**Research Paper**

# Development of Salinity and Submergence Tolerant Rice Lines

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## Abstract

**Paddy fields of costal belt of Wet Zone of Sri Lanka are subjected to submergence during rainy period and saline water intrusions during dry spell. These fields require rice varieties with both salinity and submergence tolerance. To incorporate submergence and salinity tolerance, two crosses At 354/Bg 455 and Ld 12-2-22-2-1-1 / Ld13-5-7 were made during 2014 *Yala* and segregating populations were evaluated at Rice Research Station (RRS), Labuduwa under plant house conditions (by submerging 5 days old seedlings for 10 days and surviving plants subjecting to 12 dS m$^{-1}$ NaCl solutions) at RRS, Bentota and in selected farmer fields under natural conditions. IRRI 119 x Bg 369 and IRRI 64(*Sub1*) x Bg 369 crosses were made during 2015/16 *Maha* and subjected to artificial screening at RRS Labuduwa for both submergence and salinity. From the four crosses 10 lines were selected and screened for salinity and submergence tolerances. Best performing lines were evaluated for yields at RRS Labuduwa during 2018/19 *Maha*, 2019 *Yala* and 2019/20 *Maha*, and at Thunduwa and Rathgama farmer fields in 2019/20 *Maha*. SS $_4$- 4, $S_2$ $B_7$ (red), $C_1$ - 33, $C_2$ - 20, and $SS_3$-26-1 were identified as tolerant to salinity. $S_2B_7$ (red), $S_2B_7$ (white) and $N_1$ $F_2$ 1 were identified as submergence tolerant lines. $S_2B_7$ (red) identified as the variety consisting of both salinity and submergence tolerance and better yields.**

**Keywords:** **Rice lines, Salinity, Submergence**

## Introduction

Paddy fields close to river basins of costal belt of Sri Lanka are subjected to salinity and submergence stress alternately within same season due to effects of flood and sea water intrusions. This causes physiological and biochemical changes in plants to counter stress conditions. It affects growth, development and productivity of plants by reducing the actual gene potential (Kazan, 2015).

Flash floods, a rapid surge of water that subsides after several days and lasts no longer than 10 days, are common phenomena in some parts of Wet Zone. In Sri Lanka, 0.2 million ha were destroyed in 2010/2011 *Maha* and 2013, approximately 75,000 ha of paddy lands had affected by flood (Samarasinghe *et al*., 2014). Salinity stress is incurred in coastal areas due to the intrusion of seawater to paddy fields. Salinity stress affects nearly 20% of the total cultivated land area worldwide (FAO, 2008).

To overcome the submergence and salinity stresses in paddy fields of costal belt of Low Country Wet Zone, it is essential to develop varieties with both salinity and submergence tolerance.

