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Response of Some Oryza Glaberrima Genotypes to Submergence Tolerance in Kaduna State, Nigeria

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Abstract: We evaluated *Oryza glaberrima* genotypes tolerance to complete submergence, and the environmental effects of its surrounding conditions at seedling stage. Six candidate genotypes (TOG6790A, TOG9266, TOG933, TOG9281, TOG9047, TOG7428) with submergence tolerant (SWARNA SUB1) and susceptible (TOG7943) checks were subjected to submergence stress 21 days after seeding for two weeks. Submergence tolerant genotypes showed reduced plant growth, with greater reductions in all morphological growth parameters. This implies a reduction in energy utilization thus conserving energy by maintaining low growth rate. However, genotypes showing rapid shoot elongation and leaf width expansion competed for energy required for the maintenance processes for survival by increasing plant photosynthesizing ability. Thus, elongation ability negatively correlated with submergence tolerance and survival percentage after de-submergence. Shoot elongation positively correlated with leaf number (r= 0.51*) and leaf width (r= 0.74*) and negatively with submergence tolerance and survival percentage after de-submergence. Environmental characterization of water conditions during complete submergence did not confer toxicity to the genotypes. Submergence tolerant *Oryza glaberrima* genotypes could be useful for growing in flood prone areas and can be used in conferring submergence tolerance in breeding programmes for plant advancement.

Keywords: Environmental characterization; Leaf expansion; Oryza glabberrima; Shoot elongation; Submergence tolerance.

1. Introduction

Rice cultivation in lowlands is usually during the rainy season. This inevitably leads to flash floods and partial or total submergence of rice plants in most environments. Lowlands in northern 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 [1]. In rice farms, 100% yield losses have been recorded due to submergence stress in these lowlands. One of the limiting factors for sustainable rice production is poor management of water. Most 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 [2] but yields are low, compared with those of lowland ecosystems. Only about 10% of the total rice area is irrigated [3]. The rainfed lowlands therefore offer the greater potential for raising rice production.

Most rice cultivars die within several days of being completely submerged, but some cultivars, are more tolerant of submergence [4]. The issue of sea level rise occasioned by global climatic change will exacerbate it. 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 [5-8].

Water-control measures in submergence-prone areas can help reduce the damage caused by flooding, but this normally entails huge investment beyond the reach of resource poor farmers normally living in these areas Africa [2]. Floods also cannot be predicted and the damage could occur at any stage of plant development including

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germination. 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 [2].

2. Materials and Methods

The seeds of the genotypes (TOG6790A, TOG9266, TOG933, SWARNA SUB1, NERICA L34 and IR34) were procured from of Africa Rice, Ibadan station, IITA, Nigeria.

Submergence screening was performed in the greenhouse at the botanical garden of Ahmadu Bello University, Zaria, Nigeria. Six candidate submergence tolerant *Oryza glaberrima* genotypes along with the susceptible (TOG7943) and tolerant (SWARNA SUB 1) checks were planted in plastic buckets that were submerged at 21 days old under depth of 1.2m. This was evaluated adopting a completely randomized design with three replicates. Water level were maintained at the same level (1.2m) during submergence. When the susceptible check showed >60% damage, about 16 days of complete submergence, plants were de-submerged and plant survival scored after 14 days of recovery by comparing with the control variety SWARNA SUB 1.

Environmental characterization of the surrounding water parameters included dissolved oxygen (mgl^-), temperature (^OC), total dissolve solid (mgl^{-1}), electrical conductivity (dsm^{-1}) , and PH. These were monitored and evaluated daily for the duration of submergence. Morphological Parameters (Shoot elongation (cm), leaf width (cm), leaf number, tiller number, percent survival (%) were evaluated for the submerged plants and the non-submerged controls.

