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RESEARCH PAPER

Effect of Panicle Initiation Stage, Submergence on the Morphological Behavior, Number of filled and unfilled grain plant^{-1} of Different Rice Varieties

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ABSTRACT

A pot experiment was carried out at the research farm of Sher-e-Bangla Agricultural University, Dhaka with four replications following randomized complete block design during *Aman* season from July 2018 to January 2019 on medium high land of Sher-e-Bangla Agricultural University to find out the effect of panicle initiation stage submergence on plants morphological and physiological characters. The experiment comprised of two factors as follows: factor A: variety (four tolerant varieties, V_1- FR 13A, V_3- BRRI dhan51, V_4- BRRI dhan79, V_5- Binadhan-11 and one susceptible V_2- BR5), factor B: four submergence treatments (S_0- control, S_1- 4 days submergence, S_2- 7 days submergence, S_3- 10 days submergence). Study reflected that all the parameters were significantly influenced by combined effect of variety and submergence except plant height at 20, 40 DAT and at harvest.

Key words: Rice genotypes, Plant morphology, Submergence, Panicle, filled and unfilled grain

Introduction

Rice is a staple food of more than half of the world's population. More than 3.5 billion inhabitants depend on rice for obtaining 20% of their calorie intake per day (IRRI, Africa Rice and C.I.A.T., 2010). According to the UN projections, the global population will be increased from six to eight billion between 2000 and 2025 (United States Bureau of Census, 1998). This will need to produce an extra 40% more rice by 2025 due to the decrease in rice growth during the 1990s (Brown, 1996, 1997; Fahad *et al.*, 2018). According to the UN the world will need to raise rice production from 439 Mt (milled rice) in 2010 to 496 Mt in 2020, and will further increase to 555 Mt in 2035 (IRRI, Africa Rice and CIAT, 2010).. In Bangladesh, flash flood occurs from mid-June to mid-October during *Aman* season. Submergence is a major constraint for rice production in Bangladesh. In Bangladesh, flash flood occurs during *Aman* season in more or less 18 districts (Iftekharuddaula *et al*., 2009). The negative impacts of submergence on rice plants are reduced ATP production by rapid alcoholic fermentation, limited photosynthesis, carbohydrate starvation, degradation of chlorophyll and mechanical damage (Ella *et al*., 2003). Plant also faces aerobic shock induced photoinhibition, production of reactive oxygen species and accumulation of acetaldehyde after desubmergence (Luo *et al*., 2009). Infusion of SUB1 gene into Swarna rice variety has increased its complete submergence tolerance through the quiescence mechanism (Neeraja *et al*., 2007). Bangladesh Rice Research Institute (BRRI) has developed two submergence-tolerant varieties namely BRRI dhan51 (Swarna SUB1) and BRRI dhan52 (BR11-SUB1) and the Bangladesh Institute of Nuclear Agriculture (BINA) has released another two submergence-tolerant varieties namely Binadhan-11 (Ciherang SUB1) and Binadhan-12 (Sambha Mahsuri SUB1), having the tolerant SUB1 allele can tolerate around 2-3 weeks of flash flooding. BRRI has recently released BRRI dhan79 (BRRI dhan49-SUB1). BRRI dhan79 has the capacity to tolerate around 18-21 days of complete submergence along with 50-60 cm water stagnation tolerance after receding of floodwater at the seedling stage (Iftekharuddaula *et al*., 2015). Therefore, the ultimate goal is to find out morphological and reproductive characters of different rice varieties.

Materials and Methods

The pot experiment was conducted with five different rice varieties from July 2018 to January 2019 on medium high land of Sher-e-Bangla Agricultural University. The materials and methods are as follows:
The experiment has two factors such as
Rice genotype: V1- FR 13A (Tolerant check), V_2- BR5 (Susceptible check), V_3- BRRI dhan51, V_4- BRRI dhan79, V5- Binadhan-11and 2.

Submergence period: S_0 – Control/No submergence (Normal irrigation with other normal practices were applied in this treatment), S_1 – Submergence for 4 days, S_2 - Submergence for 7 days, S_3 - Submergence for 10 days.

The design of the experiment followed was Randomized Complete Block Design (RCBD) with four replications.

Cultivation procedure included Seed treatment, Seedbed preparation, sowing and raising of seedlings, Experimental pot preparation, Fertilizer application, Seedling transplanting, Intercultural operations which were done properly.

Panicle initiation stage was detected by splitting the flag leaf sheath having prior assumption from the reference in the total life cycle of the plant. Panicle initiation stage of V_1, V_2: 66 DAT, V_3, V_4: 55 DAT, V_5: 45 DAT. The plants placed for submergence were V_1, V_2: 67 DAT; V_3, V_4:56 DAT, V_5: 46 DAT.

The experimental pots were kept in the submergence tank according to their panicle initiation stage except the testing pots and plants of control treatments were 4 days, 7 days and 10 days duration. Data were collected before and after desubmergence of the experimental pots.

Harvesting were done properly and following data were collected such as Plant height (cm), Tiller number plant^{-1}, Number of fresh leaves plant^{-1}, Measurement of panicle length plant^{-1}, Weight of panicle plant^{-1}, Oven dry weight of leaf blade, leaf sheath with stem and root plant^{-1}, Total biomass weight plant^{-1}, Number of filled grain plant^{-1}, Number of unfilled grain plant^{-1}.