## Materials and Methods

### Development of rice lines under natural and artificial submerge and salinity conditions

Two crosses were made at Rice Research Station (RRS) Labuduwa using salt tolerant parents At 354 and Ld 12-2-22-2-1-1 (At 401/Ld7-18-7-2) and two submerge tolerant parental varieties Bg 455 and Ld 13-5-7 (Swarna-*sub1*/Ld6-19-12-2) as At 354/Bg 455 cross 1 ($C_1$) and Ld 12-2-22-2-1-1 / Ld13-5-7 cross 2 ($C_2$) during 2014 *Yala* and $F_1$ generation advancements were carried out in 2014/15 *Maha*. Bulk seed samples of $F_2$ were subdivided and portion of seeds was treated with 45 dS $m^{-1}$ EC concentrated salt solutions for 9 days and washed of thoroughly (Abesiriwardena, 2004). Both salts treated (ST) and non-treated (NST) populations of the two crosses advanced. Seeds of $F_2$ plants were harvested separately for (ST) and (NST) seeds to form $F_3$. Portion of $F_3$s again subdivided and one part were treated with salt as in the previous season and the other part was remained untreated with respect to seed collected from each $F_2$. $F_3$ populations with respect to two crosses and the relevant parents were evaluated in the RRS Labuduwa field during 2015/16 *Maha* and selections were carried out from each population. Genetic variability studies were carried out based on the $F_2$ and $F_3$ population (Deleepani *et al*., 2020). In parallel part of $F_3$ populations which consisted with non- salt, and salt treated were tested in Regional Research Station Bentota and selected farmer fields of Thunduwa of Bentota river basin with existing salinity and submerge conditions during 2015/16 *Maha*. Artificial submergence started from $F_4$ generation advancements at Regional Research Station Labuduwa during 2016 *Yala*, selected seeds of each population of two crosses was germinated and 5 days old seedlings were subjected to 10 days of submergence in glass tanks. After 10 days of submergence plants were de-submerged and the survived plants were treated with 12 dS $m^{-1}$ NaCl solutions. Survived plants after both treatments were planted in the field and seeds were harvested. In parallel $F_4$ generation advancement of selected lines of Regional Research Station Bentota, farmer fields of Bentota and portion of RRS Labuduwa selections were evaluated under natural salinity and submergence conditions at Regional Research Station Bentota. $F_5$ generation advancement carried out during 2016/17 *Maha* using the same procedure of previous season at RRS Labuduwa. In parallel to the $F_5$ evaluations which were of selections of $F_4$ of RRS Bentota carried out at RRS Bentota and portion of $F_4$ selections of Regional Research Station Labuduwa were evaluated at Farmer fields of Bentota.

Second set of crosses were made using different salinity and submerge tolerance parents (IRRI 119 x Bg 369 and IRRI 64 (*Sub1*) x Bg 369) during 2015/16 *Maha* and $F_1$ generation advancement was carried out 2016 *Yala*. From $F_2$ generation to $F_5$ screening was carried out artificially at RRS Labuduwa as described for the previous crosses. During 2018 *Yala* screening survived plants were planted and seeds of selected single plants were selected to establish the progeny lines (SS 3 lines form cross IRRI 64 (*Sub1*) x At 354 and SS 4 lines from IRRI 119 x Bg 369) in 2018/19 *Maha* as $F_6$.

**Evaluation of rice lines for salinity and submerge tolerance**

During 2017 *Yala*, lines which were selected from RRS Labuduwa, RRS Bentota and from farmer field evaluations were established at RRS Bentota as three row progenies. Line designations were given according to cross and place of selections (lines initiated with $C_1$.., $N_1$..and $S_1$.. were belonged to At 354/Bg 455 cross, $C_2$.., $N_2$.. and $S_2$.. were developed from Ld 12-2-22-2-1-1 / Ld13-5-7 cross and initials followed by B indicated RRS Bentota and F indicted farmer fields).

These lines were subjected to natural selection conditions at RRS Bentota and lines were selected based on morphology (Seeds per panicle, number of panicles per plant, plant height and non-lodging type). During 2017/18 *Maha* the selected lines along with 4 parents were again transplanted at RRS Bentota field and subjected to 10 days submergence. Furthermore, these lines were artificially screened at RRS Labuduwa by subjecting submergence and salt treatments as previous. By considering the results of both Regional Research Station Bentota and Regional Research Station Labuduwa, better lines were identified for further evaluations.

Further screenings were carried out during 2019/20 *Maha* for salinity and submergence using forty two lines developed from above 4 crosses, seven respective parents and 3 reference as non- replicated evaluation. Germinated 25 healthy 10-day old seedlings were subjected to salinity stress by immersing in a salt solution of 12 dS $m^{-1}$ up to seven days. Ten selected rice lines which showed the best recovery were evaluated in Complete Randomized Design (CRD) using three replicates using Ld 365 and At 354 as salinity tolerant control. Symptomless plant counts were recorded in salt treated trial after 7 days of salinity induction.

