Impact of Salinity Mitigation Management Measures on Growth, Dry Matter Partitionings and Yield Performances of Selected Rice Varieties Grown in Salt Affected Area in Ariyalai, Jaffna District

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Abstract: To study the impact of salinity mitigation management measures on plant growth, dry matter partitioning and yield of selected rice varieties in salt affected area in Jaffna, a field trial was conducted in split plot design with three replicates. Six rice varieties were tested against two depths of land preparation and three organic amendments application. Moisture retention capacity of soil, organic matter content in the soil, plant height, percentage of dry matter partitioning, harvest index, yield and yield components of each variety were measured or calculated. ANOVA and correlation analysis were performed to check the significant differences for moisture contents in different depths, varieties, ploughing depths and organic amendments application and correlation between yield and yield components, respectively. Moisture retention capacity of soil was increased with increasing depth of plough. There was no significant difference in dry matter partitioning, harvest index and organic amendments application among varieties. But there was a significant difference in number of productive panicles/m², number of filled spikelets/panicle, thousand grains weight and yield among varieties under salt condition. Among the cultivated rice varieties, Bg 369 had the highest yield due to production of higher number of filled spikelets/panicle and had higher thousand grains weight. It showed more yield in farm yard manure application compared to farm yard manure and leaf mould combination and control. Pachaperumal had the second highest yield with the production of higher number of productive panicles/m², number of filled spikelets/panicle under farm yard manure application. Bg 250 showed the lowest yield due to production of low number spikelets/panicle and filled spikelets/panicle. Bg 369 and Pachaperumal are the suitable rice varieties to cultivate under salt affected area in Ariyalai by adding farm yard manure under deep ploughing.

Key words: Dry matter • Mitigation • Organic amendments • Partitioning • Yield

INTRODUCTION

Increasing salt ion concentration in the soil solution (salinity) is becoming an important stress factor causing significant reduction in the productivity of crops, both globally and in Sri Lanka [1]. It is estimated that 2 % of the rain-fed agricultural area (32 million ha) is affected by salinity [2]. In agriculture, a soil having a salt concentration exceeding an electrical conductivity (EC) value of 4 dS m⁻¹ is classified as saline [3]. Salinity stress is complex because of the variation in sensitivity at various growth stages in the life cycle of plant. Salinity stress involves changes in various physiological and metabolic processes, depending on severity and duration of the stress and ultimately inhibits crop production [4]. Identification of salt tolerant varieties and development of management strategies are very important to reduce the salinity impacts and enhance the productivity from agricultural lands. It can be done by screening rice varieties for salt tolerant and identification of traits associated with salt tolerance which could be incorporated in to breeding programmes to develop tolerant varieties.

Rice (Oryza sativa L.) is the staple food of more than 1 billion people worldwide, which includes 20 million people in Sri Lanka [1]. Screening for salt tolerance in the field is difficult as soil salinity is dynamic and: the level of salt varies both horizontally and vertically in the soil.
profile and changes with time. Adopting different salinity mitigation management practices is ideal under field conditions to obtain sustainable yield from salt-affected lands. There are many effective ways for improving salt-affected lands, such as improving drainage, chemical remediation and phytoremediation [5, 6]. The remediation of salt-affected soil using chemical agents, including gypsum (CaSO₄·2H₂O), calcite (CaCO₃), calcium chloride (CaCl₂·2H₂O) and organic matter (farmyard manure, green manure and municipal solid waste), is a successful approach that has been implemented worldwide. This method is effective, low cost and simple [5, 7]. The physical, chemical and biological properties of soil in salt-affected areas are improved by the application of organic matter, leading to enhanced plant growth and development. Therefore, the application of organic matter for soil remediation is important for sustainable land use and crop productivity [8, 9].

