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Effect of time and duration of submergence on yield and physiological characters of rice

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ABSTRACT

Three newly developed rice cultures for flash flood affected areas of Assam were evaluated for submergence tolerance with respect to the stage of growth and duration of submergence. Experiments were conducted from 2003 to 2006 at Regional Agricultural Research Station, Titabar. The results showed that all the tested lines were at par with FR13A in their tolerance at vegetative stage while two of the lines viz. TTB 202-3 and TTB202-4 could tolerate submergence better than FR13A These cultivars also exhibited slow degradation of chlorophyll, dry matter and carbohydrate contents under submergence. Significant effect of duration of submergence was observed for different yield attributing characters.

Key words: *rice, cultivar, submergence tolerance, flood, growth stage, duration*

Submergence is considered to be the third important damaging abiotic stress in rainfed lowland rice in the world (Widawski and O'Toole, 1990). Flash flood and submergence adversely affect more than 22 m ha of rainfed lowland rice area of the world (Khush, 1984). The average annual yield loss from submergence is estimated to be 80 kg ha^{-1} (Dey and Upadhaya, 1996). Rice in eastern India is predominantly grown under rainfed condition. More than 8 m ha rice area in eastern India is subjected to flash flood and complete submergence (Roy, 1993). In Assam, 0.5 m ha of rice area is chronically flood affected and depending on the intensity and duration of rainfall in the catchments of the Brahmaputra, the Barak and their tributaries, the flood affected areas rise even to the tune of 1.3 m ha. Inundations due to floodwater cause submergence stress in both shallow and medium deep rainfed lowland fields.

Flash flooding refers to a situation where rice crop gets submerged due to sudden increase in flood water for varying periods, normally not exceeding 10-12 days (Senadhira, 1992). Flash flooding occurs mainly during vegetative stage and the period of flooding depends on the intensity and duration of rainfall. Tolerance to submergence in rice is governed by genetical, physiological and environmental factors. Rice varieties respond to submergence differently at different growth stages and duration of flooding (Chaturvedi *et. al*., 1993; 1994; 1996). Mechanisms associated with submergence have been reviewed by Ella *et al*. (2003) and Jackson and Ram (2003). Most of the modern rice cultivars are damaged if they are completely submerged for more than 3 days (Lafitte, 2006). Breeding to improve the tolerance level in the high yielding background has been emphasized for rainfed lowland ecosystem. In an attempt to breed submergence tolerant rice varieties for flash flood affected areas of Assam, three cultivars were developed at Regional Agricultural Research Station (RARS), Assam Agricultural University, Titabar having tolerance level at par with FR13A. In the present investigation, attempt was made to study the response of the newly developed lines to varying duration of submergence at various stages of plant growth and also to examine the influence of submergence on yield and physiological characters.

MATERIALS AND METHODS

The experimental materials consisted of three newly developed breeding lines viz., TTB202-3, TTB202-4 and

TTB202-25 and a resistant check FR13A. A susceptible check Mahsuri and IR42 in the physiological experiment were also included in the study. All the experiments were conducted at Titabar in different years as described below. The experiment was conducted in 2003 and 2004 in the submergence tanks at RARS, Titabar. Ten days old seedlings of the experimental materials grown in earthen pots were submerged for 10 days under 50 cm of water in two replications to subject the test materials to submergence stress in the seedling stage. For each entry, five pots each with five seedlings were grown. For evaluating the materials at other stages of growth, thirty days old seedlings were transplanted in earthen pots with three seedlings in each. Before submergence, the plants were maintained under favourable conditions outside the tank. Five pots for each entry were submerged under 60 – 80 cm deep water at 3, 15, 25, 35 and 60 days after planting in two replications. After 15 days of submergence each set of pots were taken out of water and the survival percentage (%) was determined after 7 days of withdrawing the plants from submergence.

