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Screening of Rice Genotypes for Submergence Stress Tolerance

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted at Department of Rice, Tamil Nadu Agricultural University, Coimbatore to study the effect of submergence on growth of various genotypes of paddy. The genotypes viz., AC1303, AC42088, AC38575, SABITA, NAVEEN, SWARNA *Sub1,* BLACK GORA, BAJKANI, SWARNA, PARUAT, PAU9, BRAHMANNAKHI, MAHULATA, BVD109, IET-18720, IET-18727 and IC-516009 lines were used for submergence screening. The seeds should be pre-heated at 50°C for 2-3 days for breaking the seed dormancy before sowing. The seeds were directly sown inside the tanks using wet-bed direct sowing method. Each genotype was sown in 2 rows (min.) with 3 replications with a row to row spacing of 20 cm and plant to plant spacing of 15

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cm. Germinated seedlings were allowed to grown normally till 20–25 days without submergence stress. The observations like plant height (before and after submergence), Number of plants survived (before and after submergence), survival percentage and total starch content were recorded. The genotypes IET-18727, PAU9 and AC38575 had better survival percentage (80.0 to 86.7%) with higher starch content (6.3 to 6.9 mg $g^{-1)}$ under submerged stress conditions. The genotypes of BVD109 and SWARNA registered lesser survival percentage (26.7% and 26.3%) with starch content of 2.1 mg g^{-1} among the rice genotypes.

Keywords: Submergence stress; rice genotypes; morphological; physiological; starch.

1.INTRODUCTION

"Rice is the staple food for more than half of the world's population. Asia accounts for about 90% of the global rice production. India is the second largest rice-growing country after China, with a production of more than 100 million tones. However, with a population of 1.2 billion in 2010, it is likely to be the most populous country on this planet by 2030. India needs to produce 120 million tons of rice by 2030 to feed its one and a half billion plus population by then" [1]. "Providing sufficient food for everincreasing population is possible by raising the productivity of rice under limited natural resources, particularly land and water. In India, rice is mainly cultivated on tiny farms, primarily to meet the family demand. Marketable surplus for meeting the demand of urban populace comes from affluent farmers with large landholdings. Rice production and prices fluctuate widely with the occurrence of drought, flood and many more abiotic and biotic stresses. Among the 42 biotic and abiotic stresses affecting rice production, submergence is considered the third most important constraint for higher productivity in eastern India" [2]. "Excessive flooding poses risks to human life and is a major contributor to the poverty and vulnerability of marginalized communities. During the past five decades, the flood-affected area in India has more than doubled in size from about 5% (19 million hectares) to 12% (40 million hectares) of the total geographic area" [3,4]. "The article focuses on multifaceted problems to which rice crop is exposed during submergence. Due consideration is also given to the use of innovative research approaches to build on the progress achieved so far in germplasm improvement. Rice is generally tolerant to anaerobiosis. However, excessive flooding may result in various environmental stresses that accompany partial or complete submergence [5]. The variations in floodwater characteristics across locations induce different responses in various rice cultivars and, hence, conclusions drawn on their flooding tolerance at one site cannot be extrapolated to other sites" [2]. Flooding from rainwater usually results in clear water and causes less crop damage than that with silted or turbid water. Therefore, comprehensive understanding of the relationship between floodwater qualities and plant survival is useful for developing a suitable package of management practices as well as crop improvement.

2. MATERIALS AND METHODS

A pot study was conducted in the Department of Rice, Tamil Nadu Agricultural University, Coimbatore with the objective to to screen the rice genotypes for submergence stress tolerance at seedling level of selected rice genotypes. Seventeen genotypes *viz.,* AC1303, AC42088, AC38575, SABITA, NAVEEN, SWARNA *Sub1,* BLACK GORA, BAJKANI, SWARNA, PARUAT, PAU9, BRAHMANNAKHI, MAHULATA, BVD109, IET-18720, IET-18727 and IC-516009 lines were used for submergence screening. Two treatments were imposed like., before submergence (T_1) and after submergence (T_2) with three replications. The seeds for the experiment were obtained from Department of Rice, Tamil Nadu Agricultural University, Coimbatore.

