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Inheritance of Submergence Tolerance in Lowland Rice Variety

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About 70% of the rain-fed lowland rice farms in Nigeria are prone to seasonal flooding, which is a major constraint to rice production in some major rice producing areas. Each year that there is flooding, rice farmers in these parts of the country lose their entire crop. This research focuses on developing a submergence tolerant rice variety to overcome crop loss due to flooding. A study of the inheritance pattern of submergence tolerance in rice was carried out using four parental lines, namely two submergence tolerant varieties collected from IRRI (IR05F102 and IR07F102) and two susceptible Nigerian varieties (WITA 4 and TOX 4004). Crosses of tolerant x susceptible and susceptible x tolerant varieties were made. The resulting progenies were screened for submergence tolerance and the number of susceptible and tolerant plants was counted. Data obtained were subjected to Chi-square test to determine their goodness of fit to various genetic ratios. The cross involving WITA 4 and IR05F102 parents produced 187 F_2 progenies that segregated into 143 tolerant and 44 susceptible. The reciprocal cross also produced 168 F_2 progenies that segregated into 132 tolerant and 36 susceptible. The results of both crosses fitted into 3:1 ratio of 275 tolerant and 80 susceptible as indicated by the chi-square goodness of fit analysis. The 157 F_2 progenies derived from the cross (TOX 4004 X IR07F102) segregated into 126 tolerant and 31susceptible. The 179 progenies of the reciprocal cross also segregated in the same pattern with 142 tolerant and 37 susceptible. The 336 F_2 progenies from all the crosses and reciprocal crosses segregated into 268 tolerant and 68 susceptible in the ratio 3:1, suggesting the involvement of one major gene. No difference in the reciprocal crosses in both F_1 and F_2 populations was detected in all the crosses. Hence, either of the genotypes could be used as the female parent in breeding programmes.

Keywords: Submergence tolerance, Rice, Inheritance, Hybridization, Susceptible, Tolerant.

INTRODUCTION

More than 16 million ha of rice lands of the world in lowland and deep-water rice areas are unfavorably affected by flooding. Submergence caused by flash flood is a key factor limiting the yield of lowland rice. In Nigeria, approximately 70% rain-fed lowland rice farms are prone to seasonal flooding which is a major constraint to rice production in some major rice producing states, and each year, rice farmers in these parts of the country lose their entire crop to flooding (Akinwale *et al.* 2012). Flash floods are highly unpredictable and can occur at any growth stage of the rice crop, resulting in yield loss of 10% to 100%, depending on water depth, duration of submergence, temperature, turbidity of water, light intensity, and age of the crop, etc. (Setter *et al.* 1997; Adkin *et al,* 1990; Jackson and Ram, 2003). Submergence tolerance is defined as the ability of a rice plant to survive and continue growing after being completely submerged in water for several days. Complete submergence is tolerated for a limited time by both susceptible and tolerant rice. The susceptible varieties are destroyed at a faster rate during complete submergence than the tolerant ones. Submergence tolerance has long been regarded as an important breeding objective for rainfed lowland and deep water, rice areas (Mackill, 1986; Mohanty and Chaudhary, 1986). Despite this recognition there has been limited success in developing improved submergence tolerant varieties in Africa. Varietal differences in the degree of submergence tolerance have been observed many times and

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this genetic resource has been used in several conventional breeding programmes in Asia (Mohanty and khush, 1985). Some studies in the past reported dominance of tolerance over non tolerance and involvement of both major and minor genes in the inheritance (Mohanty and Khush 1985, Mohanty *et al.* 2000).

Mishra *et al.* (1996) found both additive and non additive gene effects responsible for inheritance of submergence tolerance. In one study, the involvement of at least three genes was reported with low to moderate broad sense heritability. In another study, analysis of segregating F_2 and backcross populations made between tolerant and intolerant lines suggested the involvement of one major dominant gene in the submergence tolerance of three tolerant lines, FR13A, BKNFR and Kurkaruppan (Setter *et al*. 1997; Mazaredo and Vergara, 1982); Mohanty and Chaudhary, 1986). Incorporation of improved submergence tolerance could greatly improve the adaptation of varieties of rainfed lowland rice in Africa.

MATERIALS AND METHODS

Hybridization methods

The seeds of the four parents were sown in the hybridization block of AfricaRice, Ibadan, Nigeria at 2 week interval to synchronize the flowering date. Three plantings of parents at 10- to 14 day intervals was done to ensure simultaneous flowering of both parents. At flowering, a day prior to the day of pollination, the female parents, which were the most representative of the variety and which have the maximum number of panicles were chosen, uprooted and transplanted into pots for emasculation. Emasculation was done in the evening hour in the glass house. This is the period when there is little or no wind movement. Emasculation was performed on a plant whose panicle had emerged about half way from the boot. The spikelets that had already undergone anthesis at the top and the immature ones at the bottom of the panicle were cut off, leaving only the middle spikelets in the panicle.