The experimental materials including FR13A as resistant check were germinated in petridishes in the laboratory under submerged condition (petridishes put under water) and the number of seedlings emerged and shoot length were recorded. In another set, thirty days old seedlings of the experimental materials were grown inside concrete tanks in RBD with three replications. The seedlings were submerged under 80 cm of water for a period of 12 days. Thirty days old seedlings were planted in two other sets of 24 pots each. One set of pots was subjected to complete submergence at tillering stage (25DAP) and another set at panicle initiation stage (60DAP) for 12 days each. Change in shoot dry matter content and chlorophyll status before submergence and after relief of submergence stress were estimated in the cultivars. The chlorophyll content was determined on the second leaf from the top of submerged plants and also plants before submergence by measuring tissue extract absorb in a spectronic 20 colorimeter. Total carbohydrate content was estimated on plants before and after submergence on dry weight basis using anthrone reagent and glucose on standard solution.

Another experiment was carried out in 2006. Twenty-five days old seedlings of the test entries along with checks FR13A and Mahsuri were transplanted in earthen pots. After 5 days of planting, pots were submerged under 60 cm of water depth measured from the top of the pots. On the same day, all the entries were transplanted in the main field in two replications. Twenty plants from each entry were planted everyday from the plant lots submerged for 1 to 17 days. In the main field, fertilizer dose of 40: 20: 20 Kg NPK ha^{-1} was applied and the entries were planted in 20 cm × 20 cm spacing in RBD with two replications. Data on days to 50 % flowering, number of ear-bearing tillers per hill, panicle length, number of grains per panicle, 100-grain weight and sterility percentage were recorded. However, the performances in respect of these traits were not recorded for the entries which exhibited very high seedling mortality (<50%).

RESULTS AND DISCUSSION

All the three elite breeding lines were found to be at par with the submergence tolerant check FR13A at all the age-specific observations up to 35 days of planting in both the years of experimentation (Table 1) while susceptible check variety Mahsuri was almost completely knocked down by the stress. Significantly, two lines viz., TTB202-3 and TTB202-4 were even superior to FR13A in their tolerance to submergence at later stage of growth. Chaturvedi *et al.* (1993) reported that there was no cultivar superior to FR13A in submergence tolerance. All the entries except Mahsuri recorded more than 80 % survival at seedling stage. But, they failed to exhibit high survival rate at three days after planting. This was, of course, expected as the period of just three days was too less for the seedlings to get established after transplantation to satisfactorily withstanding the stress. It is also clear from the result that tolerance of the test lines and FR13A gradually improved with increase in duration after planting. This clearly indicates that proper planning on deciding the time of planting of the submergence tolerant varieties may help the farmers to escape damage of flood to a great extent. Chaturvedi *et al.* (1996) and Sharma and Ghosh (2001) also reported that older plants establish well under submergence because they contain more dry matter and carbohydrate. Rice can adapt to complete submergence

Table 1. Submergence tolerance of rice breeding lines at different stages of growth.

Entry	Year	Seedling (10 days old)	Survival (%) after submergence at				
			3 DAP	15 DAP	25 DAP	35 DAP	60 DAP
TTB202-3	2003	80.0	70.0	85.0	94.0	95.1	90.8
	2004	78.9	75.0	88.9	97.0	92.0	78.9
	Av	79.5	72.5	86.9	95.5	93.6	84.8
TTB202-4	2003	85.6	71.0	82.6	96.9	97.8	79.8
	2004	80.2	75.0	85.9	92.0	93.7	75.0
	Av	82.9	73.0	84.2	94.4	95.7	77.4
TTB202-25	2003	84.5	72.0	90.0	98.4	98.3	66.0
	2004	80.2	70.6	88.6	94.5	91.0	59.0
	Av	82.3	71.3	89.3	96.4	94.7	62.5
FR13A	2003	84.0	70.0	90.5	91.9	91.8	60.5
	2004	83.5	77.6	89.8	93.5	92.0	60.0
	Av	83.7	73.8	90.15	92.7	91.9	60.2
Mahsuri	2003	20.0	10.0	0.0	0.0	0.0	0.0
	2004	25.0	19.2	2.0	0.0	0.0	0.0
	Av	22.5	14.6	1.0	0.0	0.0	0.0
P = 0.05	2003	1.98	2.20	5.2	3.60	3.20	5.19
	2004	2.10	3.06	4.66	3.12	2.68	3.24

DAP - days after planting

through processes that provide necessary energy for maintenance of metabolism and minimize loss (Lafitte, 2006). Sharma and Ghosh (2006) also observed that detrimental effect of submergence is high at active tillering stage than at maximum tillering stage.

