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Mitigation of Salinity Stress in Rice with Compost

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Abstract**—Increasing salinity is a significant problem for crop production land. Overcoming salinity in an environmentally friendly and sustainable manner is necessary to increase agricultural production and cope with the increasing population and food needs. Using organic amendments from agricultural waste is a solution for dealing with waste and improving soil properties and crop yields. Salinity can be overcome by adding 5-10 t ha^{-1} compost at a salinity level of 2000-10000 ppm (NaCl). At 10.000 ppm, tillers increased from 2.67 in the no-compost treatment to 9 in applying 10 t ha^{-1} of compost. An increase in the dose of compost reduced the number of dry leaves. At a salinity level of 8000 ppm, dried leaves decreased from 11.67 in the treatment without compost to 6.67 in the 5 tha^{-1} treatment. The application of compost can increase the yield potential of rice at different salinity levels. At the level of 8000 ppm, the application of compost increased the yield potential from 1.13 t ha^{-1} to 6.16 t ha^{-1}. Compost can be recommended as a soil amendment to increase rice yields under 8000 ppm. Compost is an alternative soil amendment to overcome salinity and sustainably increase rice production. Using compost increases soil fertility, overcomes salinity, and handles agricultural wastes in the zero-waste concept.**

Keywords**— Drying leave; panicle, SPAD, salinity, tiller**

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I. INTRODUCTION

Salinity continues to increase over time. Saline land in the world increased by 1.5 million ha year^{-1} and reached 1.100 ha of soil affected by salinity. This needs immediate handling to maintain food security for the world's population, which continues to increase. In 2050, the world food supply must increase by 60% to satisfy the needs of the 8.9 billion world population. This is exacerbated by the occurrence of drought in various places. Drought exacerbates salinity stress because salt is not washed away by less rainfall. Drought and salinity cause a decline in soil fertility and crop production globally. Decreased fertility is a problem for agricultural production [1]. Salinity is a significant problem worldwide [2]. The use of tolerant rice varieties is essential for the reproductive phase of salinity [3]. Tolerant varieties can translocate salt to the shoot [4]. In addition to tolerant varieties, the application of compost and other organic amendments can reduce salinities [2], [5], [6]. Availability of nutrients is also increased by the application of compost [7].

The use of other amendments can affect the availability of other nutrients [8]. The compost material affects the release of N [9]. Compost can remediate soil [10]. Rice straw compost application can increase the bacterial community [11]. The use of straw compost together with manure can increase C/N and humification [12]. The chemical properties of compost affected N activity in lowland rice cultivation, which was not significantly different [5]. The use of manure and biochar in rice husks can reduce heavy metals in the soil [13]. The applications of compost and NPK with biochar will increase rice productivity and farmers' income [14]. Applying compost and biochar can increase the soil pH [1]. The use of compost rice straw and nitrogen can increase fertility and change the bacterial community [15]. Compost affects greenhouse gas emissions [2]. The effect of compost on soil fertility and rice yields exceeds that of other organic amendments [16].

Various types of organic soil amendments can reduce soil salinity [2]. Using stable organic amendments can reduce greenhouse gas emissions [17]. Compost can reduce the availability of Fe and Al [7] and changes in Na and Cl levels at the rhizosphere [18], [19]. Compost and rice straws can reduce heavy metal levels in the soil [20]. Applying various types of compost, such as Vermicompost and Verm waste, can reduce salinity levels and increase crop yields [2]. Using mixed compost can increase the ratio of pH and C/N [1]. The use of organic amendments in soil can increase plant adaptation to salinity [20] and plant resistance to salinity [18], [21] and increase rice tillers number [22]. Rice plants have different resistance to salinity stress [23].

Compost is a natural soil amendment that can be made with agricultural wastes. It can easily be obtained from various places, particularly in tropical regions. This is an essential characteristic and comparative advantage compared to other soil amendments. Concerning sustainable agriculture, compost application is the best alternative organic amendment for the soil [2].

II. Materials and Method

This research was conducted in the greenhouse of the Faculty of Agriculture, Universitas Syiah Kuala, Darussalam Banda Aceh, Indonesia, with an altitude of 3.8 m above sea level with an average maximum and minimum temperature of $36^0C/23^0C$ in the greenhouse in October 2021 to February 2022 with humidity 85-95% with solar radiation 11 hours, 50 minutes d^{-1}. The research was carried out with a 3x6 split-split plot design with three replications. The main plot consists of compost doses of 0, 5.0, and 10.0 t ha^{-1}, and the split-split plot consists of levels of salinity, without salinity, 2000, 4000, 6000, 8000, and 10000 ppm (NaCl) (-0,03, -0,07, -,017, -0,25, -0,34, -0,4 MPa Potential of Water of NaCl Solution or 0,9, 2,8, 5,6, 5,6, 8,4, 11,2, 14 dSm^{-1}, (S_0, S_1, S_2, S_3, S_4, S_5). The soil was filled into pots about four weeks before planting. Entisol soil was sieved with a 9-mesh sieve.