Statistical analysis

The data were statistically analyzed by STATISTICS-10 computer package program. The significance of the difference among the treatments means were estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Plant height: The highest plant height at 20 DAT and 40 DAT were found in V_1 (FR 13A) variety (60.625 cm and 88.326 cm respectively). The highest plant height at 60, 80 DAT and at harvest were found in V_2 (BR5) that is 102.00 cm, 130.88 cm, and 149.42 cm respectively. The lowest plant height due to varietal effect were found in V_3 (BRRI dhan51) at 20, 40, 60, 80 DAT and at harvest (36.100, 56.549, 72.68, 88.75, 89.29 cm respectively). Statistically significant variations were found in plant height due to submergence at 60 DAT and at harvest but no significant variations were found in plant height at 20, 40 and 80 DAT due to submergence treatment (Table 2). In 20, 40 and 80 DAT the highest plant height were found in S_1 (4 days of submergence) treatment (47.450, 75.163 and 111.70 cm respectively). In case of 60 DAT and at harvest the highest plant height (92.320 and 120.42 cm respectively) were found in S_0 (control) and S_1 (4 days of submergence) treatment. The highest plant height at harvest was found in S_1 (4 days of submergence) treatment which was statistically similar to S_0 (control) at harvest. The lowest (46.615, 105.20) plant height at 20, 80 were found in S_2 (7 days of submergence) and at 40 and 60 DAT lowest (72.868, 89.027) plant height was found in S_0 (control) and S_2 (7 days of submergence) treatment respectively. At harvest the lowest (110.66 cm) plant height was found in S_3 (7 days of submergence). Interaction effect of variety and submergence influenced plant height significantly at 60 DAT, 80 DAT and at harvest but no significant variation were found in plant height due to interaction effect of submergence and variety at 20 DAT and 40 DAT (Table 3). In 20 DAT, 40 DAT and at harvest the highest plant heights (60.725, 91.758 and 153.58 cm respectively) were recorded from the V_1S_0 (FR 13A with control treatment), V_1S_1 (FR 13A with 4 days submergence treatment) and V_2S_1 (BR5 with 4 days submergence) treatment respectively. In 60 and 80 DAT the highest plant height from the interaction effect of variety and submergence were observed from V_2S_2 (BR5 with 7 days submergence) and V_2S_3 (BR5 with 10 days submergence) treatment (104.45 cm and 145.75 cm respectively). Plant heights were measured at 20, 40, 60, 80 DAT and at harvest (Table 1) of all varieties. Significant variations were found in plant height due to the varietal effect.

Table 1. Effect of variety on plant height

Treatment	Plant height (cm) at				
	20DAT	40 DAT	60 DAT	80 DAT	Harvest
V_1	60.625a	88.326a	98.42 b	111.31b	126.54 b
V_2	48.388b	85.651b	102.00a	130.88a	149.42 a
V_3	36.100d	56.549e	72.68 d	88.75 c	89.29 d
V_4	45.169c	71.396c	88.81 c	105.77b	104.99 c
V_5	44.562c	67.583d	87.57 c	102.81b	105.52 c
$LSD_{(0.05)}$	2.9030	2.5939	3.0076	8.9131	4.1045
CV (%)	8.73	4.96	4.73	11.67	5.03

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.

Table 2. Effect of submergence on plant height

Treatment	Plant height (cm) at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
S_0	46.920	72.868	92.320a	106.41	118.10 a
S_1	47.450	75.163	89.151 b	111.70	120.42 a
S_2	46.615	73.162	89.027 b	105.20	111.44 b
S_3	46.890	74.411	89.085 b	108.30	110.66 b
$LSD_{(0.05)}$	2.5965	2.3201	2.6901	7.9722	3.6712
CV (%)	8.73	4.96	4.73	11.67	5.03

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Note: S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence.

The lowest plant height at 20, 40, 60, 80 DAT and at harvest due to interaction effect of variety and submergence were found in V_3S_0 (BRRI dhan51 with control treatment), V_3S_2 (BRRI dhan51 with 7 days submergence), V_3S_2 (BRRI dhan51 with 7 days submergence), V_3S_2 (BRRI dhan51 with 7 days submergence) and V_3S_3 (BRRI dhan51 with 10 days submergence) treatment respectively (34.750, 55.688, 69.47, 83.25 and 87.27 cm respectively).

Table 3. Interaction effect of variety and submergence on plant height

Treatment	Plant height (cm) at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
V_1S_0	60.725a	86.6a-c	98.7a-c	109.50c-f	136.70 c
V_1S_1	59.000 a	91.758a	96.82cd	111.0b-e	128.10 d
V_1S_2	60.450 a	89.085 ab	99.75 a-c	113.00 b-e	125.18 d
V_1S_3	62.325 a	85.785 bc	98.38 bc	111.75 b-e	116.20 e
V_2S_0	47.825 bc	85.408 bc	103.12 ab	124.50 b-d	148.30 ab
V_2S_1	51.925 b	86.577 a-c	103.17 ab	125.75 bc	153.58 a
V_2S_2	48.150 bc	82.930 c	104.45 a	127.50 b	143.03 bc
V_2S_3	45.650 cd	87.690 a-c	97.25 b-d	145.75 a	152.78 a
V_3S_0	34.750 g	57.355 ef	74.05 h	90.50 h-j	92.98 ij
V_3S_1	37.850 e-g	56.705 f	72.98 h	89.25 ij	89.55 ij
V_3S_2	36.025 e-g	55.688 f	69.47 h	83.25 j	87.35 j
V_3S_3	35.775 fg	56.447 f	74.23 h	92.00 f-j	87.27 j
V_4S_0	42.975 c-e	72.738 d	91.93 de	109.33 c-g	109.63 ef
V_4S_1	47.125 b-d	71.690 d	89.60 ef	107.50 d-h	103.32 fg
V_4S_2	45.500 cd	70.227 d	87.99 e-g	105.75 e-i	105.08 f
V_4S_3	45.075 cd	70.928 d	85.72 fg	100.50 e-j	101.93 f-h
V_5S_0	48.325 bc	62.163 e	93.78 c-e	98.25 e-j	102.90 f-h
V_5S_1	41.350 d-f	69.085 d	83.18 g	125.00 b-d	127.53 d
V_5S_2	42.950 c-e	67.880 d	83.48 g	96.50 e-j	96.55 g-i
V_5S_3	45.625 cd	71.202 d	89.85 ef	91.50 g-j	95.10 h-j
$LSD_{(0.05)}$	5.8060	5.1878	6.0151	17.826	8.2090
CV (%)	8.73	4.96	4.73	11.67	5.03

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability. V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.
S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence.