The study clearly indicated that the newly developed varieties were significantly superior to FR13A in respect of germination vigour (Table 2). The varieties were also at par with the resistant check FR13A in growth of shoot length. The traits like good germination, vigour and good elongation ability make physiological makeup of the crop to tolerate submergence (Singh *et al*., 1999). By and large there

Table2. Germination vigour under submergence stress imposed at seedling stage (pooled over two years)

Entry	Germination (%) under submergence	Shoot length after 10 days of germination (cm)
TTB 202-3	78.5	12.6
TTB 202-4	86.5	14.2
TTB 202-25	80.0	13.2
FR13A	60.0	14.7
IR42	50.0	10.2
P = 0.05	8.02	3.14

was reduction in the dry matter content, carbohydrate content and chlorophyll content in all the entries due to submergence stress irrespective of the time of submergence (Fig. 1, 2, 3). The susceptible variety IR 42 could not be assessed for the trait as none of the plants survived after submergence. The depletion of all these parameters was significantly less in the new lines and at par with check FR13A. Higher survival of new lines, particularly TTB202-3 and TTB202-4 were attributable to lesser degree of degradation of chlorophyll and dry matter accumulation and carbohydrate content during submergence. Ella *et al.* (2003) reported that tolerant varieties have greater ability to retain their chlorophyll content during and after submergence. Low rate of depletion of carbohydrate during submergence are desirable traits for submergence tolerance (Chaturvedi *et al*, 1994). Adak and Dasgupta (2000) reported that photosynthesis and related characters are adversely affected under submergence stress. Slow rate of degradation of carbohydrate, chlorophyll content and dry matter accumulation during the stress period are also reported by various workers (Reddy and Mitra, 1985; Chaturvedi *et al*, 1996; Mallik *et al*, 1995; Haloi and and Dey, 2003). Setter *et al.* (1996) also reported that