The middle spikelet was cut on the slant about half or two-thirds distance from the base with sterilized scissors to expose the anthers. The anthers were removed by a micropipette attached to vacuum emasculator, which sucks the anthers into a conical flask without damaging the stigma. The emasculated panicle was then covered with a pollinating bag and closed with paper clips or stapler. Optimum pollination takes place between midday and 15.00 hr. This is the period during which anthers open and pollen could be squeezed out or shed when gently touched with a finger.

The pollen bearing panicles of donor parent were harvested on the day of pollination and the emasculated panicles of the recurrent parent were pollinated by shaken the pollen bearing panicles over the emasculated panicles. The stigma is receptive up to 5 days after anthesis. The bag was replaced on the female plant and the date and the parents of the cross were written on the back of the bag. Matured F_1 seeds were harvested when they lost their green color from 25 to 30 days after pollination. The F_1 seeds were naked without glume. Seeds from each female panicle were harvested and bagged separately and parents of the cross were recorded.

Phenotypic screening of F_1 and F_2 progeny

Ten F_1 plants of each cross were selfed to produce F_2 seeds. The F_1 and F_2 seeds produced were tested for submergence tolerance in the 2011 dry season in the glass house. Seeds of parents, F_1 and F_2 of the crosses and their reciprocal were pre-germinated and seeded in plastic trays filled with soil with one seed per hill in the glasshouse. 21 days after seeding, trays were placed in a plastic tank in the glass house and submerged for 12 days. Starting from the 8th days of submergence, the susceptible cultivar was checked daily. When leaves were yellowish brown and decaying, trays were removed from the tanks. Plants were left to recover for seven days. Plants were maintained in that condition for seven days and the number of dead (susceptible) and alive (tolerant) plants were counted.

Data Analysis

Data on tolerant and susceptible plants obtained from the experiment were analyzed using chi-square test to ascertain the goodness of fit to different genetic ratios

RESULTS

The crosses between WITA 4 and IR05F102 and TOX 4004 and IR 07F102 and their reciprocal crosses yielded tolerant F_1 plants when submerged for 12 days (Table 2 and 3). Although susceptible plants were not expected to be found among the F_1 hybrids but there were eight (8) and three (3) plants from the cross between WITA 4 and IR05F102 and the reciprocal. The cross involving WITA 4 and IR05F102 parents produced 187 F_2 progenies that segregated into 143 tolerant (Alive) and 44 susceptible (Dead). The reciprocal cross also yielded 168 F_2 progenies that segregated into 132 tolerant (Alive) and 36 (Dead) susceptible (Table 2).

The results of both crosses fitted into 3:1 ratio of 275 tolerant (Alive) and 80 susceptible (Dead) as indicated by the chi-square goodness of fit analysis. The F_1 plants obtained from the cross between TOX 4004 and IR07F102 and the reciprocal also showed tolerance when submerged for 12 days in the screen house. The 157F_2 derived from the cross segregated into 126 tolerant (Alive) and 31susceptible (Dead). The reciprocal cross also produced similar segregation pattern of 142 tolerant and 37 susceptible. The 346 F_2 progenies from the cross and reciprocal segregated into 268 tolerant plants (Alive) and 68 susceptible (Dead) plants in the ratio 3:1, suggesting the involvement of one major gene (Table 2 and 3). No difference in reciprocal crosses in both F_1 and F_2 populations was detected for tolerance to submergence in all the crosses.

DISCUSSION

To incorporate any particular traits into an existing variety, the mode of inheritance of the trait should be known since this will determine the most appropriate breeding method to be used The result of this study, has therefore, unraveled the mode of inheritance of submergence tolerance in rice. A few studies in the past reported dominance of tolerance over non-tolerance and involvement of both major and minor genes in the inheritance (Mohanty and Khush, 1985, Mohanty *et al* 2000) and Mishra *et al*., (1996) found both additive and non-additive gene effects responsible for the inheritance of submergence tolerance.