Tiller number per plant: Variety influenced significantly on tiller number per plant at 20, 40, 60, 80 DAT and at harvest (Table 4). The highest number (5.8750 and 23.500) of tillers per plant at 20 DAT and 40 DAT were found in V_3 (BRRI dhan51) treatment whereas the highest (37.813, 39.688 and 39.063) number of tillers per plant at 60, 80 DAT and at harvest were found in V_1 (FR13A) treatment. The lowest number of tillers per plant at 20 and 40 DAT were found in V_1 (FR13A) and V_2 (BR5) treatment respectively which was 3.0625 and 14.375. The lowest number of tillers per plant at 60 DAT and at 80 DAT due to varietal effect were found in V_5 (Binadhan-11) treatment (26.313 and 29.250 respectively). The lowest number of tillers per plant (29.250) at harvest was found in V_3 (BRRI dhan51) treatment. This variation might be because due to variation in genetic makeup of different varieties. The number of tillers plant^{-1} of rice was significantly varied among the submergence treatments at 40, 60, 80 DAT and at harvest but no significant variation was found in tiller number at 20 DAT for submergence treatments (Table 5). At 20 DAT the highest number of tiller was found in S_0 (Control) treatment that was 4.6500. At 40 DAT, 80 DAT and at harvest the highest number of tiller (19.200, 34.450 and 43.200) per plant were found at S_3 (10 days submergence) treatment. At 60 DAT the highest number of tillers per plant was found in S_0 treatment (control treatment) which was 32.400. The lowest number of tiller due to submergence treatment at 20, 80 DAT and at harvest were found in S_1 (4 days submergence) treatment which were 4.3500, 32.650, 31.500 respectively. The lowest number of tillers due to submergence treatment were at 40 DAT and 60 DAT and were found in S_2 (7 days submergence) treatment which were 17.700 and 29.550 respectively. Interaction effect of variety and submergence influenced tiller number significantly (Table 6). The highest number of tillers (41.250 and 45.750) at 60 DAT and 80 DAT were found in V_1S_0 (FR 13A with control treatment) treatment. The highest (6.2500, 25.250, 56.500) number of tillers per plant due to interaction effect of variety and submergence at 20 DAT, 40 DAT and at harvest were found in V_3S_0 (BRRI dhan51 with control treatment), V_3S_1 (BRRI dhan51 with 4 days submergence) and V_2S_3 (BR5 with 10 days submergence) treatment respectively. The lowest number of tillers due to interaction effect at 20, 40, 60, 80 DAT and at harvest were found in V_1S_1 (FR 13A with 4 days submergence), V_2S_3 (BR5 with 10 days submergence), V_5S_2 (Binadhan-11 with 7 days submergence), V_5S_2 (Binadhan-11 with 7 days submergence), and V_5S_1 (Binadhan-11 with 4 days submergence) respectively that was 2.5000, 12.500, 22.000, 24.750 and 26.000 respectively.

Table 4. Effect of variety on tiller number

Treatment	Tiller number at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
V_1	3.0625d	14.750c	37.813a	39.688a	39.063a
V_2	3.6250c	14.375c	29.562b	32.438c	37.125b
V_3	5.8750a	23.500a	27.938c	32.125c	32.750c
V_4	5.5000a	22.937a	30.125b	35.063b	33.063c
V_5	4.8125b	17.500b	26.313d	29.250d	33.500c
$LSD_{(0.05)}$	0.4157	1.1758	1.3328	1.3335	1.2395
CV (%)	12.83	8.92	6.20	5.59	4.99

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.

Table 5. Effect of submergence on tiller number

Treatment	Tiller number at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
S_0	4.6500a	19.100a	32.400a	34.000a	32.050c
S_1	4.3500a	18.450ab	29.650b	32.65 b	31.500c
S_2	4.650 a	17.700 b	29.55 b	33.75ab	33.65 b
S_3	4.650 a	19.20 a	29.80 b	34.45 a	43.20 a
$LSD_{(0.05)}$	0.3718	1.0516	1.1921	1.1927	1.1086
CV (%)	12.83	8.92	6.20	5.59	4.99

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
Note: S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Table 6. Interaction effect of variety and submergence on tiller number

Treatment	Tiller number per plant at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
V_1S_0	3.5000 fg	16.250 ef	41.250 a	45.750 a	41.500 bc
V_1S_1	2.5000 h	12.750 hi	34.250 c	36.000 cd	34.750 d-f
V_1S_2	3.0000 f-h	13.750 g-i	37.000 b	35.750 c-e	37.000 d
V_1S_3	3.2500 f-h	16.250 ef	38.750 ab	41.250 b	43.000 b
V_2S_0	3.7500 ef	14.500 f-i	30.000 def	30.500 h-k	29.750 ij
V_2S_1	3.5000 fg	14.500 f-i	29.250 e-h	31.750 g-j	28.750 jk
V_2S_2	4.5000 de	16.000 e-g	31.500 de	37.750 c	33.500 e-g
V_2S_3	2.7500 gh	12.500 i	27.500 f-i	29.750 i-k	56.500 a
V_3S_0	6.2500 a	22.250 c	26.750 h-j	30.250 h-k	27.250 kl
V_3S_1	5.5000 a-c	25.250 a	29.500 e-g	33.750 d-g	35.500 de
V_3S_2	5.5000 a-c	21.750 c	25.500 ij	29.250 jk	28.000 j-l
V_3S_3	6.2500 a	24.750 ab	30.000 d-f	35.250 c-f	40.250 c
V_4S_0	4.7500 cd	23.750 a-c	32.250 cd	32.000 g-i	31.500 g-i
V_4S_1	5.7500 ab	22.750 bc	28.250 f-h	33.750 d-g	32.500 f-h
V_4S_2	5.2500 b-d	22.000 c	31.750 c-e	41.250 b	35.500 de
V_4S_3	6.2500 a	23.250 a-c	28.250 f-h	33.250 e-g	32.750 fg
V_5S_0	5.0000 b-d	18.750 d	31.750 c-e	31.500 g-j	30.250 h-j
V_5S_1	4.5000 de	17.000 de	27.000 g-j	28.000 k	26.000 l
V_5S_2	5.0000 b-d	15.000 e-h	22.000 k	24.750 l	34.250 ef
V_5S_3	4.7500 cd	19.250 d	24.500 jk	32.750 f-h	43.500 b
$LSD_{(0.05)}$	0.8314	2.3516	2.6656	2.6670	2.4789
CV (%)	12.83	8.92	6.20	5.59	4.99