Sri Lanka is being an agricultural country nearly 70% of its lands support the agricultural sector. Among agricultural land uses, rice occupies almost 50% (7,275,520 ha) of the total land available for agriculture in the country showing highest priority for rice farming [10]. Salinity is one of the major constraints limiting the expansion of cultivated areas in Sri Lanka and productivity improvements. It is gradually spreading, both in the coastal regions and inlands [11]. Seventy-five percent of the 720,000 ha of rice in Sri Lanka is cultivated under irrigation [1]. In the dry zone, salinity is largely the result of insufficient drainage facilities [12, 13]. Out of the total annual extent of rice-cultivated in Sri Lanka, nearly 70% of the coastal rice lands are reported to be affected by salinity [1]. Recent study indicates that currently about 100,000 hectares of paddy lands in Sri Lanka are affected by high salt conditions or salinity [14]. Salinity levels are particularly severe in areas where evaporation exceeds precipitation. Spread of salinity has the potential to reduce national rice production significantly as rice is one of the most salt-sensitive crops [15, 16].

Jaffna region in Sri Lanka belongs to the agro ecological region of DL3. The climate of Jaffna peninsula is considered to be tropical monsoonal with a seasonal rhythm of rainfall. The temperature ranges from 26°C to 33°C. Annual precipitation ranges from 696 mm to 1125 mm. The north-east monsoon rain (October to January) accounts for more than 90% of the annual rainfall [17]. Therefore, cultivation of paddy lands depends on the availability of rain water. In Jaffna, total paddy land available for the cultivation is 12,000 ha. Out of which nearly 67% is being cultivated and 17% of paddy land is being identified as marginal due to NaCl salinity [18]. The average yield of rice is about 2.5 mt/ha. Salt concentrations in the paddy lands of Jaffna fluctuate between soil profile during dry and wet seasons (By analysis). In Jaffna, the impacts of salinity development on the growth and development of paddy are not properly understood. Selection of rice cultivars which are tolerant to salt is an important requirement to Jaffna region to maintain sustainable yield in salt affected areas together with adopting different salinity mitigation management practices. Therefore, field trial was conducted to study the impact of salinity mitigation management measures (land preparation and soil amendments) on growth, dry matter partitioning and yield performances of selected rice varieties in salt affected areas in Ariyalai in the Jaffna region.

MATERIALS AND METHODS

The salt affected fields were selected in Ariyalai which is situated in Jaffna district of Sri Lanka. Experiment was conducted as a three factor factorial with land preparation, different organic amendments and varieties in a split plot design with three replicates.

The main plot factor included two levels of land preparation.

L₁ - Land was ploughed to a depth of 20 - 25 cm by tillers
L₂ - Land was ploughed to a depth of 40 - 50 cm by disc plough.

Sub plot factor: Three levels of organic amendments
Level 1: Only Farm yard manure was applied (5 t/ha)
Level 2: Farm Yard manure and leaf mould was applied at the ratio of 3:2 (5 t/ha)
Level 3: Control without any organic amendments

One month before sowing, land was prepared based on the required depth by using tiller and disc plough. Then leveling was done and hundred and eight plots were prepared including fifty four for 20-25 cm depth and another fifty four for 40 - 50 cm depth with the size of 4.5 m × 3.25 m per each plot which was separated by 30 cm length and 30 cm height bunds. After plot preparation, randomization was done and 7.5 kg of farm yard manure and farm yard manure leaf mould combinations were applied to each plots and thoroughly mixed with soil except for control (without organic amendments). Plots were allowed for one month to decompose the organic amendments which were applied to plots and released to soil. Then six rice varieties of two and a half,
three and three and a half months age classes including new improved and traditional varieties of Bg 250, Bg 300, At 308, Bg 369, Bg 352 and Pachaperumal were used based on the varying responses observed from tolerant to susceptible from previous studies on screening at germination and seedling stage. Seeds were obtained from the Rice Research and Development Institute at Bathalagoda and Paranthan. All varieties had germination percentage of seeds more than 85 %. Seeds requirement for each plot was calculated based on the seed rate recommended by the Department of Agriculture such as for Samba 100 kg/ha, for white pericarp rice 125 kg/ha and for red pericarp rice 150 kg/ha. Seed requirement for varieties Bg 250, Bg 300, Bg 369 and Bg 352 was 185 g per plot, for At 308 was 150 g per plot and for variety Pachaperumal was 220 g per plot.