All pots were filled with 10 kg of soil. The soil was stirred until muddy and left in a water-saturated condition for two weeks before planting. The soil in the pot was mixed with compost, and then the rice seedling was planted 12 days after sowing, with one seedling per pot. Salinity treatment was carried out at the end of the vegetative phase by giving a salt solution into the pot according to each treatment's salinity level and leaving it for one week by maintaining a water level of 2 cm in the pot. After one week, the pots were again irrigated with tap water until harvest. Harvesting was done when the rice plants had shown 85% of the leaves yellowing and the grain had turned hardened. Observations on soil EC values were carried out every 2 weeks until just before harvest as well as SPAD values, plant height, number of leaves, tillers, and dry leaves at 3, 7 Days after treatment (DAP), and 2, 3, 4, 5, 9 weeks after treatment (WAT). The biomass dry weight was observed at harvest, as well as the yield potential.

III. Results and Discussion

Fig. 1 shows a decrease in soil EC that had been treated with a salt solution in the range of 0.9 – 14, dSm1 after 3, 7 days, and two weeks, and three weeks to 9 weeks after planting, there was a decrease in soil EC according to the increased in compost dosage from 5.0 to 10.0 t ha^{-1}. Fig. 1 shows the ability of compost to reduce the EC of soil. In addition to the role of compost in reducing soil EC, rice also has a role in reducing soil salinity. This is due to the ability of rice to translocate salt to the canopy, which causes a decrease in the level of salinity in areas planted with rice [18].

Fig. 1 Shows that, at all levels of salinity and age, EC values were lower in rice grown using 10 t ha^{-1} compost soil amendment, which was lower than the EC value in the 5 t ha^{-1} treatment. This shows that the ability of compost increases to reduce the EC value with increasing compost dosage at various levels of salinity.

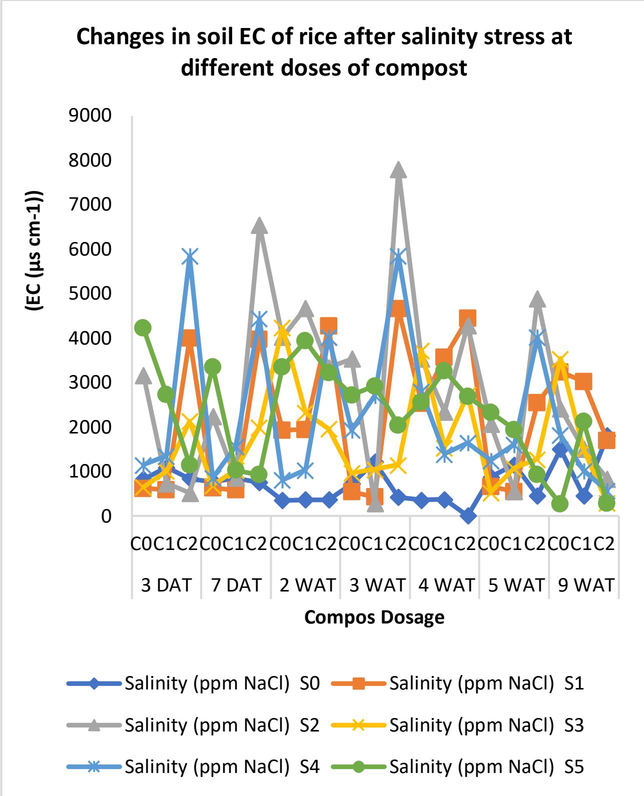

Fig. 1 Changes in soil EC of rice after salinity stress at different doses of compost DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress).

Decreased salinity can increase plant resistance and chlorophyll content, shoot dry weight, and maximize leaf weight [24]. This can also be seen in the decrease in the rate of decline in yield with an increase in salinity level in the treatment of higher compost doses. This shows that compost can mitigate the decline in growth and yield under salinity stress conditions. This is possible because compost has several advantages over other soil amendments. Compost can reduce the level of salinity and also improve the physical, chemical, and biological fertility of the soil. Other soil amendments cannot do this. Bacteria can't use other soil amendments for food; microbial life becomes better by applying compost. This will improve the physical, chemistry, and biology of the soil. Some of the studies below reveal compost's ability to improve soil's physical, chemical, and biological properties. Applying compost to soil rice planted can reduce the decline of growth rate and yields. Applying compost mitigates the decline in the growth and yield of rice. Applying compost is an important strategy to overcome the decrease in yield in rice plants due to salinity stress.