2.1 Methodology

"The seeds should be pre-heated at 50 °C for 2-3 days for breaking the seed dormancy before sowing. The seeds were directly sown inside the tanks using wet-bed direct sowing method. Each genotype was sown in 2 rows (min.) with 3 replications with a row to row spacing of 20 cm and plant to plant spacing of 15 cm. Germinated seedlings were allowed to grown normally till 20–25 days without submergence stress. Plant height (average of 5 plants/genotype per replication) and number of hills per genotype per replication (total numbers) were recorded before the imposition of submergence stress. Then the plants were subjected to the submergence stress in the form of standing water. The tanks were filled with 80-100 cm of water and the level of water must be 20-25 cm above the top of the plant canopy. The level of water maintained for 14 days after imposition of submergence stress inside the tanks. After 14 days of submergence stress, water drained out from the tanks (de-submergence), and initially plant height, the number of hills were counted from the plants" (Bayan et al., 2014). Finally, the de-submerged plants were allowed to grow 5 days in normal condition and the numbers of survived hills were calculated for each genotype.

2.2 Observations Recorded

The observations like plant height (before and after submergence), Number of plants survived (before and after submergence), survival percentage and total starch content were recorded before submergence and 14 days after submergence. The methods followed in recording each of these parameters are described below.

2.3 Morphological and Growth Characters

Plant height (cm): The plant height was measured during before and after submergence. The mean values were expressed in cm.

Number of plants survived pot^{-1}: The Number of plants survived was recorded during before and after submergence.

Survival percentage: The survival percentage were calculate as per the given formula and expressed as percentage.

$$\text{Survival \%} = \frac{\text{Number of plants survived after submergence}}{\text{Number of plants survived before submergence}} \times 100$$

2.4 Physiological and Biochemical Parameters

Total starch content: Total starch content of the leaf was estimated during fourteen days after submergence by following the Anthrone reagent method and expressed as mg g^{-1} of fresh weight [6].

Materials:

- *Anthrone:*Dissolve 200mg anthrone in 100mL of ice-cold 95% sulphuric acid
- 80% ethanol
- 52% perchloric acid
- *Standard Glucose:*Stock – 100mg in 100mL water. Working Standard – 10ml of stock diluted to 100mL with water.

Procedure:

1. Homogenize 0.1 to 0.5g of the sample in hot 80% ethanol to remove sugars. Centrifuge and retain the residue. Wash the residue repeatedly with hot 80% ethanol till the washing do not give color with anthrone reagent. Dry the residue well over a water bath.
2. To the residue add 5.0mL of water and 6.5mL of 52% perchloric acid.
3. Extract at 0°C for 20min. Centrifuge and save the supernatant.
4. Repeat the extraction using fresh perchloric acid. Centrifuge and pool the supernatant and make up to 100mL.
5. Pipette out 0.1 or 0.2mL of the supernatant and make up the volume to 1mL with water.
6. Prepare the standards by taking 0.2, 0.4, 0.6, 0.8 and 1mL in each tube with water.
7. Add 4mL of anthrone reagent to each tube.
8. Heat for eight minutes in a boiling water bath.
9. Cool rapidly and read the intensity of green to dark green color at 630nm.

3. RESULTS AND DISCUSSION

The experiment was done in the Department of Rice, Tamil Nadu Agricultural University, Coimbatore-03. The effects of submergence on various genotypes of rice were studied. The plant height, Number of plants survived per pot and survival percentage were studied before submergence and after 5 days of de-submergence. The total starch content was also studied. From the observations, the following results are made.

Plant height: The plant height (in cm) was recorded at before and after submergence and it can be seen that the genotype SABITA has the highest elongation ability which was followed by PAU9, AC38575, and BRAHNANNAKHI under submergence condition. The lowest elongation ability was registered by MAHULATA which was followed by BAJKANI and SWARNA under 14 days after submergence stress condition. These results were in accordance with Akihiko and Eiji Nawata [7] stated that "the increment of plant height affected both submergence avoidance and the duration of submergence".According to Sultana et al. [8] opined that "the increase in plant heights in all genotypes but elogation percentage was less in tolerant genotypes as compared to the susceptible ones. Because, all *Sub1* genotypes can survive very well under complete submergence conditions. Complete submergence stress always induces an increase in plant height in rice. So, all the genotypes under study had more plant heights under submergence stress as compare to the normal conditions".

