Understanding Submergence Tolerance of Some Traditional Rice Cultivars at Vegetative Stage

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Abstract

Submergence is an important abiotic stress affecting rice cultivation causing yield losses every year. Although, as a semi aquatic plant, rice is generally intolerant to complete submergence, rice plants die within few days when completely submerged. However, varieties tolerant to complete submergence are capable of surviving under water for about 14 days and recovered after the water recede. This study was conducted to investigate the submergence tolerance in traditional rice cultivars at vegetative stage. Six week old plants were subjected to complete submergence stress for 9 days and 14 days separately. Experiment was conducted according to randomized complete block design with 4 replicates and twenty plants were included in to each replicate. After the complete submergence stress, plants were allowed to recover for 14 days at normal growth conditions. Data were collected on the number of surviving plants, plant height before and after the submergence stress and plant height after the two week recovery period. Out of 20 rice cultivars *Muthumanikam* (100%) *Jamis Wee* (73.0%), *Rajes* (93.7%), *Madael Kalutara* (71.4%), *Lumbini* (80.7%), and *Murunga Wee* (96.1%) recorded more than 70% survival rates at 9 day stress period. *A 6-10-37* (89.5%), *Murunga Wee* (84.3%), *Lumbini* (88.5%), *Jamis wee* (88.1%) and *Wanni Heenati* (70.9%) recorded more than 70% survival rates at 14 day stress period.There was a negative correlation between height gain during submergence stress versus survival percentage at 14 day submerged plants at vegetative stage but not at 9 day submerged plants.

Key words: Traditional rice cultivars, Submergence tolerance, Vegetative stage, Sri Lanka)

Introduction

Rice is one of the leading food crops of the world. Currently, it is the major staple for 2.7 billion people in the world, almost half of the total population of the globe. It accounts for one-fifth of the global calorie supply. Mostly rice is cultivated in upland, lowland, irrigated or deep-water conditions with little or no control of water levels. Rain-fed lowland and deep-water rice together account for approximately 33% of global rice farmlands (http://www.knowledgebank.irri.org/retrieved). In Sri Lanka, about 75 percent of the rice lands are located within inland valley systems and other 25 is located in coastal plains and associated flood plains (Panabokke, 1996).

Submergence is an important abiotic stress affecting about 10-15 million of rice fields in South and South East Asia causing yield losses every year (Dey and Upadhyaya, 1996). This number is anticipated to increase considerably in the future given the increase in seawater level as well as an increase in frequencies and intensities of flooding caused by extreme weather events (Bates *et al.*, 2008). Although as a semi-aquatic plant, rice is generally intolerant of complete submergence, plants die within few days when completely submerged.This is also the case for deep water rice that escapes complete submergence by rapid internode elongation that pushing the plants above the water surface where it has access to oxygen and light to resume the mitochondrial oxidative pathway and photosynthesis.

According to Setter *et al.*, (1997) limited gas diffusion in water is considered to be the principal cause for the adverse effects of submergence. Therefore, tolerance to flooding is associated with the ability to cope with the problems associated with submergence, such as, for example, anaerobiosis, lower carbon assimilation due to less CO_2 and radiation, and high ethylene levels. This is partly achieved by avoidance through maintenance of growth processes leading to elongation of plants to maintain their foliage above water.

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Several morpho-physiological traits have been reported to be associated with submergence tolerance. There are 17 morpho-physiological traits of rice which are associated as part of the mechanism explaining submergence tolerance. These traits were classified in to three groups: pre submergence, during submergence and post submergence traits. Among these, the three important traits are (a) carbohydrate concentration (b) alcoholic fermentation, and (c) elongation of the stem. The favorable effects of high carbohydrate concentration and high alcoholic fermentation are well accepted. Stem elongation does favor avoidance. The elongation mechanism is effective only when the water level remains high for a considerable period, as in deep-water rice culture. It is not desirable under flash-flood conditions, because when the water recedes, the plants tend to lodge (Joshi, 1999).Tolerant rice varieties have been identified already in the 1970s (Vergara and Mazaredo, 1975) and have been used as donors for tolerance by breeders and studies on the tolerance mechanisms ever since. However, few varieties those are tolerant to complete submergence are capable of surviving under water for about 14 days and to recover after the water recedes. The most widely used such a variety is FR13A, a tall, photoperiod-sensitive variety of the aus-type rice from India. Other tolerant varieties are *Kurukarrupan* and *Goda Heenati* from Sri Lanka (Wassamann *et al.*, 1999).Therefore present study was carried out to find out the submergence tolerant rice cultivars at different growth stages in traditional rice gene pool in Sri Lanka.

