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SEEDLING SIZE AND VARIETAL CHARACTERISTICS AS THE TOOLS FOR AVOIDANCE TO SUBMERGENCE STRESS AT SEEDLING STAGE IN RICE

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SUMMARY

The survival and regeneration ability were improved in heavy seedling (low seed rate/unit seed bed area) than that of thin (high seed rate) and medium (intermediate seed rate) category of rice seedlings subjected to complete submergence stress. Heavy seedlings could maintain better shoot and root fresh weight than that of other two category seedlings. The traits for avoidance to submergence stress exhibited by the cultivars had been identified to be slow or minimum degradation of dry matter, chlorophyll content and rapid elongation ability during inundation period. The cultivars with high count of survival ability after the relief of submergence stress had the lower tissue water potential (r = -0.47). TTB 202-4 was identified to be a potential rice cultivar to avoid submergence stress during seedling stage.

Key words **: Chlorophyll content, seedling size, submergence stress, water potential.**

INTRODUCTION

In south and south east Asia, rainfed lowland rice is generally affected by submergence during flash floods. The frequency and duration of floods differ from place to place, year to year causing different degrees of plant mortality. In Assam, the occurrence of flash floods is widespread in wet season in relatively low lying areas where localized excess rainfall and water supplied by nearby rivers interact with impaired natural drainage. This situation leads to complete submergence of the rice seedlings and the situation may even continue for 10-20 days duration. This causes impairement in their physiological processes like photosynthesis, root anaerobiosis, mobilization of stored carbohydrates etc. and kills the seedlings completely. Therefore, such situation warrants for either need of rice varieties having inherent morpho-physiological makeup to tolerate complete submergence stress more so at seedling stage or needs some management practices for avoidance of the submergence stress.

In an update on development of deepwater rice, Kende *et al.* (1998) opined that while studying growth processes in submerged plants, the character elongation capacity needs to be introduced into high yielding cultivars. Setter *et al.* (1997) suggested involvement of few genes responsible for submergence stress tolerance. It was reported by Adak and Dasgupta (2000) that photosynthetic rate, stomatal conductance, intercellular CO_2 concentration decreased in rice varieties subjected to submergence stress. However, no such systematic studies have been pursed with cultivar location specificity in Assam. Therefore, an attempt was made to characterise the growth related physiological behaviour of certain rice varieties to be tolerable to complete submergence stress during seedling stage and to use seedling size as a management tool for avoidance of stress caused by submerged situation.

MATERIALS AND METHODS

Two sets of experiments were conducted during *kharif* season in the year 1999 and 2000 at Regional

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Agricultural Research Station, Titabar under Assam Agricultural University. In case of first set, five genotypes viz., IET10664, IET15265, IET15267, IET15398 and Swarna were tested to find out whether seedling size contributed for submergence tolerance. Seedlings were raised in nursery bed by adopting seed rates of 75,50 and 25 g m^{-2} and accordingly the seedlings were categorised as thin, medium and heavy seedlings respectively. One month old seedlings were transplanted in the main field maintaining spacing of 15x15 cm following recommended package of practices in a split plot design with three replications and after establishment they were subjected to complete submergence stress for a continuous period of 12 days maintaining the necessary water level through irrigation channel.

The parameters viz., seedling height, leaf number per plant, shoot and root fresh weight/100 seedlings were recorded at the time of transplanting. The plant survival count and specific leaf weight (SLW) was recorded immediately after the relief of submergence stress. The regeneration ability was noted 15 days after relief of submergence. The leaf area index (LAI) was determined at flowering stage of the crop.

In case of second set, thirteen genotypes (Table 3) with FR13A serving as the resistant check were germinated in petridishes in the laboratory under submerged situation (full cover of petridishes by water) and the number of seedlings emerged and shoot length were recorded. The seedlings of these genotypes were also raised separately in the nursery beds. Thirty days old seedlings from these nursery beds were transplanted in a cemented tank having dimension 10m x 7m x 1m following recommended package of practices in a randomized block design with three replications. The plant height of the genotypes at the time of submergence ranged from 25 to 42 cm. Ten days after seedling establishment, the seedlings were subjected to complete submergence stress for a period of continuous 12 days, maintaining a water depth of 80 cm in the tank. The survival count, shoot elongation ability at the relief of submergence stress, rengeneration ability at 15 days of relief of submergence stress and tissue water potential (expressed as Kpa, 0.1 Kpa = 1m bar and 0.133 Kpa = 1mm Hg) by Water Status Consol (Model 3005, San Dimas, CA USA), change in shoot dry matter and chlorophyll status was recorded before and after the relief of submergence stress. The chlorophyll content was determined on the second leaf from the top in submerged plants and also in plants before submergence by measuring tissue extract absorbancy in a Spectronic 20 colorimeter and total chlorophyll was calculated following the formula:

$$\text{Total chlorophyll content (mg. g}^{-1}\text{) fresh weight} = \frac{\text{OD at 652 nm}}{34.5} \times \frac{1000 \times V}{W \times 1000}$$