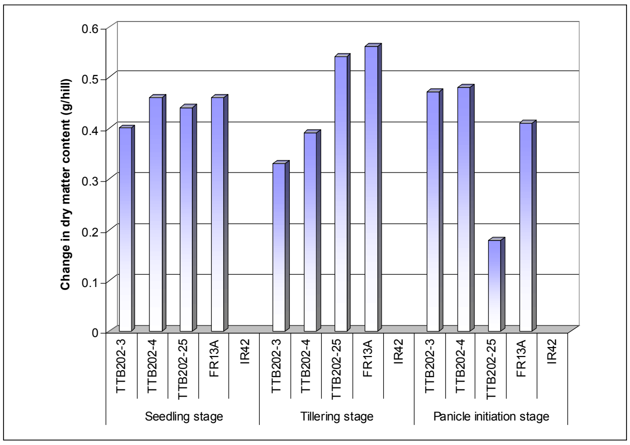

Fig. 1. **Dry matter content of submergence tolerant breeding lines.**

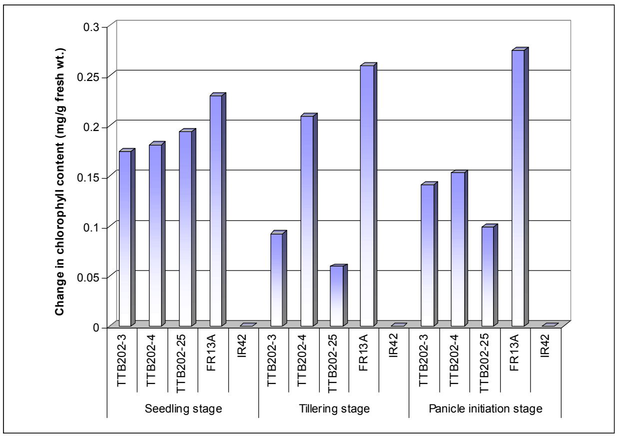

Fig. 2. **Chlorophyll content of submergence tolerant breeding lines.**

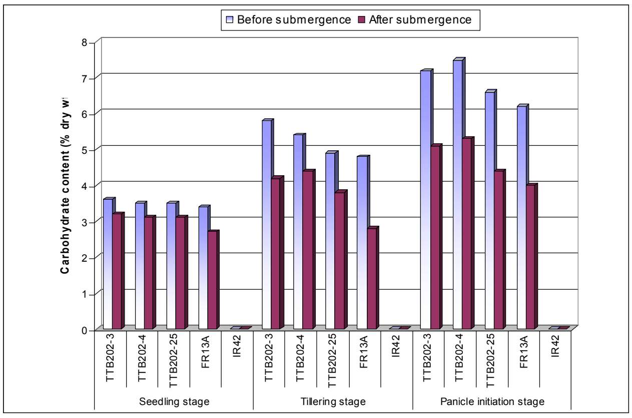

Fig. 3. **Carbohydrate content of submergence tolerant breeding lines before and after submergence**

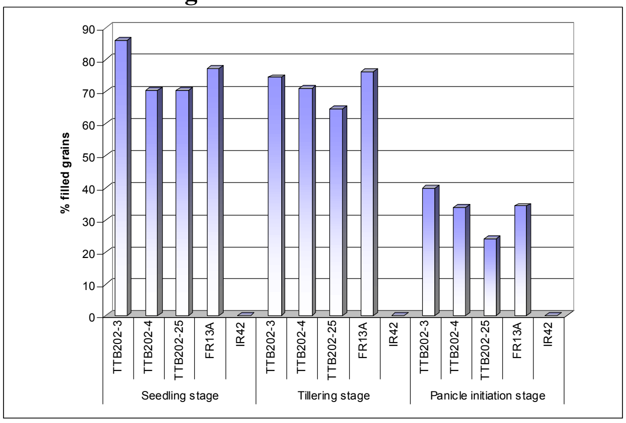

Fig. 4. **Effect of submergence on sterility of submergence tolerant breeding lines.**

carbohydrate is the primary factor in submergence tolerance in rice. The genetic diversity for carbohydrate content in rice germplasm in the present study also showed positive relationship with submergence tolerance.

The filled grains (%) was higher when the cultivars encountered stress at seedling age. Submergence stress increased proportion of chaffy grains if the stress was imposed in tillering stage and maximum chaffy grains were formed when cultivars encountered the stress at PI stage. Proportion of filled grains in new lines was high when they were submerged at early stages. Analyses of variance indicated that the variation in yield attributing traits among the varieties, duration of submergence and their interaction effects were highly significant for all the characters under study. Mahsuri survived only up to 7 days of submergence while TTB 202-3 and FR13A survived up to 15 and 16 days, respectively. Days to 50 % flowering in all the entries increased with increase in stress period in general in comparison to non-submerged counterparts. The extent of prolongation of duration was observed to be maximum when the varieties were submerged beyond 10 days of submergence in all the entries while in susceptible variety Mahsuri, the prolongation was significant beyond 4 days of submergence (Table 3). The results indicated that crop duration got prolonged if the stress period was increased.

In FR13A, the plant height increased due to submergence up to 13 days of submergence (Table 4). Further increase in stress period, however, decreased plant height over control. This trend was not observed for the new breeding lines. In TTB202-3, the plant height decreased from 5 days of submergence while in TTB 202-4 the plant height decreased over control from