Number of plants survived per pot and Survival percentage: The result on number of plants survived per pot revealed that, the genotype IET-18727 has the highest number of plants survived per pot (13.7) under 14 days after submergence stress condition which was followed by IC-516009(12.7), PAU9(12.3) and AC38575 (11.7). The genotype BV-D109 registered the lesser number of plants survived per pot (4.7) under 14 days after submergence stress condition which was followed by SWARNA (5.0) and IET-18720 (5.0). The data on survival percentage shown that, the genotype IET-18727 has the highest survival percentage (91.9%) under submergence stress condition which was followed by IC-516009 (84.5%), PAU9 (82.2%) and AC38575 (77.8%). The genotype BV-D109 had the lowest survival percentage (31.1%) under submergence condition which was followed by SWARNA (33.2%) and IET-18720 (33.3%).

Panda et al. [9] reported that "when rice plants are subjected to flash flooding, they need to adapt to two drastic environmental changes: the shift from aerobic to hypoxic conditions during complete submergence and then again from hypoxic to aerobic conditions after the floodwater recedes. Therefore, it is pertinent to understand the physiological processes that are triggered during aerobic → anaerobic transitions. When the plant tissues are subjected to hypoxic or anoxic condition, the oxygen-dependent 22 pathways especially the energy generating systems are suppressed and the functional relationship between root and shoot is disturbed; both carbon assimilation and utilization of photosynthates are suppressed. Tolerant rice cultivars have shown higher regeneration growth in terms of emergence of new leaves and survival percentage".

Total starch content: The highest starch content is obtained in IET-18727 (7.2 mg/g) followed by IC-516009 (6.7 mg/g) and PAU9 (6.6 mg/g). The genotype BVD 109 had the lowest total starch content (2.5 mg/g) which was followed by IET 18720 (2.7 mg/g) and SWARNA (2.7 mg/g). These results are in accordance with Panda et al. [9] who found that, the greater amount of sugar and starch before and after submergence seems to have considerable impact on plant survival and subsequent regeneration (Table 1) [10].

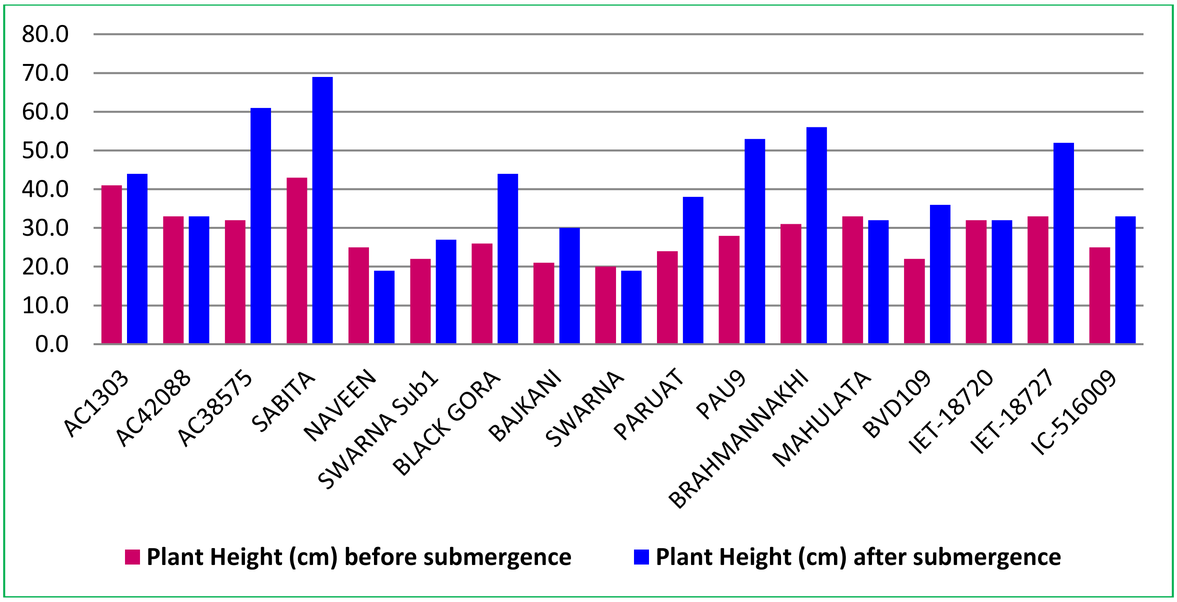

Fig. 1. Screening of rice genotypes on plant height (cm) for submergence tolerance