V=Final vol. of chlorophyll extract

W=Fresh weight (g)

RESULTS AND DISCUSSION

The survival and regeneration ability were improved in heavier seedlings than that of thin and medium category of rice seedlings subjected to complete submergence stress (Table 1). The correlation coefficient ($r = 0.51$ and $r = 0.33$ respectively) also supported this contention. The cv. IET 10664 exhibited better survival potential than other cultivars studied. Singh *et al.* (1999) considered high survival p.c. to be a major factor for rainfed low lands submerged rice. However, the cvs. IET 10664 and IET 15267 had inherent capability to regenerate better after relief of submergence stress. Heavy seedlings could maintain maximum (about 3 fold than thin seedlings) shoot and root fresh weight ($r = 0.76$ and $r = 0.58$ respectively) which probably provided an adaptable mechanism for better survival and regeneration ability after relief of submergence stress. Maintaining heavy seedlings perhaps hardened the tissue system leading to maintain high fresh shoot and root weight for better survival under submerged condition.

IET 10664 maintained stable rate of specific leaf weight during its inundation period (Table 2). The cultivar produced a significant higher quantum of stem reserve mobilization (17.7%) as compared to other cultivars. There was degradation of stem reserved carbohydrates in other cultivars after the submergence stress. Ni *et al.* (1991) reported that under condition of prolonged water-logging, chlorophyll degradation takes place more rapidly and imposes a limitation on photochemically generated reductant in the chloroplast thereby diminishing Hill activity and net photosynthesis in rice. The degradation of chlorophyll and shoot dry matter were also observed in all the cultivars except TTB202-4 during submergence period

Table 1. Submergence tolerance characteristics of rice in relation to seedling size.

Genotypes/ cultivars	Seedling category	Plant height (cm)	No. of leaves/plant at transplanting	Shoot fresh wt. (g)/100 seedlings at transplanting	Root fresh wt. (g)/100 seedlings at transplanting	Survival p.c. of plants at relief of submergence stress	Regeneration ability (%)
IET 10664 (V_1)	Thin	42.8	8	85.3	3.1	90.1	93.7
	Medium	40.2	5	150.5	5.9	92.9	95.6
	Heavy	31.4	4	233.3	12.9	96.7	95.1
IET 15266 (V_2)	Thin	41.4	7	52.0	2.6	74.7	83.3
	Medium	36.6	6	112.0	6.0	84.0	84.4
	Heavy	31.2	4	161.7	7.8	93.7	97.1
IET 15267 (V_3)	Thin	42.8	6	37.5	1.8	75.8	86.7
	Medium	36.9	5	104.6	4.1	88.5	91.7
	Heavy	26.6	3	178.6	8.0	85.1	94.5
IET 15398 (V_4)	Thin	31.1	5	46.2	1.7	64.1	79.8
	Medium	30.0	4	72.8	2.6	87.3	93.0
	Heavy	24.1	3	115.5	4.3	91.9	94.5
Swarna (V_5)	Thin	28.5	5	28.5	1.7	60.1	71.1
	Medium	25.6	4	63.5	2.6	55.5	63.0
	Heavy	20.6	3	91.9	3.2	83.6	83.6
Main Plot Mean	V_1	38.1	6	156.3	7.3	93.2	94.8
	V_2	36.4	5	108.6	5.5	84.2	88.3
	V_3	35.4	5	106.9	4.6	80.9	91.0
	V_4	28.4	4	78.1	2.9	81.1	89.1
	V_5	24.9	4	61.5	2.5	66.4	72.6
Sub-Plot Mean	Thin	37.3	6	49.9	2.2	73.0	82.9
	Medium	33.8	5	108.8	4.2	81.7	85.5
	Heavy	26.8	3	156.2	7.2	88.9	93.0
C.D. (0.05)	Main Plot (M)	1.02	0.42	4.62	0.32	7.56	5.17
	Sub Plot (S)	0.79	0.32	4.12	0.21	4.07	3.37
	M in S	7.77	0.72	8.83	0.49	10.59	3.03
	S in M	1.76	0.72	9.22	0.46	9.10	7.53

Table 2. Source related physiological traits in submerged rice.

