RESPONSE OF SOME *ORYZA GLABERRIMA* GENOTYPES TO FLASH FLOODING

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ABSTRACT

The tolerance of some Oryza glaberrima genotypes was evaluated against complete submergence at seedling stage and the effects of the water conditions on the genotypes under submergence. High yielding genotypes of Oryza glaberrima (TOG6790A, TOG9266, TOG933, TOG9281, TOG9047, TOG7428), submergence tolerant (SWARNA SUB1) and susceptible (TOG7943) checks were subjected to flash flooding at 21 days after seeding for two weeks. Submergence tolerant genotypes (TOG7428 and TOG9047) showed mean reduced plant growth of 17.43% with significant ($p<0.05$) reductions in all morphological growth parameters. This implies a reduction in energy utilization thus conserving energy by maintaining low growth rate. However, genotypes with escape growth strategies showed rapid shoot elongation and leaf expansions by competing for energy required for the maintenance processes for survival. Thus, elongation ability negatively correlated with submergence tolerance (r-= -.05 and survival percentage (r=-0.31) upon de-submergence. Shoot elongation positively correlated with leaf number (r= 0.51) and leaf width (r= 0.74*). Water conditions during complete submergence (dissolved oxygen- 12.63±0.71mgl^{-1}, total dissolved solids 124.33±7.45mgl^{-1} and electrical conductivity 2.04±2.26dSm^{-1}) were not toxic to the genotypes. Submergence tolerant Oryza glaberrima genotypes could be adopted to mitigate flooding in flood prone areas and can be used in conferring submergence tolerance in breeding programmes for plant advancement.*

Keywords: Submergence, *Oryza glabberrima,* Shoot elongation, desubmergence.

INTRODUCTION

One of the limiting factors to sustainable rice production is poor management of water (Akinwale *et al*., 2012). Rice in West Africa is cultivated in upland, lowland or deep-water conditions with little or no control of water levels. Rainfed uplands occupy around 40% of total rice growing area in West Africa (Ikeda, 2004) but yields are low, compared with those of lowland ecosystems. Only about 10% of the total rice area is irrigated (Setter, 2010). The rainfed lowlands therefore offer the greater potential for raising rice production. Lowlands in Nigeria are susceptible to flooding with average to high rainfall. The resultant damage in yields ranges from 60% to 100%. Specifically, over 80% of lowland rice ecology was inundated by floods in Nigeria in 2011, causing severe economic loss (Akinwale, *et al*., 2012). In rice farms, 100% yield losses have been recorded due to submergence stress in these lowlands.

Most rice cultivars die within several days of being completely submerged, but some cultivars, are more tolerant to submergence (Khan *et al*., 2013). The issue of sea level rise occasioned by global climatic change will exacerbate flooding conditions in growing areas. In many cases, young rice seedlings are too small to escape by means of underwater leaf elongation and cannot successfully develop a canopy above the water surface. Several studies on the African rice drew attention to the potential of the indigenous cultivated rice species which presents a rich reservoir of genes for resistance to several stresses (Futakuchi, 2005; Sarla *et al*., 2005; Bailey-Serres & Voesenek, 2010).

Water-control measures in submergence-prone areas can help reduce the damage caused by flooding (Laurentius *et al*., 2015), but this normally entails huge investment beyond the reach of resource poor farmers normally living in these areas (Ikeda, 2004). Floods also cannot be predicted and the damage could occur at any stage of plant development including germination (Rahman and Zhang, 2016). The achievement of sustainable rice production will therefore be necessary to identify and incorporate adaptability to submergence into rice cultivars used by West African farmers (Ikeda, 2004). This study was therefore designed to evaluate the tolerance of *Oryza glaberrima* to mitigate flash flooding in flood prone ecologies.

MATERIALS AND METHODS

The seeds of *Oryza glaberrima* genotypes (TOG6790A, TOG9266, TOG933, TOG9281, TOG9047, TOG7428) were procured from AfricaRice, Ibadan, Nigeria. Submergence screening was performed in the greenhouse at the botanical garden of Ahmadu Bello University, Zaria, Nigeria. Six *Oryza glaberrima* genotypes along with the susceptible (TOG7943) and tolerant (SWARNA SUB 1) checks were sown in plastic buckets and completely submerged at 21 days old in plastic tanks at a depth of 1.2m. Submergence tolerance was evaluated by adopting a completely randomized design with three replicates. Water level was maintained at 100cm above soil during submergence. When the susceptible check showed >60% damage, plants were de-submerged and plant survival scored after 14 days of recovery.