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Number of fresh leaves per plant just after desubmergence: Number of fresh leaves was taken from each plant after desubmergence except control plants. Fresh leaves just after desubmergence differed significantly due to combination effect of variety and submergence in each variety. In case of 4 days submergence treatment all the variety showed fewer number of fresh leaves than the control variety (Figure 1). In case of 4 days submergence control of BRRI dhan79 showed the highest (165.75) number of leaf and Binadhan-11 with 4 days submergence showed the lowest (100) number of fresh leaves just after desubmergence. In case of seven days submergence treatment all the variety showed fewer number of fresh leaves than the control variety (Figure 2). In case of 7 days submergence control of BRRI dhan79 showed the highest (176) number of leaf which is statistically similar (172) to FR 13A with control treatment and Binadhan-11 with 7 days submergence showed the lowest (97.5) number of fresh leaves just after desubmergence. In case of ten days submergence treatment all the varieties showed fewer number of fresh leaves than the control variety (Figure 3). In case of 10 days submergence control of FR 13A showed the highest (182.5) number of leaf which is statistically similar to BRRI dhan-79 (180.75) with control treatment and Binadhan-11 with 7 days submergence showed the lowest (86.25) number of fresh leaves just after desubmergence.

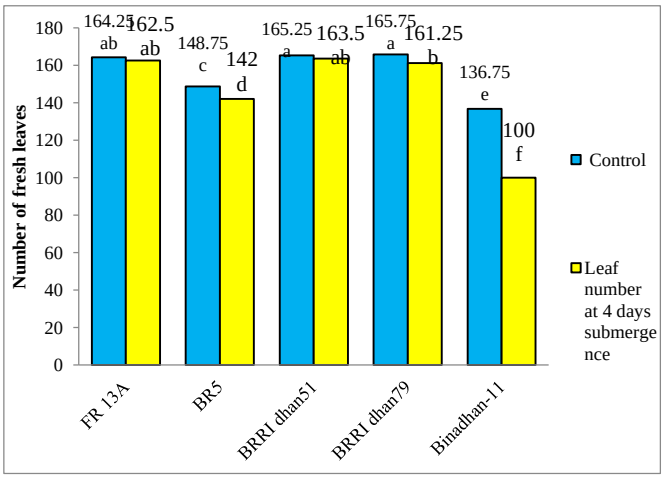

Figure 1. Number of fresh leaf per plant just after 4 days submergence treatment. Values followed by the same letter are not significantly different from each other by LSD at 5% level of significance.

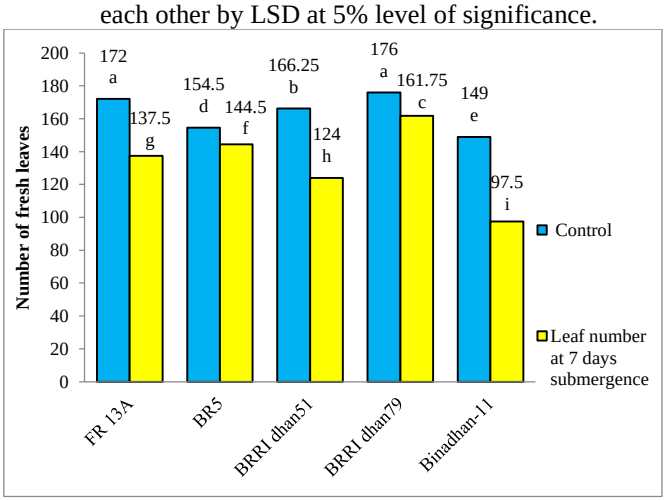

Figure 2. Number of fresh leaf per plant just after 7 days submergence treatment. Values followed by the same letter are not significantly different from each other by LSD at 5% level of significance.

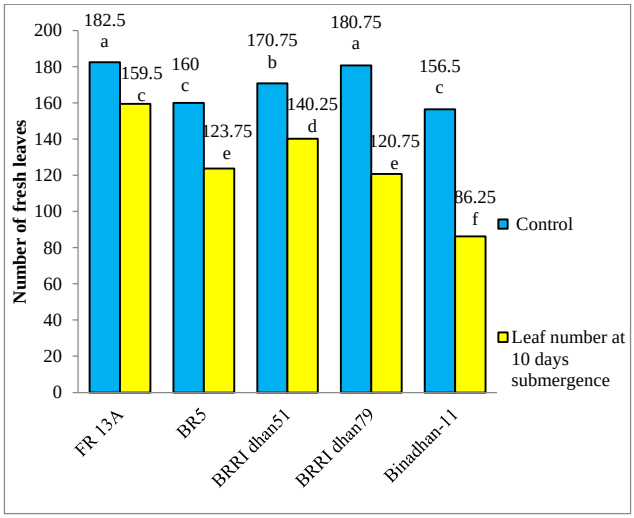

Figure 3. Number of fresh leaf per plant just after 10 days submergence treatment. Values followed by the same letter are not significantly different from each other by LSD at 5% level of significance