Genotypes/ cultivars	LAI at flowering	SLW (mg cm^{-2})		Stem reserve mobilization (%)
		Before inundation	After inundation	
IET 10664	3.3	3.2	4.1	13.9
IET 15266	2.9	2.2	2.1	17.7
IET 15267	4.0	3.8	3.9	15.2
IET 15358	3.1	0.8	0.7	11.8
Swarna	3.0	1.1	0.8	11.3
Mean	3.3	2.22	2.32	14.0
C.D. (0.05)	0.59	0.43	1.24	3.56

(Table 4). Therefore, the cultivars exhibiting low or slow degradation of carbohydrate or chlorophyll content during inundation period will be of greater advantage for the farmers in the submerged situation to avoid submergence stress. Adak and Dasgupta (2000) also opined the imbalances of normal plant water relations and productivity due to detrimental effects on photosynthesis in rice varieties subjected to high water stress by submergence. Setter *et al.* (1989) indicated that complete submergence of rice led to low concentration of carbohydrate and reduced growth partly due to low rate of photosynthesis associated with slow diffusion of CO_2 in water and partly due to anaerobiosis, leakage of carbohydrate and high ethylene production.

Another important trait of the cv. TTB202-4 was its good germination vigour (86.5%) and rapid growth of shoot length (14.2cm) (Table 3). This rapid growth was almost at par with the resistant check FR13A (14.7 cm). The p.c. of seedling survival of cvs. TTB202-3 and TTB202-4 was at par with the check FR13A under submerged stress situation maintained in the cemented tank (Table 4). The first five cultivars died because of severe submergence stress. These two cultivars had shoot elongation ability during submerged period to the tune of 9.3 and 12.8 cm, respectively. Such genotypic traits of high survival p.c. and good elongation ability make physiological makeup of the crops to be tolerant to submergence as also envisaged by Singh *et al.* (1999). The notable trait of the cv. TTB202-4 was that it had the inherent capability to regenerate to a considerable degree after the relief of submergence stress. Awasthi *et al.* (1997) reported appreciable genetic variability for flood resistance in the traits like leaf and shoot cuticle thickness, nature of lignification, number of xylem and phloem

Table 3. Germination vigour under submergence stress.

Genotypes/ Cultivars	Seedling emerged (%)	Shoot length after 10 days of germination (cm)
IET 16237	58.3	9.1
IET 16473	31.7	7.3
IET 16474	61.7	9.7
IET 16475	70.0	10.9
IET 16477	58.3	10.3
IET 16481	50.0	16.2
FR13A	60.0	14.7
Sabita	68.3	14.0
Purnendu	65.0	12.3
TTB 202-3	70.0	10.6
TTB 202-4	86.5	14.2
TTB 202.25	80.0	9.9
TTB 202-16	43.4	11.8
CD (0.05)	8.02	3.14

Table 4. Survival potential, shoot elongation ability, regeneration ability, tissue water potential, change in shoot dry matter and chlorophyll concentration in different rice genotypes under submergence stress situation (in cemented tank)

Genotypes/ Cultivars	Seedling survival percentage after 12 days of submergence	Shoot elongation (cm) between start of submergence and immediately after relief of stress	No. of shoots regenerated/ hill	Water potential (KPa) before submergence	Water potential (KPa) after relief of submergence	Change in shoot dry matter (g/10) seedling at relief of submergence)	Change in chlorophyll content (mg/g fr. wt.) at relief of submergence
IET 16237	0	0	0	2300	0	0	0
IET 16473	0	0	0	2200	0	0	0
IET 16474	0	0	0	2400	0	0	0
IET 16475	0	0	0	2200	0	0	0
IET 16477	0	0	0	2100	0	0	0
IET 16481	30.0	14.8	No regeneration	1920	2000	-1.70	-0.005
FR 13A	96.8	7.2	-do-	1920	1400	-0.63	-0.023
Sabita	30.5	No change	-do-	2540	2700	-0.77	-0.03
Purnendu	60.0	-do-	-do-	2460	2400	-1.40	-0.01
TTB 202-3	96.7	9.3	-do-	1940	1800	-1.15	-0.01
TTB 202-4	100.0	12.8	32.0	2000	1500	-0.22	No degradation
TTB 202-25	10.0	7.5	No regeneration	3000	3000	-3.21	-0.043
TTB 202-16	20.0	8.2	-do-	3000	3100	-2.06	-0.048
C.D. (0.05)	15.21	2.43	-	50.8	61.3	-	-

elements, air cavities etc. They were of the view that such anatomical attributes did contribute directly or indirectly to flood resistance in lowland rice by providing a strong mechanical support against fast flowing water currents.

It was interesting to observe that the cultivars with high survival p.c. had the lower water potential value at the relief of the submergence stress (r = -0.47) while the cultivars with higher tissue water potential tended to become susceptible to submerged situation (Table 4). Such effects are due to the fact the osmotic potential of fully submerged leaves when reach above a critical point leads to lower stomatal conductance and intercellular CO_2 concentration, retards carboxylation process as also supported by Hirasawh *et al.* (1996). The result is that the crop become susceptible to submerged situation.

From the study, it can be concluded that maintenance of heavier seedlings and selecting cultivars with high survival p.c., potential regeneration ability coupled with elongation ability, low tissue water potential, minimum degradation of dry matter and chlorophyll content may serve as the basis to avoid submergence stress situation at the seedling stage in low land rice.

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