Preliminary screening for submergence were carried out for selected 52 rice lines by planting each rice line in single pot. Ten days old seedlings were subjected to complete submergence stress for 10 days inside glass tank. De-submerged plants were given a seven days recovery period. Eight selected lines which showed the best recovery, Ld 365 and reference rice variety for submergence, IRRI 64 (*Sub1*) evaluated in Complete Randomized Design (CRD) with three replicates of ten plants pots per each line and subjected to submergence of 10 days. Simultaneously same lines were evaluated without submergence using three replicates. Seedling height, root length, leaf area of upper most leave, fresh weight and dry weight were recorded using 5 plants per each replicate for both submergence (7 days after de-submerge) and non- submerged and salinity (seven days after salinity induction) non- salinity evaluation trials.

### Yield performances of selected lines

Lines with better tolerance and better yield characteristics were advanced to Major Yield Trials at Regional Research Station Labuduwa to find out yield performance in non-affected conditions and at RRS Bentota and in selected farmer fields of Bentota and Rathgama under existing salinity and submerge conditions during 2018/19 *Maha*, 2019 *Yala* and 2019 /20 *Maha*. Farmer evaluation based on visual observations in milking stage was carried out at Rathgama field by voting each variety in the trial by putting a voting card containing " √ " for preferred variety and " x" for less preferred variety. A matrix ranking also carried out to compare each variety.

Analyses of variance were carried out separately for salinity treated, and non-treated replicated trials and submerged and non-submerged trails and yield trials using SAS 9.1.3. Individual mean comparisons were performed per each line for treated and non-treated of each stress by T- tests with MINITAB 15. SPSS 16 used for Friedman test of ranked data.

## Results and Discussion

It was expected to incorporate both salinity and submerge tolerance to same variety by using relevant submerge and salinity parents. Site specific selection was targeted to screen the segregating populations and the developed lines to give the natural selection conditions to identify the best adapted lines for the area. During the selection process both submergence and salinity occurrence were studied using $F_3$ generation at farmer fields and RRS Bentota. Natural submergence condition (more than ten days submergence) were observed during early seedling stage of rice plants. During the flowering (8-9 dS $m^{-1}$) salinity was observed hence, considerable selection pressure was incurred during the season. From 2016 *Yala* to 2017/18 *Maha* submergence was occurred for more than 10 days and selection pressure was incurred but the level of salinity ranged 2-4 dS $m^{-1}$ and selection pressure for salinity was low. A artificial screening of segregating populations and lines for both salinity and submergence at RRS Labuduwa were provided better selection pressure on them.

Performances of selected lines from the preliminary evaluations in replicated trials under salt treated and non-salt condition and submerged and non-submerged conditions are presented in Table 1 and 2, respectively. In the salinity screening evaluations there were significant difference among varieties for symptom less plants under 10-12 Ec conditions, At

354 has shown the best result. $C_1$ 33, $SS_4$ and $S_2B_7$ also recorded above 40% symptom less plants.

Islam *et al*., (2007) observed the differences in plant height of rice varieties with different salinity levels. In this study mean comparison between salt and non-salt conditions per each variety At 354, $SS_3$, $C_2$ 20 and $SS_4$-4 were not significant for t-test for the plant height character that indicates that the capabilities to withstand salinity conditions without having much compensation to the height of the plant. When consider the root length At 354, $C_1$-33, $C_2$ -20, $SS_4$-4, and $S_1F_3$- 2 did not differ significantly between salt treated and non-salt condition in each individual comparison that indicates the capability of adjusting to the salinity stress. According to Wang *et al*., 2008, salinity stress regulates the formation and development of roots, the first ones, which are exposed to salinity stress. Leaf area is reduced under saline conditions due to the shrinkage of cells, reduction of development and differentiation of cells, unbalanced nutrients and damage of cell membranes (Ali *et al*., 2004). Hasamuzzaman *et al*.,(2009) reported that leaf area index of different rice varieties decreases with the increase of salinity levels. These results also have shown the similarities with results appeared in Table 1. Some varieties $S_2B_7$ red, $S_1F_3$ 2, $SS_4$-4, SS 4-2 and $SS_3$-26-1 were not significantly different under salt and no salt conditions and it indicates the withstand of salinity without considerable leaf damage. $S_1$ $F_3$ 2 and $C_2$ 43 showed significantly different fresh weight of seedling under salt and non-salt conditions. $C_2$ 43, $N_2$ $B_4$, $SS_3$-26-1, $SS_4$ -4, $S_1F_3$ 2 and $S_2$ $B_7$ did not show significant variation for dry weights under salt and non-salt condition. Yet At 354, $C_2$ 20 and Ld 12-2-22-1 reported significant difference for the individual t-test.