Number of effective tillers per plant: Variety influenced significantly on number of effective tillers per plant (Table 7). The maximum (35.875) number of effective tillers was found in V_1 (FR 13A) variety and the minimum (23.188) number of effective tillers was found in V_2 (BR5) variety. Submergence influenced number of effective tillers per plant significantly (Table 8). Maximum number of effective tillers were found in S_3 (10 days submergence) treatment whereas the minimum number was found in S_1 (4 days submergence) treatment which is statistically similar to S_0 (control) and S_2 (7 days submergence) treatment. Interaction effect of variety and submergence influenced significantly on number of effective tillers per plant (Table 9). The maximum (38.750) number of effective tiller was found in V_1S_3 (FR 13A with 10 days submergence) which is statistically similar to V_1S_0 (FR 13A with control treatment) and V_5S_3 (Binadhan-11 with control treatment) those had 37.000 and 37.500 effective tillers respectively. Minimum number (19.250) of effective tiller was found in V_2S_3 (BR5 with 10 days submergence).

Table 7. Effect of variety on number of effective and ineffective tillers per plant

Treatment	Number of tillers per plant	
	Effective	Ineffective
V_1	35.875 a	3.312 e
V_2	23.188 d	13.000 a
V_3	26.875 c	5.750 c
V_4	26.500 c	6.687 b
V_5	28.437 b	5.063 d
$LSD_{(0.05)}$	1.1963	0.4278
CV (%)	6.00	8.94

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.

Table 8. Effect of submergence on number of effective and ineffective tillers per plant

Treatment	Number of tillers per plant	
	Effective	Ineffective
S_0	27.600 b	4.500 c
S_1	26.900 b	5.200 b
S_2	26.950 b	5.450 b
S_3	31.250 a	11.900 a
$LSD_{(0.05)}$	1.0700	0.3826
CV (%)	6.00	8.94

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
Note: S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Number of ineffective tillers per plant: Number of ineffective tillers per plant differed significantly due to variety (Table 7). The maximum (13.000) number of ineffective tillers due to variety was found in V_2 (BR5). The minimum (3.312) number of ineffective tillers due to varietal effect was found in V_1 (FR 13A). Submergence influenced number of ineffective tillers significantly (Table 8). The maximum (11.900) number of ineffective tillers due to submergence was found in S_3 treatment (10 days submergence). The minimum (4.500) number of ineffective tillers due to the submergence effect was found in S_0 treatment (control). Number of ineffective tillers increased with the increasing duration of submergence. The combined effect of variety and submergence influenced number of ineffective tillers significantly (Table 9). The maximum (37.250) number of ineffective tillers was found in V_2S_3 (BR5 with 10 days submergence). The minimum number (1.750) of ineffective tillers was found in V_1S_1 (FR 13A with 4 days submergence) which was statistically similar to V_1S_2 (FR 13A with 7 days submergence), V_3S_0 (BRRI dhan51 with control treatment), V_5S_0 (Binadhan-11 with control treatment) and V_5S_1 (Binadhan-11 with 4 days submergence) those were 2.500, 2.250, 2.250 and 2500 respectively.

Panicle length per plant (cm): Panicle length differed significantly due to the varietal effect (Table 10). The highest (22.991 cm) panicle length was found in V_5 (Binadhan-11) which is statistically similar (22.564 cm) to V_2 (BR5) and the lowest (21.586cm) panicle length was found in V_4 (BRRI dhan79) which is statistically similar (22.098 cm) to V_3 (BRRI dhan51). Submergence influenced panicle length significantly (Table 11). The maximum length (25.167 cm) of panicle was found in S_0 (control) treatment and the minimum (19.362 cm) panicle length due to submergence effect was found in S_3 (10 days submergence) treatment. Interaction effect of variety and submergence influenced panicle length significantly (Table 12). The highest (26.965 cm) panicle length was found in V_5S_0 (Binadhan-11 with control) which is statistically similar (26.895 cm) to V_2S_0 (BR5 with control) and the lowest (18.133cm) panicle length was found in V_2S_3 (BR5 with 10 days submergence)

which is statistically similar (19.178 cm and 19.072 cm respectively) to V_1S_3 (FR 13A with 10 days submergence) and V_5S_3 (Binadhan-11 with 10 days submergence).

Table 9. Interaction effect of variety and submergence on number of effective and ineffective tillers per plant

Treatment	Number of tillers	
	Effective	Ineffective
V_1S_0	37.000 a	4.750 e
V_1S_1	33.250 bc	1.750 g
V_1S_2	34.500 b	2.500 g
V_1S_3	38.750 a	4.250 ef
V_2S_0	25.500 fg	4.250 ef
V_2S_1	24.250 f-h	4.750 e
V_2S_2	23.750 gh	5.750 d
V_2S_3	19.250 i	37.250 a
V_3S_0	25.000 fg	2.250 g
V_3S_1	25.500 fg	9.000 b
V_3S_2	25.250 fg	3.750 f
V_3S_3	31.750 c	8.000 c
V_4S_0	22.500 h	9.000 b
V_4S_1	28.000 de	8.000 c
V_4S_2	26.500 ef	5.750 d
V_4S_3	29.000 d	4.000 ef
V_5S_0	28.000 de	2.250 g
V_5S_1	23.500 gh	2.500 g
V_5S_2	24.750 f-h	9.500 b
V_5S_3	37.500 a	6.000 d
$LSD_{(0.05)}$	2.3926	0.8556
CV (%)	6.00	8.94

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11. S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence.