Fertilizer was applied to the field based on the latest recommendation made by the Department of Agriculture in year 2013. At the time of sowing, 51 g triple super phosphate (TSP) and 7.5 g Zinc sulphate (ZnSO₄) were applied to each plot and incorporate with soil thoroughly. After establishment of rice seedlings, top dressings of nitrogen were done at different time intervals based on the recommendation. Weeds were controlled three weeks after sowing by applying weedicide “goal” (Oxyfluorfen) based on the recommendation made by the Department of Agriculture.

Moisture cans were used to take soil samples to measure moisture content in the field at three different depths such as 15, 30 and 45 cm during cultivation. Empty moisture cans weight, moisture cans with fresh soil weight and soil weight after oven drying at 105°C until to reach constant weight was measured. Moisture content in the soil was calculated on dry basis.

Measurements: Plant height was measured every two weeks interval commenced from three weeks after germination by using measuring tape. Shoot dry weight was measured at seedling, heading and harvesting stages after oven drying at 70°C for three days. Harvest index of grain was calculated. Yield components such number of plants/m², number of productive panicles/plant, number of spikelet/panicle and 1000 grains weight were measured during harvesting. Electrical conductivity (EC) of soil was measured before land preparation, at planting, at flooding and harvesting stages. Organic matter content of soil was measured before land preparation, at planting and after harvesting of rice plants.

Calculation:

Grain Harvest Index = (Grain weight) / (Grain weight + Straw weight)

Data Analysis: To check the difference among moisture contents in different depths, varieties, ploughing depths and organic amendments application, analysis of variance were performed using Proc GLM procedure followed by the LSMEANS procedure for mean separation. All the significances were expressed at α = 0.05.

The correlation analysis was done for organic amendments application, number of productive panicles / m², number of filled spikelets/panicle, 1000 grains weight and yield to find the relationship between tested variables.

RESULTS AND DISCUSSION

During the cultivation period due to unexpected drought condition, one of the main plot factor land preparation by tiller plough to a depth of 20 – 25 cm was failed after seedling stage. But other main factor land preparation by disc plough to a depth of 40 – 50 cm succeeded well. This could be due to higher moisture retention capacity of soil in the deep ploughed treatment. It was obvious that deeply ploughed land held more water in the soil at different layers due to fine tilth condition of the soil up to 40 to 50 cm. Therefore, growth, dry matter partitioning and yield performances of the tested rice varieties under disc plough was discussed in the future text.

Moisture Content in the Soil: Land ploughed to a higher depth showed higher moisture retention capacity compared to lower depth of ploughing (Fig. 1). But there was no significant difference in moisture retention capacities of soil with two different methods of plough. Moisture retention capacity of soil increased with increasing soil depth. But there was no significant difference in moisture retention capacity of soil at 15 cm and 30 cm depths in both methods. Disc plough showed 1.72 % and 1.18 % more moisture content in the top soil (15 cm) and bottom soil (45 cm), respectively, compared to normal tiller plough.

Organic Matter Content in the Soil: At the initial stage, top soil (15 cm) had higher percentage of organic matter content compared to 30 cm and 45 cm depth, i.e.
Fig. 1: Percentage of moisture content in the soil with different methods of plough and different depths of soil

Fig. 2: Percentage of organic matter content in different methods of plough, different organic amendments and three different depths of soil

Fig. 3: Plant height of selected rice varieties under farm yard manure, farm yard manure and leaf mould and control
percentage of organic matter content was decreased with increasing depth of soil (Fig. 2). After land preparation and organic amendment addition, percentage of organic matter content in soil was increased compared to initial soil in all treatments including different methods of plough and different types of organic amendments used. This could be due to decomposition of organic amendments and weeds after land preparation. But farm yard manure added treatment showed the highest percentage of organic matter content at the depth of 15 cm and farm yard manure leaf mould combination showed the highest percentage of organic matter content at 30 cm depth compared to control.