Characteristics of the surrounding water were evaluated with a hand held Hanna conductivity meter at a depth of 5cm after manual stirring of water. These included dissolved oxygen (mgl^{-}), temperature (^{O}C), total dissolve solid (mgl^{-1}), electrical conductivity (dsm^{-1}), and pH. These were monitored and evaluated daily for the duration of submergence. Morphological parameters were evaluated fourteen days after submergence. The water in the tanks was let out via the water tap at the base of the tank. Growth parameters evaluated for the submerged plants and the non-submerged controls were: shoot elongation (cm), leaf width (cm), leaf number, tiller number and percent survival (%). Data obtained were subjected to analysis of variance. Where significant, Duncan's Multiple Range Test was used to separate the means. The degrees of association of the morphological parameters were determined using the Pearson's correlation index.

RESULTS

Response of Genotypes to Submergence Stress

Genotypes showed varied response to submergence stress. A significant ($p<0.05$) effect of submergence on shoot elongation amongst the genotypes was observed. Shoot elongation was most rapid in TOG6790 (16.15%) with a survival score of 9 after de-submergence. The survival score was comparable with the susceptible check (TOG7943) which showed a 6% increase in height due to submergence. TOG9266 and TOG9281 also showed reduced growth of -8.1% and -3.2% respectively. However, their survival score upon de-submergence was 7. TOG933 showed moderate tolerance to submergence stress with a score of 5 and a 35.24% reduction in shoot length. SWARNA SUB 1, TOG7428 and TOG9047 with a survival score of 3 showed reductions in shoot length of 21.49%, 23% and 11.86% respectively (Fig1).

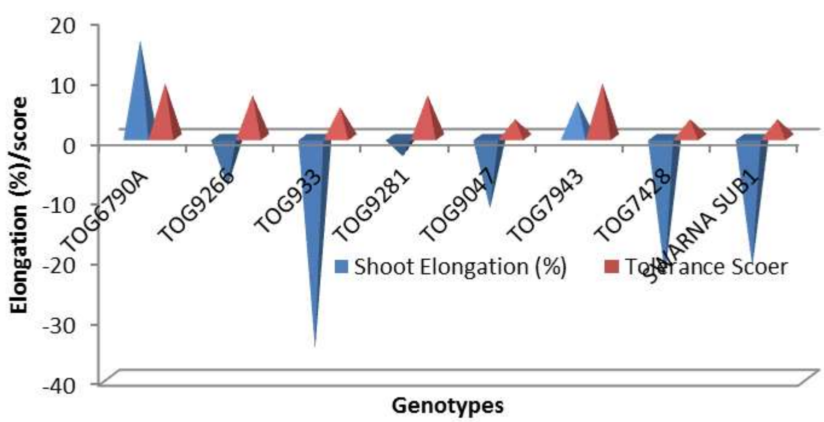

Fig 1: Shoot elongation and submergence tolerance of *Oryza glaberrima* genotypes.

Leaf width, leaf number and tillering ability varied with the genotypes. A significant ($P<0.01$) effect of submergence on leaf expansion rate was observed across genotypes. Leaf width expansion due to submergence stress was highest (5.26%) in TOG9266 and lowest (-34.7%) in TOG933. Sequential leaf reductions of -18.37%, -10.34%, -9.33%, -8.72%, -8.0%, -3.2% were observed in TOG9047, WARNA SUB 1, TOG6790, TOG7428, TOG9281, and TOG7943 respectively (Fig. 2). At 5% probability level, all genotypes showed varied reductions in leaf and tillering ability except for TOG933 whose tillering ability was not affected by complete submergence. Reductions in leaf number and tillering ability ranged from -16.79 to -7.06% in SWARNA SUB 1 and TOG9047 and from -24.81% to 0% in SWARNA SUB 1 and TOG933 respectively (Fig 2).

Survival percentage upon de submergence ranged from 10% to 88%. SWARNA SUB 1 and TOG9047 showed no significant difference in survival percentage. However, TOG7428 showed tolerance to submergence stress with a 60% survival upon de submergence. Other genotypes were susceptible to submergence stress.

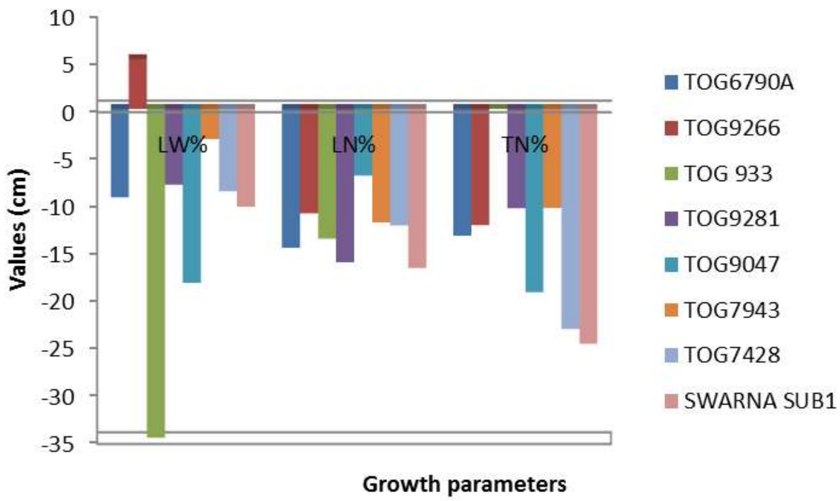

Figure 2: Comparative growth response of *Oryza glaberrima* under submergence stress relative to control treatment. Key: LW=leaf width, LN=leaf number, TN=tiller number