Materials and Methods

Twenty Sri Lankan traditional rice cultivars obtained from PGRC, Gannoruwa, were used for this study. The experiment was carried out at the Faculty of Agriculture, University of Ruhuna, Mapalana, Sri Lanka.

Seeds were kept at 50 °C for 5 days for dormancy breakage. Seeds were kept in incubator at 35°C under dark condition with enough water for proper germination for 7 days. Experiment was carried out in a randomized complete block design (RCBD) with four replications using 20 seeds per plot.

Uniformly germinated seeds were planted in plastic cups (12 cm diameter, 10 cm height) filled with homogenized soil and maintained them at control growth conditions. Six week old seedlings were subjected to 9 day and 14 day complete submergence conditions (so that the longest leaf of the plant is covered by water) in an outdoor concrete tank separately and control experiment was carried out all along the experiment period. After complete submergence period plants were allowed two week period for recovery under normal conditions.

Green plant height was measured both in stress plants and control plants just before submergence stress, just after submergence stress and after two weeks recovery period. Data were analyzed using SAS statistical software.

Submergence tolerance was measured by the survival percentage (number of survival plants after recovery/ Number of plants before submergence) multiply by 100.

Height reduction or height gain during submergence = Average height of plants just after the submergence stress − Average height of the plants just before the submergence stress

Height reduction or height gain of the plant was calculated as below.

Results and Discussion

There was a significant difference between control plants and submergence stressed plants in average plant height after 9 day and 14 day submergence stresses. *Rajes, Sudu Karayal, Heendik Wee, A 6-10-37* and *Wanni Heenati* survived at 9 day completely submergence stress while reducing the plant height (Figure 1). *Polayal* died after recovery period at 9 day completely submerged condition while reducing plant height.

Sixty five percent of survived cultivars elongated while 30% reduced their height during 9 day submergence period (Figure 2).

The highest plant height gains were recorded by rice cultivar Maha Murunga Badulla, and Kaharamana, during 9 day complete submergence stress. Sudu Karayal, Murunga Wee, Jamis Wee, Kaharamana, Wanni Heenati, and Polayal did not gain plant height during 9 day stress period (Figure 2).

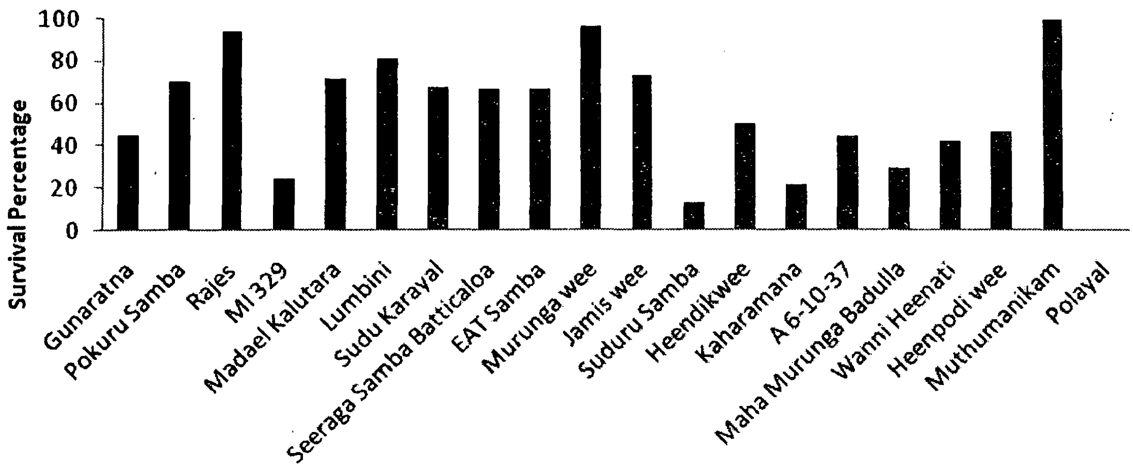

Figure 1. Survival percentage of 9 day submerged plants after the 14 day recovery period

Among 19 survived traditional rice cultivars, 6 cultivars name by Muthumanikam Jamis Wee Rajes, Madael Kalutara, Lumbini, and Murunga Wee recorded more than 70% of survival rates after 9 day submergence period.