When symptomless plant percentage and mean performances of seedlings under salt and non-salt condition were considered At 354 was found to be the best variety for salt tolerance. Individual comparisons for plant height and root length were not significant for this variety for both salt and non-salt comparisons. At 354 variety recorded higher dry weight under salt treated conditions, showing the withstanding for salinity. Further $SS_4$-4, $S_2$ $B_7$ (red) $C_1$ 33, $C_2$ 20, and $SS_3$-26-1 recorded better survivals with symptom less plants and comparable mean performance for other characters with At 354. T- test was not performed for Ld 365 due to survival counts were low under salt treated condition.

There was significant difference for survival percentage for submergence among tested lines. $S_2B_7$ (red), IRRI 64 (*sub1*), $S_2B_7$ (white) and $N_1F_2$-1 recorded better survival. When considered the submerged and non-submerged conditions for plant height character, except $C_2$ - 42 other varieties did not show significant results. Maintaining minimum shoot elongation and a higher level of stored carbohydrates is a submergence tolerance mechanism (Das *et al*., 2005).

$S_2B_7$ (white) and $SS_4$-2 were the highest root length recorders. Except $N_2B_4$ other varieties did not show significant variations in root length under submerged and non-submerged conditions. Since data were taken after 7 days of de-submergence all the varieties showed increased root length.

**Table 1. Mean performance of agronomic characters of selected rice lines for salt treated and no salt condition and individual mean comparison of each variety under salt and no salt condition in seedling stage during 2019/20 *Maha***