During the growing season of paddy EC levels in soil fluctuates between soil layers. Before land preparation, top soil showed the highest EC levels and it was decreased with increased depth. After land preparation and ploughing, EC level of the soil decreased and bottom layer showed the highest. At field capacity the highest EC level was observed in bottom layer. At harvest again EC level of top soil increased compared to bottom layers (from analysis). This could be due to high evaporation from top soil which brought the salt in the bottom layer to top.

**Plant Height**: Plant heights of each rice variety was increased with increasing duration and showed same trend in increments in all treatments. There was a difference in plant height with organic amendments application and control (Fig. 3). But these differences were not statistically significant with organic amendments application. Varieties Bg 369 and Pachaperumal showed the highest plant height in farm yard manure and farm yard manure and leaf mould combination compared to control.

**Dry Matter Partitioning**: Dry matter partitioning of varieties at harvest varied with different organic amendments application. Dry matter partitioning to panicle was higher in all the varieties with organic amendments (Fig. 4). But varieties of Bg 250, Bg300, Bg 369 and Bg 352 showed higher percentage of partitioning to panicle under the farm yard manure application than farm yard manure and leaf mould combination and control. Bg 369 and Pachaperumal showed higher percentage of dry matter partitioning to panicle at harvest in farm yard manure and leaf mould combination and Bg 300 and At 308 showed higher partitioning to panicle in control compared to farm yard manure and farm yard manure and leaf mould combination.

**Harvest Index of Grain**: Harvest index of selected rice varieties varied with organic amendments application (Fig. 5). There was no significant difference in harvest index between organic amendments application and control within varieties. Bg 369, Pachaperumal and Bg 352 showed the highest harvest index in farm yard manure and leaf mould combination. Bg 300 and At 308 showed the highest harvest index in farm yard manure application and other variety showed the highest harvest index at control.

**Number of Productive Panicles/m²**: Number of productive panicles/m² varied with different organic amendments application and varieties (Table 1, 2 & 3). There was a no significant difference in number of productive panicles/m² with different organic amendments application. But, there was a significant difference in number of productive panicles/m² among varieties. Among the cultivated varieties, the highest number of productive panicles/m² was observed in Bg 250 (444) followed by Pachaperumal.
Fig. 5: Harvest index of selected rice varieties with different organic amendments application

Table 1: Yield and yield components of rice varieties under Farm Yard Manure:

<table>
<thead>
<tr>
<th>Characters</th>
<th>Bg 250</th>
<th>Bg 300</th>
<th>At 308</th>
<th>Bg 369</th>
<th>Bg 352</th>
<th>Pachaperumal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of productive panicle/m²</td>
<td>428</td>
<td>216</td>
<td>300</td>
<td>311</td>
<td>211</td>
<td>372</td>
</tr>
<tr>
<td>Number of filled grains/panicle</td>
<td>18</td>
<td>20</td>
<td>43</td>
<td>62**</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>1000 grains weight</td>
<td>25.2</td>
<td>25.33</td>
<td>18.23</td>
<td>30.47**</td>
<td>25.18</td>
<td>23.67</td>
</tr>
<tr>
<td>Grain yield (mt/ha)</td>
<td>0.19</td>
<td>0.25</td>
<td>0.235</td>
<td>0.385**</td>
<td>0.240</td>
<td>0.485**</td>
</tr>
</tbody>
</table>

** Significant at α 0.05

Table 2: Yield and yield components of rice varieties under Farm Yard Manure and leaf mould combination:

<table>
<thead>
<tr>
<th>Characters</th>
<th>Bg 250</th>
<th>Bg 300</th>
<th>At 308</th>
<th>Bg 369</th>
<th>Bg 352</th>
<th>Pachaperumal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of productive panicle/m²</td>
<td>444</td>
<td>189</td>
<td>255</td>
<td>300</td>
<td>227</td>
<td>405</td>
</tr>
<tr>
<td>Number of filled grains/panicle</td>
<td>17</td>
<td>37</td>
<td>54**</td>
<td>58**</td>
<td>51**</td>
<td>47**</td>
</tr>
<tr>
<td>1000 grains weight</td>
<td>25.32</td>
<td>24.97</td>
<td>17.74</td>
<td>30.68**</td>
<td>25.80</td>
<td>25.17</td>
</tr>
<tr>
<td>Grain yield (mt/ha)</td>
<td>0.185</td>
<td>0.170</td>
<td>0.245</td>
<td>0.535**</td>
<td>0.300</td>
<td>0.480**</td>
</tr>
</tbody>
</table>