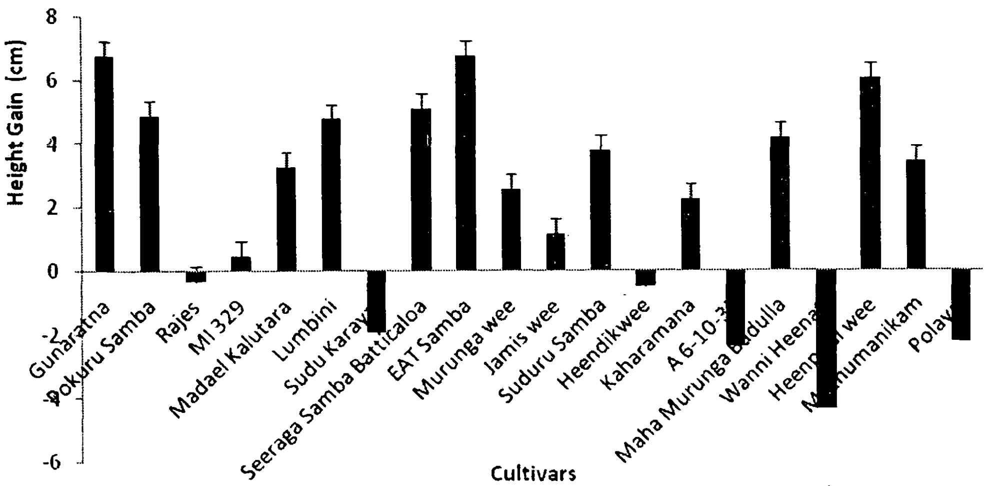

Figure 2. Average height gain/reduction during submergence stress over 9 days in traditional rice cultivars

Among tested rice cultivars 90% of cultivars survived after two week recovery period at 14 day completely submerged plants. A 6-10-37(89.49%), Murunga Wee (84.3%), Lumbini (88.46%), Jamis wee(88.09%) and Wanni Heenati (70.97%) recorded more than 70% survival rates.

Gunaratna, Rajes, Sudu Karayal, Seeraga Samba Batticalo, A 6-10-37 and Wanni Heenati survived at 14 day completely submergence stress while reducing the plant height.

The highest gained plant height was recorded by rice cultivar Kaharamana (60.75 cm) compared to control plant at 14 day complete submergence stress.

According to the Duncun's multiple range test rice cultivars *Murunga Wee (96.16%), Rajes (93.73%), Muthumanikam (100%)* recorded the highest significant survival rate at 9 day complete submergence stress at vegetative stage but at 14 day submergence stress period *Muthumanikam* cultivar was not survived. Rice cultivars A 6-10-37 (89.49%). *Murunga Wee* (84.3%), *Lumbini* (88.46%), and *Jamis wee* (88.09%) recorded the highest significant survival ratesat 14 day submergence stress. Rice cultivar *Polayal* did not survive even at 9 day and 14 day tress period (Table 1).

Among tested rice cultivars 30% and 25% of rice cultivars recorded more than 70% survival rates at 9 day and 14 day submergence periods respectively. Sixty eight percent and 94% survived rice cultivars increased their height during submergence period at 9 day and at 14day respectively.

Table 1. DMRT groupings for survival percentage at two different submergence periods at vegetative stage

Cultivars	9 day submergence	14 day submergence
Gunaratna	45[abcde]	62.78[ab]
Pokuru Samba	70[abcd]	54.54[abcd]
Rajes	93.73[a]	60.29[abc]
MI 329	23.96[bcde]	34.76[abcde]
MadaelKalutara	71.43[abc]	60[abc]
Lumbini	80.77[ab]	88.46[a]
SuduKarayal	67.5[abcd]	57.52[abcd]
Seeraga Samba Batticaloa	66.67[abcd]	27.78[bcde]
EAT Samba	66.67[abcd]	16.67[bcde]
Murunga wee	96.16[a]	84.3[a]
Jamis wee	73.08[abc]	88.09[a]
Suduru Samba	12.5[de]	5.56[cde]
Heendikwee	50[abcde]	55.36[abcde]
Kaharamana	21.67[cde]	28.57[bcde]
A 6-10-37	44.45[abcde]	89.49[a]
MahaMurunga Badulla	29.17[bcde]	4.17[de]
WanniHeenati	42.3[abcde]	68.49[ab]
Heenpodi wee	46.43[abcde]	37.5[abcde]
Muthumanikam	100[a]	0[e]
Polayal	0[e]	0[e]

According to the Duncun's multiple range test rice cultivars *Murunga Wee* recorded the best survival rates at 9 and 14 day submergence stress.

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