| Rice line | | Seedling height (cm) | | | Root length (cm) | | | Leaf area of uppermost leaf (cm2) | | | Fresh weight of seedlings (g) | | | Dry weight of seedlings (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Symptomless plant percentage | Salt | Non-salt | P value | Salt | Non-salt | P value | Salt | Non-salt | P value | Salt | Non-salt | P value | Salt | Non-salt | P value |
| At 354 | $50^{a}$ | $21.00^{a}$ | $21.23^{f}$ | 0.68 | $5.37^{a}$ | $5.7^{bcde}$ | 0.43 | $4.73^{ab}$ | $6.6^{cd}$ | 0.01 | $0.67^{a}$ | $0.73^{bc}$ | 0.68 | $0.31^{ab}$ | $0.13^{cd}$ | 0.00 |
| $C_1$ - 33 | $46.7^{a}$ | $23.40^{a}$ | $25.13^{bc}$ | 0.02 | $3.37^{abc}$ | $4.2^{fg}$ | 0.17 | $4.01^{ab}$ | $7.93^{ab}$ | 0.02 | $0.60^{a}$ | $0.77^{bc}$ | 0.25 | $0.17^{bc}$ | $0.16^{bcd}$ | 0.10 |
| $C_2$ - 20 | $36.7^{a}$ | $22.23^{a}$ | $26.27^{b}$ | 0.18 | $4.77^{ab}$ | $5.43^{de}$ | 0.22 | $4.58^{ab}$ | $7.59^{ab}$ | 0.01 | $0.47^{ab}$ | $0.6^{c}$ | 0.14 | $0.16^{bc}$ | $0.13^{cd}$ | 0.00 |
| $C_2$ - 43 | $303^{abc}$ | $22.17^{a}$ | $28.93^{a}$ | 0.03 | $2.67^{bc}$ | $5.57^{cde}$ | 0.04 | $4.07^{ab}$ | $7.24^{bc}$ | 0.01 | $0.43^{ab}$ | $0.87^{b}$ | 0.04 | $0.13^{c}$ | $0.16^{bcd}$ | 0.67 |
| Ld 12-2-22-1 | $30^{abc}$ | $15.30^{ab}$ | $28.07^{a}$ | * | $1.83^{c}$ | $6.6^{abc}$ | 0.02 | $2.99^{abc}$ | $8.24^{a}$ | 0.07 | $0.40^{ab}$ | $0.87^{b}$ | 0.16 | $0.19^{bc}$ | $0.25^{b}$ | 0.02 |
| Ld 365 | $6.7^{c}$ | $5.37^{b}$ | $16.33^{g}$ | * | $1.50^{c}$ | $3.37^{g}$ | * | $0.71^{c}$ | $2.52^{h}$ | * | $0.10^{b}$ | $0.37^{d}$ | * | $0.37^{a}$ | $0.10^{d}$ | * |
| $N_2B_4$ | $30^{abc}$ | $15.83^{ab}$ | $24.3^{cd}$ | * | $3.40^{abc}$ | $6.5^{abcd}$ | | $2.83^{abc}$ | $5.99^{de}$ | 0.03 | $0.73^{a}$ | $1.2^{a}$ | 0.35 | $0.27^{abc}$ | $0.37^{a}$ | 0.34 |
| SS 3-26-1 | $40^{a}$ | $22.63^{a}$ | $23.17^{de}$ | 0.53 | $5.57^{a}$ | $7.4^{a}$ | 0.03 | $4.91^{a}$ | $5.76^{ef}$ | 0.11 | $0.73^{a}$ | $0.76^{bc}$ | 0.63 | $0.21^{abc}$ | $0.17^{bcd}$ | 0.27 |
| $SS_4$- 2 | $10^{bc}$ | $12.77^{ab}$ | $20.93^{f}$ | * | $1.90^{c}$ | $4.6^{ef}$ | * | $2.22^{bc}$ | $4.9^{g}$ | 0.14 | $0.53^{ab}$ | $0.67^{bc}$ | 0.30 | $0.20^{abc}$ | $0.22^{bc}$ | 0.55 |
| $SS_4$- 4 | $46.7^{a}$ | $21.33^{a}$ | $22.2^{ef}$ | 0.39 | $5.27^{ab}$ | $5.87^{bcd}$ | 0.10 | $4.36^{ab}$ | $4.83^{g}$ | 0.21 | $0.73^{a}$ | $0.81^{bc}$ | 0.39 | $0.31^{ab}$ | $0.17^{bcd}$ | 0.74 |
| $S_1F_3$ - 2 | $33.3^{ab}$ | $25.17^{a}$ | $28.3^{a}$ | 0.01 | $2.67^{bc}$ | $4^{fg}$ | 0.11 | $4.17^{ab}$ | $5.19^{fg}$ | 0.26 | $0.57^{a}$ | $0.77^{bc}$ | 0.01 | $0.22^{abc}$ | $0.11^{d}$ | 0.25 |
| $S_2$ $B_7$ (red) | $40^{a}$ | $23.87^{a}$ | $26.27^{b}$ | 0.03 | $4.50^{ab}$ | $6.73^{ab}$ | 0.00 | $5.28^{a}$ | $5.76^{ef}$ | 0.37 | $0.73^{a}$ | $0.77^{bc}$ | 0.70 | $0.23^{abc}$ | $0.23^{b}$ | 1.00 |
| CV | 41 | 36.4 | 3.6 | | 38.1 | 9.8 | | 36.1 | 4.7 | | 42.6 | 10.5 | | 37.9 | 6.4 | |

*DMRT groups of each value are indicated in superscript. Means with the same letter in each column are not significantly differ p (<0.05).*
*P values were given for the t-test of each character separately for comparison of means of salt and non-salt conditions*