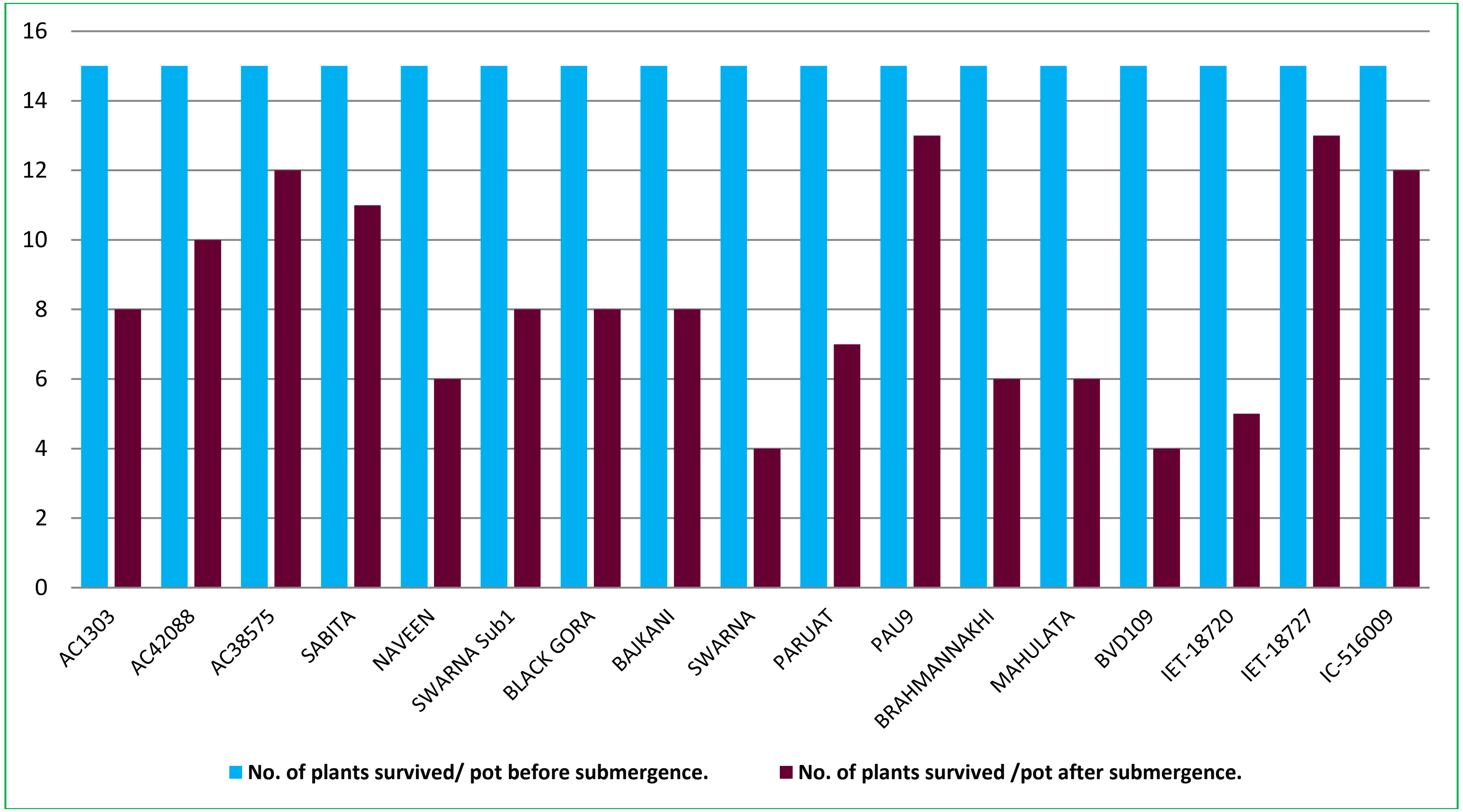

Fig. 2. Screening of rice genotypes on number of plants survived for submergence tolerance

