS	F	P
Cultivar	5	356.958	71.392	5.210	<0.001
Water	1	284.014	284.014	20.727	<0.001
Cultivar x Water	5	97.736	19.547	1.427	0.228

Cultivars /NPK	DF	SS	MS	F	P
Cultivar	5	356.958	71.392	4.176	0.003
NPK	1	23.347	23.347	1.366	0.247

DF = degree of freedom, SS = sum of squares, MS = means of squares, F = F ratio, P = Probability level.

Table 3. Effect of water deficit and NPK on shoot to root ratios of rice cultivars

Cultivars /Water	DF	SS	MS	F	P
Cultivar	**5**	**9.250**	**1.850**	**2.047**	**0.085**
Water	**1**	**4.654**	**4.654**	**5.150**	**0.027**

Cultivars /NPK	DF	SS	MS	F	P
Cultivar	5	9.250	1.850	2.442	0.044
NPK	1	10.484	10.484	13.838	<0.001
Cultivar x NPK	5	7.114	1.423	1.878	0.112

DF = degree of freedom, SS = sum of squares, MS = means of squares, F = F ratio, P = Probability level

NPK could suggest genetic variability within the Faro 44 (Sippi). When plants experience environmental stresses such as drought, salinity, high and low nutrients they activate a diverse set of physiological, metabolic and defence systems to survive and to sustain growth. Tolerance and susceptibility to abiotic stresses are very complex. Abiotic stress is the primary cause of crop loss worldwide, causing average yield losses of more than 50% for major crops. Plant traits that are associated with resistance mechanisms are multigenic and thus difficult to control and engineer. Transcriptomics, proteomics and gene expression studies (Salekdeh, *et al.,* 2002, Agrawal, *et al.,*2006, Périn, *et al.*, 2007) have identified the activation and regulation of several stress-related transcripts and proteins, which are generally classified into two major groups. One group is involved in signalling cascades and in transcriptional control, whereas members of the other group function in membrane protection, as osmoprotectants, as antioxidants and as reactive oxygen species (ROS) scavengers. Manipulation of genes that protects and maintains cellular functions or that maintain the structure of cellular components has been the major target of attempts to produce plants that have enhanced stress tolerance. Among the various abiotic stresses, drought (Aline, *et al*., 2008) and low nutrients are the major factors that limit crop productivity worldwide. Exposure of plants to a water-limiting environment and low nitrogen and phosphorus during various developmental stages appears to activate various physiological and developmental changes (Somonte *et al.,* 2006 and Eagle *et al.,* 2000).

The finding of this research has showed that the rice cultivars under investigation had resilience to low NPK fertilizer. This is a milestone to rice farming especially in developing countries that are impeded with high cost of inorganic fertilizers in the cultivation of rice. The environ-