**Table 2. Percentage survival of submerged, mean performance of agronomic characters of selected rice lines for submerged and no submerged condition and individual mean comparison of each variety under submerged and no submerged in seedling stage during 2019/20 *Maha***

| Rice line | | Seedling height(cm) | | | Root length (cm) | | | Leaf area of upper most leaf (cm$^2$) | | | Fresh weight of seedlings (g) | | | Dry weight of seedlings (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percentage survival submerged | Sub-merged | Non-sub | P value | Sub-merged | Non-sub | P value | Sub-merged | Non-sub | P value | Sub-merged | Non-sub | P value | Sub-merged | Non-sub | |
| $C_1$ - 28 | 80$^{ab}$ | 38.13$^{ce}$ | 40.8$^{ad}$ | 0.10 | 8.57$^{b}$ | 6.17$^{cd}$ | 0.03 | 9.00$^{bc}$ | 10.87$^{a}$ | 0.01 | 1.73$^{b}$ | 1.60$^{c}$ | 0.23 | 0.34$^{b}$ | 0.10$^{g}$ | 0.01 |
| $C_2$ - 42 | 86.7$^{a}$ | 41.33$^{abc}$ | 38.56$^{bcd}$ | 0.04 | 8.60$^{b}$ | 5.37$^{de}$ | 0.01 | 8.67$^{cd}$ | 10.05$^{b}$ | 0.02 | 1.83$^{b}$ | 1.07$^{ef}$ | 0.00 | 0.23$^{d}$ | 0.10$^{g}$ | 0.01 |
| IRRI 64 (*Sub1*) | 96.7$^{a}$ | 40.97$^{abc}$ | 39.13$^{bc}$ | 0.22 | 7.03$^{cd}$ | 4.57$^{ef}$ | 0.01 | 6.08$^{e}$ | 7.88$^{c}$ | 0.06 | 1.63$^{b}$ | 1.40$^{cd}$ | 0.04 | 0.35$^{b}$ | 0.10$^{g}$ | 0.01 |
| Ld 365 | 53.3$^{b}$ | 33.30$^{f}$ | 31.70$^{e}$ | 0.18 | 6.53$^{d}$ | 4.57$^{ef}$ | 0.03 | 5.86$^{e}$ | 5.19$^{d}$ | 0.12 | 1.20$^{c}$ | 0.83$^{f}$ | 0.02 | 0.11$^{e}$ | 0.10$^{g}$ | 0.50 |
| $N_1$ $F_2$ - 1 | 90$^{a}$ | 40.37$^{bcd}$ | 38.10$^{cd}$ | 0.051 | 7.00$^{cd}$ | 3.93$^{f}$ | 0.01 | 8.34$^{cd}$ | 7.85$^{c}$ | 0.24 | 1.13$^{c}$ | 1.17$^{de}$ | 0.86 | 0.21$^{d}$ | 0.26$^{e}$ | 0.01 |
| $N_2$ $B_4$ | 76.7$^{ab}$ | 39.60$^{cd}$ | 36.33$^{d}$ | 0.08 | 7.93$^{bc}$ | 8.30$^{a}$ | 0.50 | 7.97$^{d}$ | 11.53$^{a}$ | 0.00 | 2.10$^{a}$ | 2.13$^{b}$ | 0.82 | 0.11$^{e}$ | 0.53$^{a}$ | 0.00 |
| SS $_4$ - 2 | 80$^{ab}$ | 36.90$^{e}$ | 34.00$^{e}$ | 0.13 | 10.07$^{a}$ | 5.13$^{de}$ | 0.01 | 10.31$^{a}$ | 10.01$^{b}$ | 0.24 | 1.67$^{b}$ | 1.13$^{def}$ | 0.07 | 0.35$^{b}$ | 0.20$^{f}$ | 0.02 |
| $S_1$ $F_3$ - 2 | 56.3$^{b}$ | 39.70$^{cd}$ | 37.07$^{cd}$ | 0.15 | 8.43$^{b}$ | 6.03$^{cd}$ | 0.01 | 9.46$^{b}$ | 9.36$^{b}$ | 0.69 | 1.30$^{c}$ | 2.03$^{b}$ | 0.02 | 0.30$^{c}$ | 0.33$^{d}$ | 0.18 |
| $S_2$ $B_7$ (red) | 96.7$^{a}$ | 43.17$^{a}$ | 42.27$^{a}$ | 0.57 | 8.33$^{b}$ | 6.93$^{bc}$ | 0.01 | 10.21$^{a}$ | 11.64$^{a}$ | 0.15 | 1.73$^{b}$ | 2.50$^{a}$ | 0.01 | 0.36$^{b}$ | 0.48$^{b}$ | 0.01 |
| $S_2$ $B_7$ (white) | 93.3$^{a}$ | 42.40$^{ab}$ | 40.97$^{ab}$ | 0.37 | 10.13$^{a}$ | 7.20$^{b}$ | 0.02 | 8.58$^{cd}$ | 9.57$^{b}$ | 0.07 | 1.83$^{b}$ | 2.10$^{b}$ | 0.13 | 0.42$^{a}$ | 0.37$^{c}$ | 0.03 |
| CV % | 18.2 | 3.6 | 3.6 | | 6.8 | 9.8 | | 5 | 4.7 | | 8.8 | 10.8 | | 8.15 | 6.4 | |