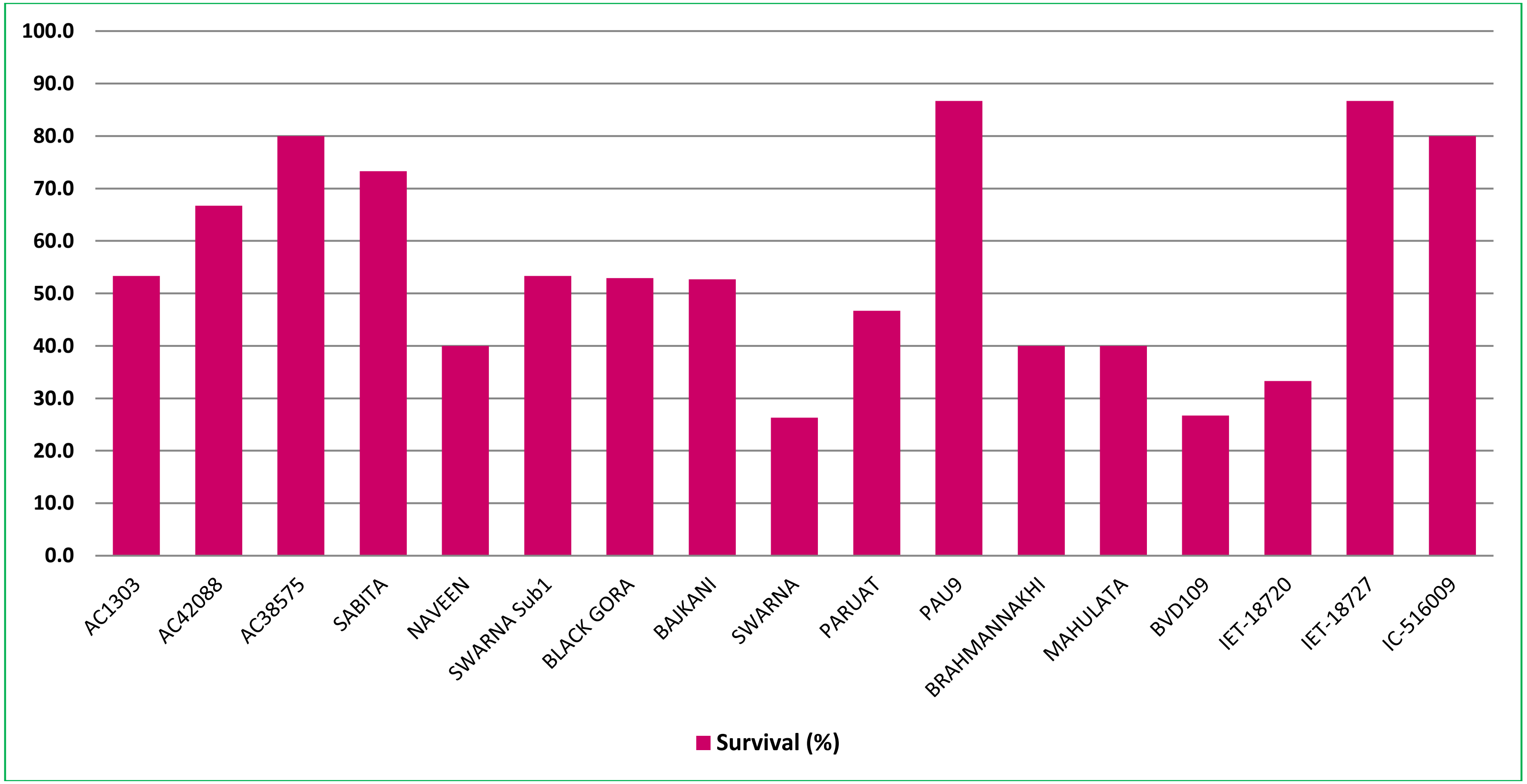

Fig. 3. Screening of rice genotypes on survival percentage (%) for submergence tolerance

Table 1. Impact of rice genotypes on plant height (cm), Number of plants survived, Survival percentage and total starch content for submergence tolerance