Table 3. Effect of duration of submergence on days to 50% flowering

Days of submergence	TTB 202-3	TTB 202-4	TTB 202-25	FR 13A	Mahsuri
0	125.5	125.0	123.5	122.5	109.0
1	125.0	125.0	124.0	123.0	109.5
2	124.5	124.5	123.0	123.5	108.5
3	124.5	123.0	126.0	123.0	108.0
4	125.0	123.0	126.5	123.5	108.5
5	127.0	125.0	126.5	124.0	118.5
6	129.0	124.5	126.0	123.0	117.5
7	130.0	126.5	125.5	123.0	131.5
8	130.5	126.5	125.5	121.5	0.0
9	131.5	126.0	125.0	122.5	0.0
10	131.0	126.0	127.0	122.5	0.0
11	130.5	127.0	127.5	125.0	0.0
12	131.0	127.5	126.5	124.5	0.0
13	132.0	129.0	127.0	124.5	0.0
14	132.5	129.5	126.5	124.5	0.0
15	131.0	130.0	129.0	125.0	0.0
16	0.0	129.5	126.0	126.5	0.0
17	0.0	130.0	127.5	0.0	0.0

CD(0.05) : Variety(V) 0.33; Date of submergence(DOS) 0.63; V X DOS 1.42

Table 4. Effect of duration of submergence on plant height (cm)

Days of submergence	TTB 202-3	TTB 202-4	TTB 202-25	FR 13A	Mahsuri
0	139.90	137.85	129.70	132.80	137.35
1	137.60	137.65	125.70	151.50	138.70
2	139.35	138.45	126.70	148.65	139.55
3	141.00	137.15	126.25	153.60	139.90
4	143.00	137.70	126.15	164.05	137.25
5	134.40	136.00	126.30	167.50	129.20
6	137.85	136.40	129.55	164.80	127.40
7	133.00	137.45	130.35	158.30	121.25
8	133.40	137.05	130.40	156.60	0.00
9	133.00	133.95	130.30	158.30	0.00
10	130.90	133.20	130.75	157.60	0.00
11	120.95	130.70	127.50	157.25	0.00
12	117.70	124.45	126.85	151.55	0.00
13	111.50	123.50	127.75	139.35	0.00
14	101.50	119.50	128.05	129.85	0.00
15	99.50	115.75	127.20	125.05	0.00
16	0.00	110.10	97.00	112.20	0.00
17	0.00	112.50	99.00	0.00	0.00

CD(0.05) : Variety(V) 0.68; Date of submergence(DOS) 1.28; V X DOS 2.86

9 days of submergence. Plant height in TTB 202-25 was lower than non submerged control from one day of submergence. In the susceptible variety Mahsuri there was increase in plant height up to 3 days of submergence but it decreased from 5 days onward. Thus, the effect of submergence on decreasing plant height was minimum on TTB 202-4 followed by TTB 202-3 and TTB 202-25. Non elongation of the plants after the submergence is desirable as they prevent lodging after recession of flood water.

Number of ear bearing tillers per plant was higher in control plants of FR13A, TTB202-3, TTB202-25 and Mahsuri as compared to plants submerged for different duration. In these entries the tillers stared decreasing from 1 day of imposition of submergence. Decrease in tiller number is primarily due to tiller mortality during early tillering stage. In contrary, in TTB 202-4 ear bearing tiller was found to be either at par or more than the plants without submergence (Table 5). Sharma and Ghosh (2006) observed high mortality of tillers in semi dwarf varieties when plants were submerged in active tillering stage. There was very little adverse effect on the resistant entries although there

Table 5. Effect of duration of submergence on ear bearing tillers hill^{-1}

Days of submergence	TTB 202-3	TTB 202-4	TTB 202-25	FR 13A	Mahsuri
0	23.10	17.45	20.35	24.55	16.65
1	19.60	18.05	18.20	12.70	17.25
2	17.65	16.40	15.50	15.20	11.20
3	16.60	20.45	17.60	18.40	12.60
4	16.60	19.50	16.20	15.90	16.70
5	20.40	17.70	16.50	16.75	14.45
6	16.00	17.85	18.20	18.10	14.65
7	18.60	20.65	13.90	17.00	13.05
8	18.80	18.45	16.95	15.20	0.00
9	20.10	20.75	16.20	15.30	0.00
10	21.20	21.40	18.65	16.05	0.00
11	16.20	20.20	17.55	14.40	0.00
12	17.70	20.20	14.85	15.25	0.00
13	15.75	20.80	18.70	15.20	0.00
14	12.85	20.80	15.55	16.55	0.00
15	11.50	10.60	17.65	17.20	0.00
16	0.00	7.75	18.40	13.35	0.00
17	0.00	6.75	11.55	0.00	0.00