*DMRT groups of each value are indicated in superscript. Means with the same letter in each column are not significantly differ P (<0.05).*
*P values were given for the t-test of each character separately for comparison of means of submerge and non-submerge conditions*

compared to the non-submerged varieties. According to Bui *et al*., (2019) after submergence, tolerant rice genotypes have higher root dry weight compared to sensitive ones. $S_2$ $B_7$ (red) and $SS_4$- 2 gave the highest leaf area of uppermost leaf and significantly differed from the rest. Leaf elongation and carbohydrate metabolism are closely related to the submergence tolerance (Shiratsuchi *et al*., 2006).When compared to IRRI 64 (*Sub1*) $S_2B_7$ red $S_2B_7$ (white) and $N_1F_2$ 1 showed capability of withstanding submerged conditions. $C_2$-42, $S_1F_3$ -2 and $SS_4$ -2 also recorded more than 80% of survival under tendays submergence.

Yield performances of selected varieties under research and farmer field conditions and farmer preference evaluations for the varieties are presented in Table 3 and 4. There were significant differences in yields during 2019 *Yala* and 2019/20 *Maha* evaluations at Regional Research Station Labuduwa. $S_2B_7$ (Red) and $S_1F_3$ - 2 recorded comparable yields with the released popular rice varieties for the Wet Zone in research station yield trials. The trials at Thuduwa and Rathgama farmer fields were not received expected level of salinity during this season (recorded 2-4 dS $m^{-1}$). Yield performances of the varieties were not significant at both farmer fields.

According to farmer participatory evaluations there was no significant difference between tested rice varieties for farmer preference according to the Friedman test at Rathgama farmer field. There was a significant difference between tested varieties for the derived rank based on bi -varietal comparison by farmers at < 0.05 level. In this test number 1 rank was given to the highest preference. The lowest mean rank represented the highest farmer preference. According to the matrix test $S_1F_3$-2, was the lowest mean ranker and the most preferred variety by the farmers followed by At-354, $C_1$-28. Considering the result of both tests for farmer preference by visual observations in the field level $S_1F_3$-2, $C_1$-28, and $S_2B_7$ (Red) rice verities had more farmer preference than other varieties.