Variety	Plant height (cm)		Number of plants survived pot^{-1}		Survival %	Total starch content (mg g^{-1})
	Before Submergence	After Submergence	Before Submergence	After Submergence		
AC1303	35.8	43.0	15.0	8.0	53.3	4.3
AC42088	31.7	35.5	15.0	10.0	66.7	5.3
AC38575	32.9	63.5	15.0	11.7	77.8	6.2
SABITA	39.7	67.4	15.0	10.3	68.9	5.5
NAVEEN	23.2	20.9	15.0	6.0	40.0	3.2
SWARNA *Sub1*	22.3	24.1	15.0	7.7	51.1	4.1
BLACK GORA	26.2	42.1	15.0	7.7	51.0	4.1
BAJKANI	21.4	24.3	15.0	7.7	50.9	4.1
SWARNA	20.5	21.0	15.0	5.0	33.2	2.7
PARUAT	25.1	29.0	15.0	6.3	42.2	3.4
PAU9	28.5	57.9	15.0	12.3	82.2	6.6
BRAHMANNAKHI	30.4	55.6	15.0	6.0	40.0	3.2
MAHULATA	34.0	31.0	15.0	6.3	42.2	3.4
BVD109	23.8	34.5	15.0	4.7	31.1	2.5
IET-18720	30.1	32.5	15.0	5.0	33.3	2.7
IET-18727	31.8	53.0	15.0	13.7	91.1	7.2
IC-516009	30.8	34.3	15.0	12.7	84.5	6.7
Mean	**28.72**	**39.39**	**15.00**	**8.30**	**55.26**	**4.42**
SEd	0.594	0.667	0.131	0.098	1.172	0.0364
CD (0.05)	1.076	1.238	0.273	0.196	2.089	0.0691

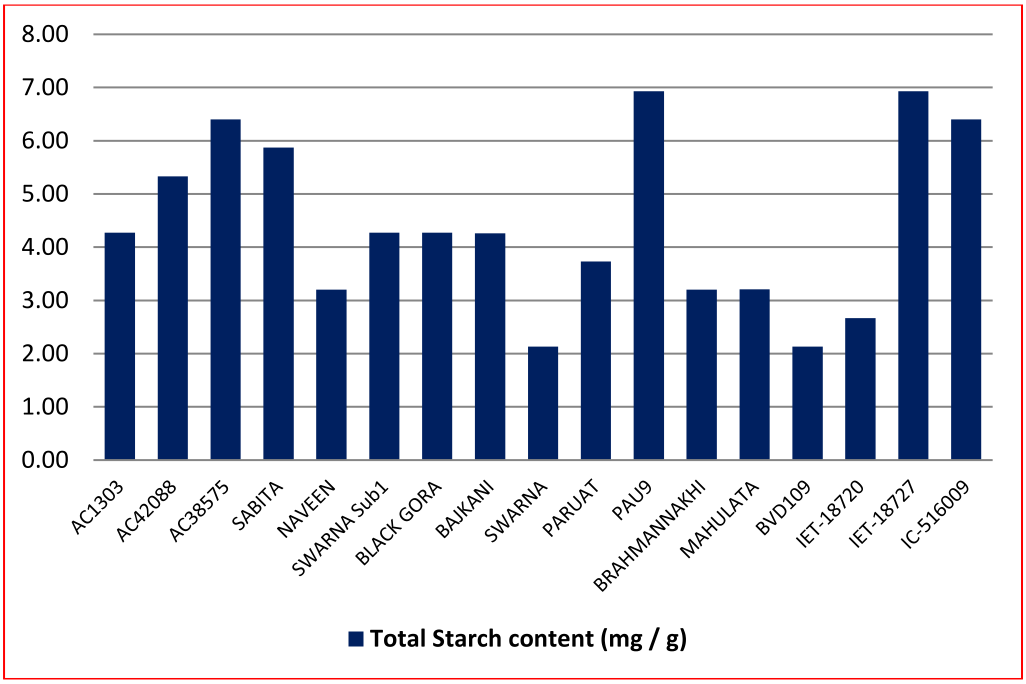

Fig. 4. Screening of rice genotypes on total starch content (mg/g) for submergence tolerance

4. CONCLUSION

The genotypes like IET-18727, IC-516009 and PAU9 are tolerant to submergence stress conditions. Cultivars with higher carbohydrate content at the time of re-emergence were able to develop new leaves very quickly. Total non-structural carbohydrate (sugar + starch) content after submergence showed highly significant positive association with survival percentage and regeneration growth.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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