CD(0.05) : Variety(V) 0.58 ; Date of submergence (DOS) 1.11; V X DOS 2.48

was reduction in panicle length in TTB202-3 and TTB202-4 panicle length decreased from 13 and 14 days of submergence (Table 6). However, in Mahsuri the there was significant reduction in panicle length due to submergence. The panicle length was not greatly affected by submergence, which might be because of the fact that the cultivars were submerged during vegetative stage only. Panicle length is determined during panicle initiation stage of the crop and the cultivars escaped the stage in the experiment. But the result indicated that the character is influenced by submergence in vegetative stage in susceptible variety.

Table 6. Effect of duration of submergence on panicle length (cm)

Days of submergence	TTB 202-3	TTB 202-4	TTB 202-25	FR 13A	Mahsuri
0	24.38	22.55	21.75	23.65	27.65
1	23.80	22.15	23.05	24.30	24.90
2	24.04	25.25	22.60	24.35	25.40
3	24.73	24.95	23.50	24.75	25.05
4	23.93	24.50	23.20	25.80	25.95
5	22.63	23.30	25.45	25.00	25.10
6	21.78	23.40	25.60	24.70	24.90
7	24.53	22.90	23.30	24.10	26.20
8	24.18	23.35	24.25	25.50	0.00
9	25.83	22.90	25.00	25.65	0.00
10	24.00	23.30	24.00	24.95	0.00
11	23.89	24.25	25.25	25.10	0.00
12	23.41	23.35	25.45	24.40	0.00
13	22.69	23.20	24.20	24.40	0.00
14	21.03	20.75	25.40	26.25	0.00
15	20.78	20.75	22.55	24.20	0.00
16	0.00	21.30	22.45	23.55	0.00
17	0.00	19.80	20.65	0.00	0.00

CD(0.05) : Variety(V) 0.34; Days of submergence (DOS) 0.65; VX DOS 1.46

Grain numbers of TTB202-3 was not reduced significantly due to submergence up to 9 days while in TTB 202-4 it was significantly reduced from 1 day of submergence. In TTB202-25 and resistant variety FR13A too similar trend was observed. The grain number was significantly reduced from second day of submergence susceptible variety Mahsuri. There was drastic reduction of grain number in the panicles in all the cultivars when submerged for more than 10 days (Table 7).The result indicated that the trait is highly influenced by the duration of submergence. The 100 grain weight was affected in TTB 202-3, TTB202-25 and FR13A due to submergence irrespective of duration of submergence. However, in TTB 202-4, effect of submergence duration was not observed up to 6 days. It is the susceptible check Mahsuri there was no significant reduction in test weight up to 4 days submergence (Table 8). The result indicated that there may be some effect of submergence grain size. Test weight was affected due to submergence in larger grains in the experiment up to total period of stress. Effect of submergence on sterility (%) indicated significant increase in sterility from 5 days of submergence in TTB202-4, TTB202-25 and Mahsuri while in TTB 202-3 it increased from 7days of submergence (Table 9). In FR13A the sterility was observed to be significantly higher from 3days of submergence. Significance of interaction effects (Variety x Duration of submergence) in all the characters under study indicates that the effect of submergence depends both on the variety and duration of submergence.