**Table 3. Comparison of yield performances (kg $ha^{-1}$) of selected rice varieties at farmer fields and Rice Research Station Labuduwa**

| | RRS-Labuduwa | | | Famer fields | |
|---|---|---|---|---|---|
| **Verity** | **2018/19 *Maha*** | **2019 *Yala*** | **2019/20 *Maha*** | **Thunduwa 2019/20 *Maha*** | **Rathgama 2019/20 *Maha*** |
| $S_1F_2$ -10 | $3892.8^a$ | $3251.5^{bc}$ | $3626.6^{ba}$ | $2339.4^a$ | $4120.4^a$ |
| $S_2B_7$ (Red) | $5336.7^a$ | $3359.8^{ab}$ | $3870.9^{ba}$ | $2326.1^a$ | $3611.1^a$ |
| Ld-368 | $4515.9^a$ | $3838.4a^{bc}$ | $3896.6^{ba}$ | $2020.8^a$ | $3592.6^a$ |
| $N_1F_2$ -8 | $3665.3^a$ | $4585.9^a$ | $4166.7^{ba}$ | $1516.4^a$ | $4203.7^a$ |
| $S_1F_3$ -2 | $4168.5^a$ | $4625.3^a$ | $4719.6^a$ | $1818.6^a$ | $3759.3^a$ |
| $C_1$ -28 | - | - | $3793.7^{ba}$ | $1795.3^a$ | $3981.5^a$ |
| $S_2B_7$ (White) | - | - | $3253.6^b$ | $2017.8^a$ | $4500^a$ |
| Bw-372 | $5298.8^a$ | $3977.3^{ab}$ | $4102.3^{ba}$ | $2287^a$ | $4463^a$ |
| | 20.1 | 17.5 | 15 | 45 | 20.1 |

*DMRT groups of each value are indicated in superscript. Means with the same letter in each column are not significantly differ P (<0.05).*

**Table 4. Mean score, standard deviation, and mean rank for Friedman test for farmer scores of voting and matrix ranking of varieties trial at Ratgama**

| | Individual voting of varieties | | | Matrix ranking | | |
|---|---|---|---|---|---|---|
| Variety | Mean score | Std. Deviation | Mean Rank | Mean of rank | Std. Deviation | Mean Rank |
| $S_2B_7$ (Red) | 2.33 | 2.31 | 4.33 | 3.47 | 1.74 | 4.06 |
| $S_2B_7$ - W | 0.33 | 6.11 | 3.67 | 5.76 | 1.64 | 6.38 |
| $N_1F_2$ -10 | 3.00 | 7.21 | 5.17 | 4.18 | 2.10 | 5.09 |
| $N_1F_2$- 8 | -4.33 | 10.07 | 2.50 | 5.06 | 2.61 | 5.59 |
| $S_1F_3$- 2 | 5.67 | 1.15 | 6.00 | 2.06 | 1.52 | 2.68 |
| $C_1$-28 | 5.00 | 11.14 | 4.67 | 2.76 | 1.35 | 3.50 |
| Bw-372 | 7.00 | 5.29 | 6.83 | 4.76 | 1.89 | 5.53 |
| At-354 | -1.00 | 2.00 | 2.83 | 2.59 | 2.00 | 3.18 |
| Chi-Square | | 8.36 | | | 38.49 | |
| Asymp. Sig. | | 0.302 | | | 0.0001 | |

## Conclusion

At 354 variety was the most withstanding variety for salinity. Further performed well under salt treated conditions $SS_4$-4, $S_2B_7$ (red) $C_1$- 33, $C_2$- 20, and $SS_3$-26-1 by recording better survival percentages, better plant shoot and root growth and maintained dry weight. $S_2B_7$ (red) $S_2B_7$ (white) and $N_1F_2$ -1 were identified as best submergence tolerance with high survival, better maintenance of shoot, root lengths and leaf area. $S_2B_7$ red was identified as the variety consisting of both salinity and submerge nce tolerance. $S_2B_7$ Red and $S_1F_3$-2 recorded high yields in Regional Research Station Labuduwa and in farmer fields. $S_2B_7$ Red, $S_1F_3$-2 and $C_1$- 28 were preferred by the farmers.

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