** Significant at α 0.05

Table 3: Yield and yield components of rice varieties under control:

<table>
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<tr>
<th>Characters</th>
<th>Bg 250</th>
<th>Bg 300</th>
<th>At 308</th>
<th>Bg 369</th>
<th>Bg 352</th>
<th>Pachaperumal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of productive panicle/m²</td>
<td>372</td>
<td>289</td>
<td>233</td>
<td>283</td>
<td>283</td>
<td>266</td>
</tr>
<tr>
<td>Number of filled grains/panicle</td>
<td>16</td>
<td>40</td>
<td>61**</td>
<td>64**</td>
<td>34</td>
<td>57**</td>
</tr>
<tr>
<td>1000 grains weight</td>
<td>23.94</td>
<td>23.84</td>
<td>16.26</td>
<td>28.40**</td>
<td>23.22</td>
<td>21.03</td>
</tr>
<tr>
<td>Grain yield (mt/ha)</td>
<td>0.135</td>
<td>0.270</td>
<td>0.235</td>
<td>0.510**</td>
<td>0.245</td>
<td>0.320</td>
</tr>
</tbody>
</table>

** Significant at α 0.05

(406) under farm yard manure and leaf mould combination. Bg 300 showed the lowest number of productive panicles/m² (189) under farm yard manure and leaf mould combination.

**Number of Filled Spikelets/Panicle:** Number of filled spikelet/panicle varied with different organic amendments application and varieties (Table 1, 2 & 3). There was a no significant difference between organic amendment applications. But there was a significant difference between varieties. Bg 369 showed the highest (62) number of filled spikelet/panicle compared to other varieties under farm yard manure application. Pachaperumal (55) showed next highest to Bg 369 in number of filled spikelet/panicle. Among farm yard manure and leaf mould combination, Bg 369 showed the highest filled spikelet/m² followed by At 308. Variety Bg 250 showed the lowest number of filled spikelet/panicle (18, 17) in both farm yard manure and farm yard manure and leaf mould combination respectively.

**Thousand Grains Weight:** There was a significant difference between organic amendment applications and varieties in thousand grains weight (Table 1, 2 & 3). There was a significant difference between control (without organic amendments) and organic amendment applications. But there was a no significant difference between farm yard manure and farm yard manure leaf mould combination. Among the cultivated varieties, Bg 369 (30.68 g) showed the highest thousand grain weight under farm yard manure and leaf mould combination.
followed by Bg 352 (25.80 g) compared to other varieties. Varieties Bg 352 and Bg 250 showed more or less similar in thousand grains weight under farm yard manure and leaf mould combination. The lowest thousand grains weight was observed in At 308 at control. At 308 is a samba variety and size of grain is very small compared to other varieties.

**Yield (mt/ha):** Yield of cultivated varieties varied with organic amendment application and varieties (Table 1, 2 and 3). There was a significant difference in yield between organic amendment application and control and also among varieties. Bg 369 showed the highest yield followed by Pachaperumal and it was significantly difference compared to other varieties Bg 250, Bg 300, At 308 and Bg 352 under farm yard manure application. There was no significant difference in yield between Bg 369 and Pachaperumal. Bg 369 showed the highest yield of 0.585 mt/ha under farm yard manure application and Pachaperumal showed the second highest yield of 0.485 mt/ha. Bg 250 showed the lowest yield of 1.35 mt/ha under control and 0.19 and 0.185 mt/ha under farm yard manure and farm yard manure and leaf mould combination respectively. Bg 352 and At 308 showed better yield performance under farm yard manure and leaf mould combination compared to farm yard manure alone and control.