Table 7. Effect of duration of submergence on number of grains per panicle

Days of submergence	TTB 202-3	TTB 202-4	TTB 202-25	FR 13A	Mahsuri
0	216.00	212.50	207.00	249.35	289.00
1	202.50	137.50	124.10	229.40	303.50
2	209.00	123.50	175.50	228.65	227.50
3	209.00	126.00	204.50	212.60	251.00
4	204.00	116.00	201.00	257.25	209.50
5	213.50	117.00	168.50	229.10	195.00
6	208.00	119.00	178.00	226.80	190.50
7	206.00	105.50	191.50	225.00	178.00
8	204.50	106.00	192.00	224.05	0.00
9	209.00	109.00	143.00	230.00	0.00
10	184.00	110.50	115.50	236.30	0.00
11	117.50	112.50	126.50	238.35	0.00
12	106.00	97.50	126.25	174.80	0.00
13	98.50	104.50	106.65	161.25	0.00
14	80.50	104.50	110.00	141.90	0.00
15	93.00	97.50	94.50	134.85	0.00
16	0.00	69.50	96.50	135.20	0.00
17	0.00	65.50	94.00	0.00	0.00

CD(0.05) : Variety(V) 8.66; Days of submergence (DOS) 16.44; VX DOS 36.77

The experimental findings suggest that the developed breeding lines TTB202-3 and TTB202-4

Table 8. Effect of duration of submergence on 100-grain weight

Days of submergence	TTB 202-3	TTB 202-4	TTB 202-25	FR 13A	Mahsuri
0	2.94	2.74	2.85	2.85	1.59
1	2.77	2.71	2.83	2.72	1.63
2	2.65	2.71	2.78	2.59	1.63
3	2.60	2.76	2.50	2.78	1.56
4	2.76	2.76	2.71	2.81	1.58
5	2.82	2.71	2.66	2.77	1.47
6	2.83	2.67	2.76	2.75	1.50
7	2.64	2.49	2.59	2.79	1.55
8	2.70	2.64	2.52	2.77	0.00
9	2.71	2.35	2.69	2.90	0.00
10	2.84	2.38	2.69	2.79	0.00
11	2.73	2.38	2.65	2.81	0.00
12	2.71	2.30	2.67	2.81	0.00
13	2.63	2.29	2.72	2.80	0.00
14	2.59	2.29	2.70	2.65	0.00
15	2.56	2.28	2.69	2.60	0.00
16	0.00	2.16	2.61	2.64	0.00
17	0.00	2.07	2.51	0.00	0.00

CD(0.05) : Variety(V) 0.014 ; Days of submergence (DOS) 0.027; VX DOS 0.060

Table 9. Effect of duration of submergence on sterility (%)

Days of submergence	TTB 202-3	TTB 202-4	TTB 202-25	FR 13A	Mahsuri
0	14.75	8.20	11.00	17.90	11.90
1	19.00	11.05	14.00	21.60	9.00
2	18.50	11.00	15.30	30.05	9.40
3	16.90	11.50	13.25	32.10	11.30
4	14.50	12.50	14.25	28.40	13.45
5	17.15	19.55	18.30	38.10	33.20
6	17.30	20.15	15.55	34.80	28.75
7	21.05	22.90	21.50	39.00	28.75
8	18.65	24.50	23.00	35.00	0.00
9	26.65	22.25	22.65	42.50	0.00
10	35.85	27.20	29.00	43.55	0.00
11	38.90	32.30	35.50	38.10	0.00
12	28.55	30.50	35.00	41.95	0.00
13	38.90	52.50	40.85	44.85	0.00
14	35.70	47.00	36.30	40.00	0.00
15	40.65	57.50	30.65	39.70	0.00
16	0.00	63.50	42.80	48.05	0.00
17	0.00	77.50	48.00	0.00	0.00

CD(0.05) : Variety(V) 0.014 ; Days of submergence (DOS) 0.027; VX DOS 0.060

could tolerate submergence at vegetative stage to the extent that was exhibited by FR13A which is known for its submergence tolerance all over the world. These lines also showed better tolerance than FR 13A in panicle initiation stage. It was also observed that the chlorophyll degradation, dry matter accumulation and carbohydrate depletion during submergence was low in these cultivars that helped in conferring tolerance to submergence. Most of the yields attributing characters were influenced by duration of submergence. But least effect was observed in TTB 202-3 and TTB202-4 and can be grown in flash flood affected rice growing areas.

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