Panicle weight per plant (gm): Panicle weight differed significantly due to varietal influence (Table 10). The highest (64.077 gm) panicle weight was found in V_1 (FR 13A) which is statistically similar (63.869 gm) to V_5 (Binadhan-11) and the lowest (49.953 gm) panicle weight was found in V_2 (BR5). Submergence influenced panicle weight significantly (Table 11). Maximum weight (75.767 gm) of panicle was found in S_0 (control) treatment and the minimum (42.467 gm) panicle weight due to submergence effect was found in S_3 (10 days submergence) treatment. Panicle weight was decreased with the increased duration of submergence. Interaction effect of variety and submergence influenced panicle weight significantly (Table 12). The highest (79.545 gm) panicle weight was found in V_4S_0 (BRRI dhan79 with control) which is statistically similar (79.165 gm) to V_2S_0 (BR5 with control) and the lowest (10.368 gm) panicle weight was found in V_2S_3 (BR5 with 10 days submergence).

Table 10. Effect of variety on panicle length per plant and panicle weight per plant

Treatment	Panicle length per plant (cm)	Panicle weight per plant (gm)
V_1	21.904 bc	64.077 a
V_2	22.564 ab	49.953 c
V_3	22.098 bc	62.316 b
V_4	21.586 c	61.219 b
V_5	22.991 a	63.869 a
$LSD_{(0.05)}$	0.8721	1.1320
CV (%)	5.54	2.65

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.

Table 11. Effect of submergence on panicle length per plant and panicle weight per plant

Treatment	Panicle length per plant (cm)	Panicle weight per plant (gm)
S_0	25.167 a	75.767 a
S_1	23.310 b	67.570 b
S_2	21.074 c	55.344 c
S_3	19.362 d	42.467 d
$LSD_{(0.05)}$	0.7800	1.012
CV (%)	5.54	2.65

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Note: S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Table 12. Interaction effect of variety and submergence on panicle length per plant and panicle weight per plant

Treatment	Panicle length per plant(cm)	Panicle weight per plant (gm)
V_1S_0	23.505 b	75.090 b
V_1S_1	23.438 b	74.890 b
V_1S_2	21.495 cd	66.932 d
V_1S_3	19.178 e-g	39.398 i
V_2S_0	26.895 a	79.165 a
V_2S_1	24.315 b	69.725 c
V_2S_2	20.913 de	40.553 i
V_2S_3	18.133 g	10.368 j
V_3S_0	24.325 b	71.113 c
V_3S_1	22.840 bc	65.905 d
V_3S_2	21.208 cd	62.663 e
V_3S_3	20.020 d-f	49.585 h
V_4S_0	24.148 b	79.545 a
V_4S_1	21.578 cd	62.110 e
V_4S_2	20.213 d-f	51.275 gh
V_4S_3	20.405 d-f	51.948 g
V_5S_0	26.965 a	73.923 b
V_5S_1	24.380 b	65.218 d
V_5S_2	21.545 cd	55.298 f
V_5S_3	19.072 fg	61.040 e
$LSD_{(0.05)}$	1.7442	2.2640
CV (%)	5.54	2.65

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11. S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Oven dry weight of leaf blades per plant (gm): Dry weight will provide a precise measurement of biomass eliminating fluctuations caused by water content. Plant total biomass can be directly related to our plant performance as a response to photosynthetic capacity, nutrition, environmental conditions, and more. Oven dry weight of leaf blades varied significantly due to variety (Table 13). Maximum (26.077 gm) oven dry weight of leaf blades was found in V_1 (FR 13A) and minimum (10.373 gm) oven dry weight of leaf blades was found in V_5 (Binadhan-11) variety due to varietal effect. Submergence influenced oven dry weight of leaf blades significantly (Table 14). Maximum (17.982 gm) oven dry weight of leaf blades was found in S_2 (7 days submergence) which was statistically similar to S_0 (control) and S_1 (4 days submergence) those were 17.489 gm and 17.365 gm respectively. Minimum (14.927 gm) oven dry weight of leaf blades was found in S_3 (10 days submergence) treatment. Interaction effect of variety and submergence influenced significantly on oven dry weight of leaf blades (Table 15). Maximum (27.682 gm) oven dry weight of leaf blades was found in V_1S_2 (FR 13A with 7 days submergence) which was statistically similar to V_1S_0 (FR 13A with control) and V1S1 (FR 13A with 7 days submergence) those were 24.854 gm and 26.298 gm respectively. Minimum (9.148 gm) number of oven dry weight of leaf blades was found in V_5S_2 (Binadhan-11 with 7 days submergence) which was statistically similar to V_5S_1 (Binadhan-11 with 4 days submergence) and V_5S_3 (Binadhan-11 with 10 days submergence) those were 10.080 gm and 10.142 gm respectively.

Oven dry weight of leaf sheath and stem per plant (gm): Oven dry weight of leaf sheath and stem varied significantly due to variety (Table 13). Maximum (66.740 gm) oven dry weight of leaf sheath and stem was found in V_2 (BR5) which was statistically to (65.892 gm) with V_1 (FR 13A) and minimum (34.248 gm) oven dry weight of leaf sheath and stem was found in V_5 (Binadhan-11) variety which was statistically similar (34.734 gm) to V_3 (BRRI dhan51).Submergence influenced oven dry weight of leaf sheath and stem significantly (Table 14). Maximum (55.552 gm) oven dry weight of leaf sheath and stem was found in S_2 (7 days submergence). Minimum (46.565 gm) oven dry weight of leaf sheath and stem was found in S_0 (control) treatment. Interaction effect of variety and submergence influenced significantly on oven dry weight of leaf sheath and stem (Table 15). Maximum (82.385 gm) oven dry weight of leaf sheath and stem was found in V_2S_2 (BR5 with 7 days submergence). Minimum (27.678 gm) oven dry weight of leaf sheath and stem was found in V_3S_0 (BRRI dhan51 with control) which was statistically similar (30.355 gm) to V_5S_1 (Binadhan-11 with 4 days submergence).