Yield of all varieties was very poor compared to average yield (2.5 mt/ha) of Jaffna under normal condition. Farmers in Jaffna are unable to get yield in salt affected field after heading stage due to production of unfilled grains and crop failure. This study showed that adopting salinity mitigation management practices of deep ploughing and application of organic amendments helped to get at least some yield from salt affected field rather than nothing.

Within the cultivated varieties in Jaffna, there was a correlation between organic amendments application and number of productive panicles/m², organic amendments application and number of filled spikelets/panicle, organic amendments application and yield, thousand grain weight and number of productive panicles/m², number of productive panicles/m² and number of filled spikelets/panicle.

Yield of rice crop depends on plant growth, dry matter partitioning and yield components. Among the cultivated varieties, Bg 369 and Pachaperumal showed the highest plant height compared to other varieties in all treatments and these two varieties were significantly different from other varieties in plant height due to production of large leaves. There was no significant difference in dry matter partitioning at heading to harvesting stages between varieties. In rice, yield depends on amount of dry matter partitioning to grain, number of productive panicle /m², number of filled spikelets/panicle and thousand grain weights. Number of panicles/m² depends on number of plants/m². Salinity influenced the growth of plant, number of plants per plot and tiller number in rice. [19] found that salinity delayed flowering and reduced productive tiller number, fertile florets per panicle, weight per grain and over all grain yield. Among the cultivated rice varieties in Jaffna, all the varieties produced one tiller per plant under salt stress in the field but number of spikelets/panicle varied with varieties and organic amendments application. Bg 250 showed the lowest yield. This could be due to short growth duration of a variety (21/2 months) and had very short period for vegetative growth. Photosynthetic assimilates available to transfer to panicle was low even though it produced highest number of productive panicles/m². Therefore, production of number of spikelets/panicle and filled spikelets/panicle was less compared to other rice varieties. This could be the reason for lowest production of yield in Bg 250.

Salinity increases pollen sterility in rice plants during flowering it also lead to decrease the number of filled spikelets. [20] stated that salinity increases the pollen sterility of rice plants possibly resulting in the lower grain yields of certain rice varieties even if the rice plants performed well during the growth stages. [21] found that filled grain per panicle and sterility percentage appear to be the most reliable indices for selection under saline conditions. They also stated that reduction in grain size and increase in the number of sterile florets was the primary causes for yield reduction under saline condition. [22] and [23] found that the numbers of filled grains per panicle and grain weight are most sensitive yield components to salinity. Among the cultivated varieties of rice, except Bg 250 other varieties were more than three months age groups and had sufficient period for vegetative growth. Among those varieties, even though Bg 369 and Pachaperumal produced average number of productive panicles/m², they produced the highest number of filled spikelet/panicle and thousand grain weights and showed the first and second highest yield under farm yard manure application respectively.

**CONCLUSIONS**

Deep disc ploughed (40 – 50 cm) land showed higher moisture retention capacity than normal tiller ploughed (20 - 25 cm) land. Percentage of organic matter content in
soil increased after organic amendments application and in control due to land preparation. There was no significant difference in plant height and dry matter partitioning with organic amendments application and control within varieties. Similarly, there was no significant difference in yield with organic amendments application and control within varieties. But there was significant difference in yield between varieties with organic amendments application. Among the cultivated rice varieties Bg 369 had the highest yield by production of higher number of filled spikelets/m² and had higher thousand grain weight. It showed more yield in farm yard manure application compared to farm yard manure leaf mould combination and control. Pachaperumal produced the second highest yield with the production of higher number of panicles/m², number of filled spikelets/m² under farm yard manure. Bg 250 showed the lowest yield due to production of very low number of filled spikelets/panicle. Therefore, Bg 369 and Pachaperumal are the suitable rice varieties to cultivate under salt affected area in Ariyalai by adding farm yard manure with deep ploughing by disc.

Suggestions: Unexpected weather condition during cultivation caused failure to portion of the field (tiller ploughed). Therefore, this study has to be continued for more than two seasons to produce representative conclusions by increasing the application of amount of organic amendments and ploughing depths.

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