The associations between plant morphological growth parameters showed that shoot elongation positively correlated with leaf number (r= 0.51*) and leaf width (r= 0.74*) at p<0.05.
Environmental Characterization of surrounding water.

Temperature values of submergence water obtained ranged from 25.5°C to 28.3°C. The pH was maintained at 5.4 ±0.4 °C. Significant variance in total dissolved solids (TDS) and dissolved oxygen (DO) across the genotypes was obtained. Electrical conductivities were within acceptable limit (<4 dsm^{-1}) for all genotypes and did not significantly vary across genotypes. Values for Dissolved oxygen and TDS ranged from $12.00mgl^{-1}$ to $13.33mgl^{-1}$ and $134.6700mgl^{-1}$ to $11700mgl^{-1}$ respectively.

Table 1: Characterization of flood water used for Subergence of *Oryza glaberr*ima in Plastic Tanks under Field Conditions.

Tanks	DO (mgl^{-1})	TDS(mg/l^{-1})	EC (dsm^{-1})
1	12.67^{ab}	128.33^{bc}	2.05^{ab}
2	12.67^{ab}	134.67^{a}	1.71^{b}
3	13.33^{a}	132.0^{ab}	2.22^{a}
4	13.01^{ab}	123.00^{de}	2.01^{ab}
5	12.02^{b}	112.67^{a}	2.14^{b}
6	13.33^{a}	126.67^{dc}	2.06^{ab}
7	12.02^{b}	120.06^{fe}	2.08^{ab}
8	12.00^{b}	117.33f	2.06^{ab}
9	12.64^{ab}	124.00^{de}	2.05^{ab}
X ± SDEV	12.63±0.71	124.30±7.45	2.04±2.26
C.V	4.19	2.1	9.99
P VALUE	< 0.02	<0.01	<0.22

Key: DO- Dissolved Oxygen, TDS- Total dissolved solids, EC- Electrical conductivity

DISCUSSION

Factors controlling energy production by plants have an impact depending on how that energy is utilized for the best survival strategy of any induced stress. Submergence tolerant genotypes showed reduced plant growth, with greater reductions in all morphological growth parameters. This implied a reduction in energy utilization, thus conserving energy by maintaining low growth rate. The results obtained suggests that rapid shoot elongation and leaf width expansion may compete for energy required for maintenance processes for survival. This was indicated by a negative correlation between elongation ability, submergence tolerance and reduced survival percentages after de-submergence. Leaf expansion due to submergence stress further corroborate increasing energy utilization in order to increase plant photosynthetic ability. Hence the observed positive association between leaf expansion and shoot elongation. Furthermore, shoot elongation during submergence was probably influenced by the genetic character of the genotype as well as the submergence environment. These findings corroborated several researches on submergence tolerance where it was implied that some genotypes elongated their shoot during total submergence (Luo, 2011). Stem elongation due to submergence have been reported in susceptible varieties (Das *et al*., 2005). In small seedlings, rapid elongation is restricted to emerging leaves. Shoot elongation is one of the escape strategies for adaptation to submergence that promotes a return of part of the foliage to the air (Kende *et al*., 1998; Sarkar & Bhattacharjee, 2011). This helps to ensure adequate supplies of oxygen and carbon dioxide to support vigorous aerobic respiration and photosynthesis

(Bailey-Serres, & Voesenek, 2010). Renewed growth and development in tolerant elite varieties have also been reported. (Khan *et al*, 2013). Singh, *et al.* (2001) and Akinwale, *et al. (*2012) also reported negative correlation between plant elongations with percentage survival.
The submerged water that supported the growth of *Oryza glaberrima* genotypes was not toxic to the submerged genotypes. The electrical conductivity and total dissolved solids of the surrounding water were within acceptable limits (WHO, 2011). However, the water body was slightly polluted due to plant metabolism as observed from water turbidity. Turbid water, in addition to submergence stress must have triggered stem elongation growth process. An interrelationship between gas diffusion and metabolism of rice related to growth and survival during complete submergence have been exemplified by Setter *et al.* (1997) where plant submerged in floodwater in equilibrium with air at 0.03kpa died within 1-2weeks.

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