Table 13. Effect of variety on oven dry weight of leaf blade plant^{-1}, oven dry weight of leaf sheath and stem plant^{-1}, oven dry weight of root plant^{-1}, total biomass plant^{-1}

Treatment	Oven dry weight of leaf blade plant^{-1} (gm)	Oven dry weight of leaf sheath and stem plant^{-1} (gm)	Oven dry weight of root plant^{-1} (gm)	Total biomass plant^{-1} (gm)
V_1	26.077 a	65.892 a	30.843 bc	186.90 a
V_2	18.253 b	66.740 a	32.114 b	167.06 b
V_3	12.446 c	34.734 c	29.969 c	139.49 c
V_4	17.554 b	55.470 b	34.620 a	168.73 b
V_5	10.373 d	34.248 c	27.542 d	134.37 c
$LSD_{(0.05)}$	1.1850	1.8654	1.3180	5.1386
CV (%)	9.88	5.12	6.00	4.56

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.

Table 14. Effect of submergence on oven dry weight of leaf blade plant^{-1}, oven dry weight of leaf sheath plant^{-1}, oven dry weight of root plant^{-1}, total biomass plant^{-1}

Treatment	Oven dry weight of leaf blade (gm)	Oven dry weight of leaf sheath and stem (gm)	Oven dry weight of root (gm)	Total biomass plant^{-1} (gm)
S_0	17.489 a	46.565 c	34.460 a	169.99 a
S_1	17.365 a	51.149 b	29.968 bc	165.94 ab
S_2	17.982 a	55.552 a	30.564 b	162.34 b
S_3	14.927 b	52.400 b	29.078 c	138.97 c
$LSD_{(0.05)}$	1.0599	1.6684	1.1788	4.5961
CV (%)	9.88	5.12	6.00	4.56

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability. S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Oven dry weight of root plant^{-1} (gm): Dry weight will provide a precise measurement of biomass eliminating fluctuations caused by water content. Plant total biomass can be directly related to our plant performance as a response to photosynthetic capacity, nutrition, environmental conditions, and more. Oven dry

weight of root plant^{-1} varied significantly due to variety (Table 13). Maximum (34.620 gm) oven dry weight of root plant^{-1} was found in V_4 (BRRI dhan79) and minimum (27.542 gm) oven dry weight of root plant^{-1} was found in V_5 (Binadhan-11) variety due to varietal effect. Submergence influenced oven dry weight of root plant^{-1} significantly (Table 14). Maximum (34.460 gm) oven dry weight of root was found in S_0 (control) treatment. Minimum (29.078 gm) oven dry weight of root was found in S_3 (10 days submergence) treatment which is statistically similar (29.078 gm) to S_1 (4 days submergence) treatment. Interaction effect of variety and submergence influenced significantly on oven dry weight of root plant^{-1} (Table 15). Maximum (48.110 gm) oven dry weight of root plant^{-1} was found in V_5S_0 (Binadhan-11 with control) treatment. Minimum (16.520 gm) number of oven dry weight of root was found in V_5S_3 (Binadhan-11 with 10 days submergence).

Table 15. Interaction effect of variety and submergence on oven dry weight of leaf blade plant^{-1}, oven dry weight of leaf sheath plant^{-1}, oven dry weight of root plant^{-1}, total biomass plant^{-1} and 100 grain weight per plant (gm)

Treatment	Oven dry weight of leaf blade plant^{-1} (gm)	Oven dry weight of leaf sheath and stem plant^{-1} (gm)	Oven dry weight of root plant^{-1} (gm)	Total biomass plant^{-1} (gm)
V_1S_0	25.845 ab	68.755 bc	35.878 d	205.59 a
V_1S_1	26.298 ab	65.920 cd	28.183 ij	195.29 b
V_1S_2	27.682 a	63.355 de	25.300 kl	183.27 c
V_1S_3	24.483 b	65.538 c-e	34.010 d-f	163.43 ef
V_2S_0	20.153 c	51.188 gh	25.173 l	176.03 cd
V_2S_1	20.193 c	69.987 b	39.155 c	199.06 ab
V_2S_2	20.432 c	82.385 a	35.435 d	178.30 c
V_2S_3	12.235 e-g	63.400 de	28.695 ij	114.85 l
V_3S_0	11.685 fg	27.678 m	32.590 e-g	143.06 hi
V_3S_1	12.127 e-g	32.597 kl	28.060 ij	138.81 h-j
V_3S_2	12.535 ef	35.830 jk	27.830 jk	138.86 h-j
V_3S_3	13.438 ef	42.830 i	31.398 f-h	137.24 ij
V_4S_0	17.640 d	49.075 h	30.550 g-i	176.81 c
V_4S_1	18.127 cd	56.885 f	29.832 h-j	166.19 de
V_4S_2	20.110 c	62.067 e	43.328 b	176.76 c
V_4S_3	14.337 e	53.853 fg	34.770 de	155.16 fg
V_5S_0	12.123 e-g	36.130 jk	48.110 a	148.44 gh
V_5S_1	10.080 gh	30.355 lm	24.612 l	130.33 jk
V_5S_2	9.148 h	34.125 jk	20.925 m	134.50 ij
V_5S_3	10.142 gh	36.380 j	16.520 n	124.19 kl
$LSD_{(0.05)}$	2.3701	3.7308	2.6359	10.277
CV (%)	9.88	5.12	6.00	4.56

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability. Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.