In one study, the involvement of at least three genes was reported with low to moderate broad sense heritability. In another study, analysis of segregating F_2 and backcross populations made between tolerant and intolerant lines suggested the involvement of one major dominant gene in the

Table 1. List of crosses and number of seeds

S/N	Crosses	Number of seeds
1	WITA 4 X IR05F102(F1)	80
2	IR05F102 X WITA 4(F1)	69
3	WITA 4 X IR05F102(F2)	187
4	IR05F102 X WITA 4(F2)	168
5	TOX 4004 X IR07F102 F1	80
6	IR07F102 X TOX 4004 F1	80
7	TOX 4004 X IR07F102 F2	157
8	IR07F102 X TOX 4004 F2	179

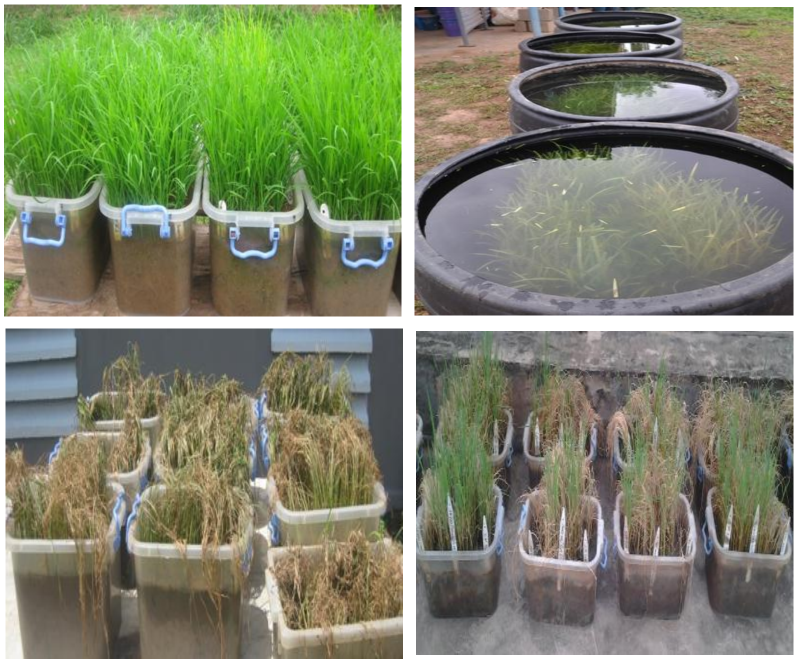

Plate 1. F_2 plants undergoing phenotypic screening

Table 2. Phenotypic distribution of submergence tolerance of F_1, F_2 and their parents

	Number of plants					
Genotype/Crosses	Alive	Dead	Total	Ratio	X^2 computed	P value
WITA 4 (P1)	4	76	80			
IR05F102(P2)	78	2	80			
IR 42(susceptible check)	2	78	80			
WITA 4 XIR05F102(F1)	72	8	80	1:0		
IR05F102 X WITA 4(F1)	66	3	69	1:0		
WITA 4 X IR05F102(F2)	143	44	187	3:1	0.240	0.64
IR05F102 X WITA 4(F2)	132	36	168	3:1	0.260	0.55

Table 3. Phenotypic distribution of submergence tolerance of F_1, F_2 and their parents

	Number of plants					
Genotype Intolerant/tolerant	Alive	Dead	Total	Ratio tested	X^2 computed	P value
TOX 4004(P3)	0	80	80			
IR07F102(P4)	80	0	80			
TOX 4004/IR07F102(F1)	75	5	80	1:0		
IR07F102/TOX 4004(F1)	62	3	65	1:0		
TOX 4004/IR07F102(F2)	126	31	157	3:1	0.266	0.50
IR07F102/TOX 4004(F2)	142	37	179	3:1	0.240	0.56

submergence tolerance of three tolerant lines, FR13A, BKNFR (76106-16-0-1-0) and Kurkaruppan (Setter *et al*. 1997). The results of segregation pattern of these genotypes support the hypothesis that submergence tolerance in FR13A derived line is controlled by a single dominant gene. The F_2 population segregation fits 3:1 phenotypic ratio, with an X^2 value of 0.240 and 0.266 (Table 3). The results implied the action of one dominant gene governing submergence tolerance (Mazaredo and Vergara, 1982; Mohanty and Chaudhary, 1986). Comparing the F_2 progenies of tolerant x susceptible parents with those of the reciprocal cross (susceptible x tolerant).

It was evident that there were no reciprocal differences with respect to the trait studied. This implies the submergence character is controlled by nucleic factor and that there were no maternal or cytoplasmic effects in the inheritance of the trait, hence, any of the genotypes could be used as female parent in crossing as observed by Chen *et. al*, (2006). Submergence tolerance results of the two parental controls and the susceptible check (IR42) were distinct either -tolerant (IR05F102 and IR 07F102) or susceptible (IR 42) (Table 2 and 3)

CONCLUSION

The results of this study, have therefore, unraveled the mode of inheritance of submergence tolerance in rice for rapid enhancement of submergence tolerance among African germplasm through hybridization.

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