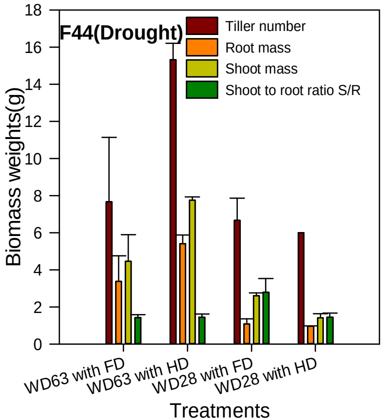

Figure 1 = F44 Drought

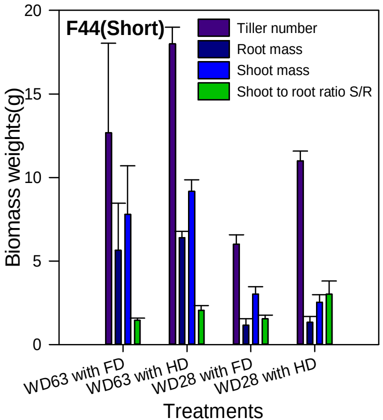

Figure 2 = F44 Short

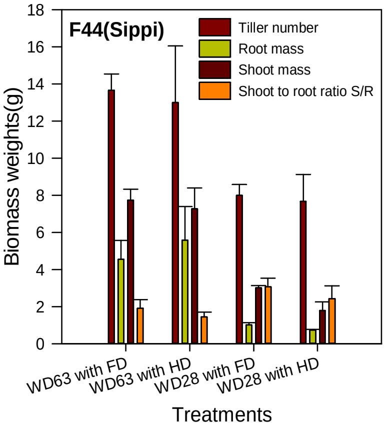

Figure 3 = F44 Sippi

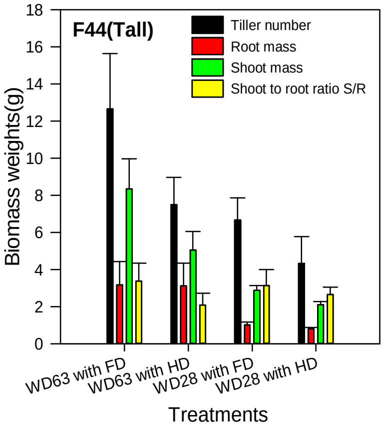

Figure 4 = F44 Tall

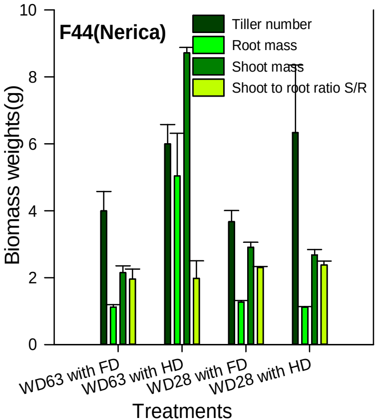

Figure 5 = F44 Nerica

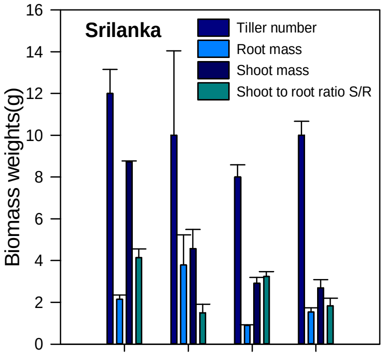

Figure 6 = Srilanka

Figure 1. Tiller number, Plant biomass i.e. root and shoot and Shoot to root ratio of Faro 44 (SD drought) for WD63 with FD, WD63 with HD, WD28 with FD and WD28 with HD; Figure 2**:** Tiller number, Plant biomass (root and shoot) and Shoot to root ratio of Faro 44 (SD short) for WD63 with FD, WD63 with HD, WD28 with FD and WD28 with HD; Figure 3: Tiller number, Plant biomass (root and shoot) and Shoot to root ratio of Faro 44 (Sippi) for WD63 with FD, WD63 with HD, WD28 with FD and WD28 with HD; Figure 4**:** Tiller number, Plant biomass (root and shoot) and Shoot to root ratio of Faro 44 (SD tall) for WD63 with FD, WD63 with HD, WD28 with FD and WD28 with HD; Figure 5: Tiller number, Plant biomass (root and shoot) and Shoot to root ratio of Faro 55 (Nerica 1) for WD63 with FD, WD63 with HD, WD28 with FD and WD28 with HD; and Figure 6**:** Tiller number, Plant biomass (root and shoot) and Shoot to root ratio of Srilanka for WD63 with FD, WD63 with HD, WD28 with FD and WD28 with HD (bars = standard error bars).

mental impacts of accumulation of these fertilisers and its deleterious effects on soil biota would also be greatly reduced.

Shoot: root ratio

The records of the root mass compared to the shoot mass (increase shoot: root ratio) is shown in Table 3.

In this study, there was differential sensitivity of shoots and roots of the rice plants with shoot growth being relatively less sensitive to water deficits than the root. This lead to large increase in the shoot to root ratio in the droughted experiment This result was contrary to the findings of Boyer, 1985; Sharp and Davies, 1985, Sikuku *et al*, 2010 who reported decrease of shoot root ratio under water deficit in some Nerica 2 and Nerica 4 rice cultivars. A reduction in root growth coupled with an increase in shoot growth would result in a plant that is not tolerant to extreme water deficit. This could be the reason why the rice cultivars in this study showed no resilience to drought. Increase in root surface area which results to increase in the root mass permits the absorption of more water from the soil. This would results to plants being tolerant to water deficit conditions. This condition was not observed in this study.

CONCLUSION

We conclude that rice cultivars under investigation i.e. Faro 44 (Sippi), Faro 44 (SD short), Faro 44 (SD tall), Faro 44 (SD drought), Faro 55 (Nerica 1) and Srilanka had tolerance to low NPK application com parable to what most farmers apply. They had NPK use efficiency and could be grown with a much reduced NPK application as low as 90kg/ha. This is good news to agriculture in sub Saharan rice cultivated areas. The study also showed no sign of tolerance to extreme water deficit in all the rice cultivars. A drastic reduce in the input of NPK fertilizer will save cost of cultivation and the environment (soil ecosystem) from unnecessary accumulation. This could enhance the production of rice toward attainment of food security in developing countries.

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