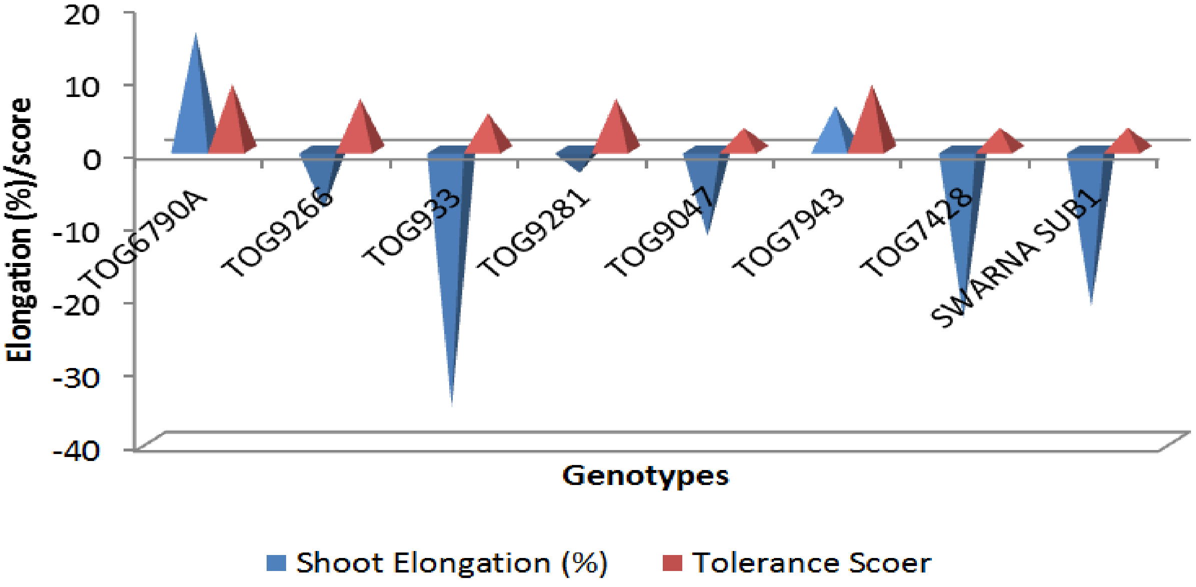
The results were subjected to analysis of variance. Where significant, Duncan's Multiple Range Test was used to separate the means. The degrees of association of the morphological parameters were determined using the Pearson's correlation index.

3. Results

3.1. Response to Morphological Parameters

Genotypes showed varied response to the parameters under study. A significant ($p<0.05$) difference in shoot elongation amongst the genotypes was observed. Shoot elongation was most rapid in TOG6790 (16.15%) when compared to the unsubmerged treatment with a plant height of 46.04cm and 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. (Fig 1).

Fig-1. Shoot elongation percentage and submergence tolerance score of *Oryza glaberrima* genotypes.