S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Total biomass plant^{-1} (gm): Variety influenced significantly on total biomass plant^{-1} (Table 13). Maximum (186.90 gm) total biomass was found in V_1 (FR 13A) and minimum (134.37 gm) of total biomass was found in V_5 (Binadhan-11) due to varietal effect which was statistically similar (139.49 gm) to V_3 (BRRI dhan51).Submergence influenced total biomass plant^{-1} significantly (Table 14). Maximum (169.99 gm) total biomass of plant was found in S_0 (control) treatment which is statistically similar (165.94 gm) to S_1 (4 days submergence) treatment. Minimum (138.97 gm) total biomass plant^{-1} was found in S_3 (10 days submergence) treatment. Combined effect of variety and submergence influenced total biomass plant^{-1} significantly (Table 15). Maximum (205.59 gm) total biomass was found in V_1S_0 (FR 13A with control) and minimum (114.85 gm) total biomass was found in V_2S_3 (BR5 with 10 days submergence) treatment which is statistically similar (124.19 gm) to V_5S_2 (Binadhan-11 with 7 days submergence).

Number of filled grains per plant: Variety had a significant effect on the number of filled grain per plant (Table 16). Maximum (3809.5) number of filled grains per plant was found in V_2 (BR5) and minimum (2161.2) number of filled grains found in V_1 (FR 13A). Submergence had a significant effect on the number of filled grains per plant (Table 17). Maximum (3731.6) number of filled grains per plant was found in S_0 (control) treatment and minimum (1880.2) number of filled grains found in S_3 (10 days submergence). Number of filled grains decreased with the increasing submergence duration (Table 20). Number of filled grains per plant was significantly influenced by combined effect of variety and submergence (Table 18). Maximum (6241.5) number of filled grains per plant was found in V_2S_0 (BR5 with control) treatment and minimum (534.3) number of filled grain found in V_2S_3

(BR5 with 10 days submergence). Due to submergence, the injury level was higher in submerged plants and as a result, their maintenance cost was also higher. As a result, all the spikelets did not get sufficient photosynthates and finally, the number of filled grains become lower than the control treatment. This was also found by Nugara et al. (2012).

Number of unfilled grains per plant: Variety had a significant effect on the number of unfilled grains per plant (Table 16). Maximum (604.88) number of unfilled grains per plant was found in V_2 (BR5) and minimum (209.63) number of unfilled grains found in V_5 (Binadhan-11). Submergence had a significant effect on the number of unfilled grains per plant (Table 17). Maximum (553.60) number of unfilled grains per plant was found in S_3 (10 days submergence) treatment and minimum (333.30) number of unfilled grains found in S_0 (control). Number of unfilled grains increased with the increasing submergence duration (Table 20). Number of unfilled grains per plant was significantly influenced by the combined effect of variety and submergence (Table 18). Maximum (798.75) number of unfilled grains per plant was found at V_2S_3 (BR5 with 10 days submergence) treatment and minimum (149.50) number of unfilled grains found in V_5S_0 (Binadhan-11 with control) which is statistically similar (151.00) to V_5S_2 (Binadhan-11 with 7 days submergence).

Table 17. Effect of submergence on number of filled grains per plant, number of unfilled grains per plant

Treatment	Number of grains per plant	
	Filled	Unfilled
V_1	2161.2 e	305.44 d
V_2	3809.5 a	604.88 a
V_3	2873.7 b	497.00 b
V_4	2627.0 c	454.50 c
V_5	2423.4 d	209.63 e
$LSD_{(0.05)}$	115.28	2.9993
CV (%)	5.86	1.02

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.

Table 17. Effect of submergence on number of filled grains per plant, number of unfilled grains per plant

Treatment	Treatment	
	Filled	Unfilled
S_0	3731.6 a	333.30 d
S_1	3061.4 b	341.00 c
S_2	2442.7 c	429.25 b
S_3	1880.2 d	553.60 a
$LSD_{(0.05)}$	103.11	2.6827
CV (%)	5.86	1.02

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
Note: S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Table 18. Interaction effect of variety and submergence on number of filled grains per plant, number of unfilled grains per plant, number of filled grains per panicle and number of unfilled grains per panicle.

Treatment	Number of grains per plant	
	Filled	Unfilled
V_1S_0	2448.8 fg	225.75 n
V_1S_1	2435.0 f-h	262.75 l
V_1S_2	2165.0 i	245.25 m
V_1S_3	1596.0 j	488.00 g
V_2S_0	6241.5 a	487.00 g
V_2S_1	5593.8 b	458.00 i
V_2S_2	2868.5 e	675.75 b
V_2S_3	534.3 k	798.75 a
V_3S_0	3754.5 c	328.00 j
V_3S_1	2591.0 f	487.50 g
V_3S_2	2572.8 f	529.25 e
V_3S_3	2576.5 f	643.25 c
V_4S_0	3159.8 d	476.25 h
V_4S_1	2482.3 f	283.50 k
V_4S_2	2369.3 f-i	545.00 d
V_4S_3	2496.8 f	513.25 f
V_5S_0	3053.3 de	149.50 p
V_5S_1	2205.3 hi	213.25 o
V_5S_2	2238.0 g-i	151.00 p
V_5S_3	2197.3 i	324.75 j
$LSD_{(0.05)}$	230.56	5.9986
CV (%)	5.86	1.02

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
Note: V_1 – FR 13A, V_2 – BR5, V_3 - BRRI dhan51, V_4 - BRRI dhan79 and V_5 – Binadhan-11.
S_0 – No submergence, S_1– 4 days submergence, S_2 – 7 days submergence and S_3 -10 days submergence

Conclusion

The overall results of the present experiment lead to conclude that different morphological processes were hampered in all varieties due to panicle initiation stage submergence. Changes occurred in both the vegetative and reproductive characters. Number of filled gains at 10 days submergence were highest BRRI dhan51 and lowest at BR5. Reduction of filled grains due to prolonged submergence was also less in BRRI dhan51. As yield is the ultimate goal of any experiment in areas were 4-7 days submergence appear at panicle initiation stage BRRI dhan51 can be suggested to minimize loss.

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