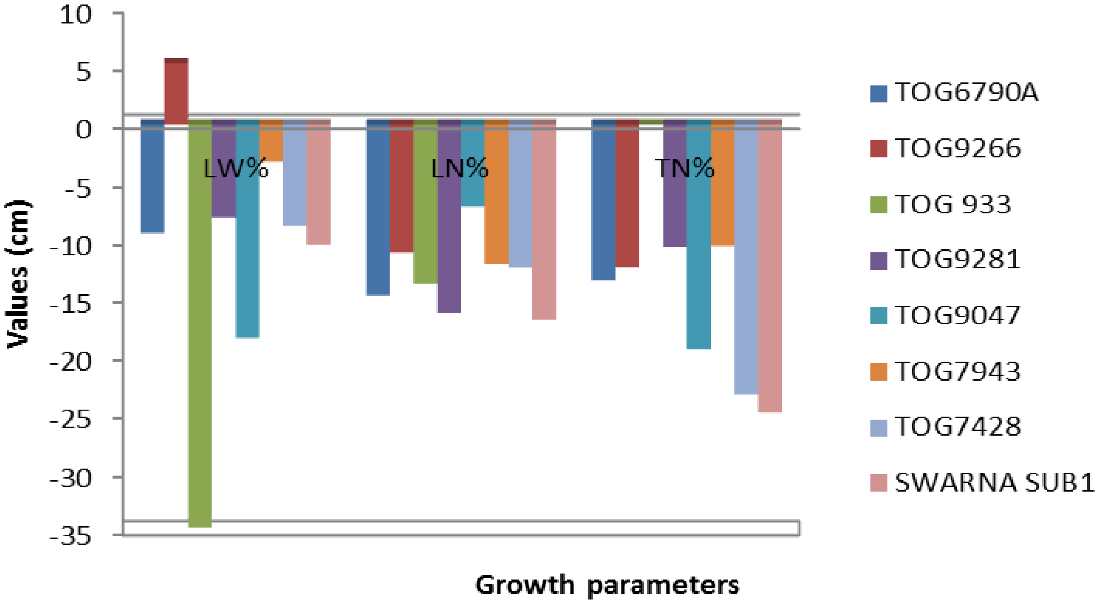


Leaf expansion, leaf number and tillering ability varied with the genotypes. A significant ($P<0.01$) difference in leaf expansion rate was observed across the genotypes. Leaf expansion due to submergence stress was highest (5.26%) in (TOG9266) and lowest (-34.7%) in TOG933. sequential reductions of -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 tiller number 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%-88%. SWARNA SUB 1 and TOG9047 showed no significance difference in survival percentage using the Duncan's Multiple Range tests. TOG7428 showed tolerance to submergence stress with 60% survival after de submergence. All other genotypes were susceptible to submergence stress.

Figure-2. Comparative growth response of *Oryza glaberrima* under submergence stress relative to control treatment The associations between plant morphological growth parameters showed that shoot elongation was positively correlated with leaf number (r= 0.51*) and leaf width (r= 0.74*) at p<0.05.



Key: LW=leaf width, LN=leaf number, TN=tiller number

3.2. Environmental Characterization of Surrounding Water

The temperature values of water obtained from the samples ranged from 25.5^{o}C to 28.3^{o}C. The PH was maintained at 5.4 ±0.4 ^{o}C. Variance (P<0.05) was obtained in Total dissolved solids (TDS) and dissolved oxygen (DO) across the genotypes. Electrical conductivities were within acceptable limit (<4 dsm^{-1}) for all genotypes. This did not significantly vary across genotypes. Values for Dissolved oxygen and TDS in our investigation ranged from 12.00mgl^{-1} to 13.33mgl^{-1} and 134.6700mgl^{-1} to 11700mgl^{-1} respectively. Among the genotypes evaluated, dissolved oxygen and total dissolved solids values were lowest in the tolerant genotypes.

Table-1. Environmental characterization of flood water causing submergence stress in *Oryza glaberr*ima genotypes.

GENOTYPE	DO (mgl^{-1})	TDS(mg/l^{-1})	EC (dsm^{-1})
TOG6790A	12.67^{ab}	128.33^{bc}	2.05^{ab}
TOG9266	12.67^{ab}	134.67^{a}	1.71^{b}
TOG 933	13.33^{a}	132.0^{ab}	2.22^{a}
TOG9281	13.01^{ab}	123.00^{de}	2.01^{ab}
TOG9047	12.02^{b}	112.67^{a}	2.14^{b}
TOG7943	13.33^{a}	126.67^{dc}	2.06^{ab}
TOG7428	12.02^{b}	120.06^{fe}	2.08^{ab}
SWARNA SUB1	12.00^{b}	117.33f	2.06^{ab}
X ± SDEV	12.63±0.71	124.33±7.45	2.04±2.26
C.V	4.19	2.1	9.99
P VALUE	< 0.02	<0.0001	<0.22

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

4. Discussion

Factors controlling energy productions 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 reduce plant growth, with greater reductions in all morphological growth parameters which implies 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 and submergence tolerance as well as survival percentage after de-submergence. Leaf expansion due to submergence stress further corroborates increasing energy utilization in order to increase plant photosynthesizing ability. Hence, the positive association between leaf expansion and shoot elongation. Furthermore, shoot elongation during submergence depends on the genetic character of the genotype and may also be affected by the submergence environment. These findings are corroborated by several researches on submergence tolerance where it was implied that some genotypes elongate their shoot during total submergence [9]. Stem elongation due to submergence has been reported in susceptible varieties [10]. 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 [11]. This helps to ensure adequate supplies of oxygen and carbon dioxide to support vigorous aerobic respiration and photosynthesis [12]. Renewed growth and development in tolerant elite varieties have also been reported. [13]. Singh, *et al.* [14] and Akinwale, *et al.* [1] also reported the negative correlation between plant elongations with percentage survival.

Environmental characterization of water conditions during complete submergence did not confer toxicity to the genotypes. The electrical conductivity and total dissolved solids of the surrounding water were within acceptable limits [15]. However, the water body was slightly polluted due to plant metabolism. This must have triggered elongation growth process. There is an interrelationship between gas diffusion and metabolism of rice related to growth and survival during complete submergence [9] as exemplified by Setter, *et al.* [16] where plant submerged in floodwater in equilibrium with air at 0.03kpa died within 1-2weeks.

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