Applying 5.0 to 10.0 t ha^{-1} compost can mitigate reduced growth rates and rice yields. Increasing food security by increasing rice productivity in the last decades was important. Rice that is resistant to drought and salinity can form secondary metabolites [25]. Rice is resistant to salinity in the seedling phase, but in the reproductive phase, it is resistant to salinity [26]. Those that are tolerant to salinity can translocate Potassium and sodium to a shoot of more resistance [3]. The state of Sodium in rice flag leaf is more than that in unhulled rice [27]. Salinity is the most complex agricultural problem in the world [2]. Salinity-resistant varieties are reflected in the ratio of Na/K. Resistance to salinity is shown by the weight of 1000 grains and yield potential. Salinity is a global problem that affects agricultural lands around the world. It is estimated that half of the agricultural land in the world in 2050 will be affected by salinity. Salinity is exacerbated by drought, causing dissolved salts not to be washed out of the topsoil layer and an increase in salinity. This happens because of changes in rainfall patterns that prevent rain from occurring for a long time. Salinity will decrease if rain occurs two to three times within a certain period. This situation causes much agricultural land to be lost.

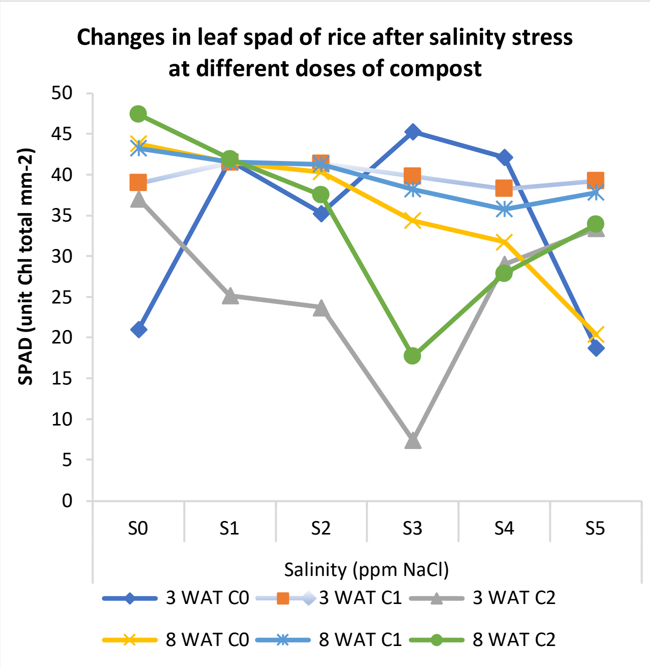

Fig. 2 Changes in leaf SPAD of rice after salinity stress at different doses of compost. DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress), Chl (chlorophyll)

Fig. 2 shows that the SPAD value at the age of 3 WAT, the SPAD value on leaves in the treatment without compost was lower, compared to the 5 and 10 t ha^{-1}compost treatment. There was a decrease in the SPAD value at the age of 3 WAT with increasing salinity, but at 8 WAT, there was an increase in SPAD value in the treatment of compost 5 and 10 t ha^{-1} at 6000 ppm. However, at 8000 and 10000 ppm, there was an increase in SPAD value. While the treatment without compost decreased the value of SPAD. This indicates a mechanism in rice leaf cells that induces SPAD values to increase SPAD values to overcome salinity. This is possible because of rice's ability to increase dissolved compounds in sugar and other compatible compounds to maintain homeostasis in cells and protect chlorophyll from damage due to osmotic stress. This is in agreement with the result by [23].

There was an increase in chlorophyll content in the leaves with increasing doses of compost up to a salinity level of 6000 ppm. However, there was a decrease in chlorophyll at the higher salinity level three weeks after treatment, with different levels of increase according to the salinity level. At the age of 8 weeks after treatment, there was an increase in chlorophyll levels with different levels according to the salinity level. Still, the chlorophyll content was higher in the treatment given 5.0 t ha-1 of compost than without adding compost, it was able to reduce the level of salinity. Reducing salinity causes a decrease in chlorophyll degradation. So that chlorophyll levels become higher by adding compost. This is in agreement with the results by [18], [28] that applying vermicompost to wheat crops on saline soils can increase chlorophyll content. Salinity extends globally, affecting one and a half million agricultural lands yearly. Various strategies must be implemented to reduce soil salinity and support sustainable crop productivity. Various organic amendments can reduce salinity stress and increase crop productivity. Other organic materials like biofertilizers have the potential to increase tolerance to salinity [2]. Applications of compost at salinity stress can increase growth, dry matter accumulation, and wheat yield but reduce proline content and increase RWC and chlorophyll content [29]

The use of PGPR in the form of organic matter containing microbiota can affect the chemical activity of the soil. Using PGPR affects biomass growth, chlorophyll, and proline [30] organic amendment affects plant adaptation to salinity. Compost can reduce the soil's electrical conductivity and specific gravity, increase the water content at field capacity, and also increase one point of hydraulic conductivity [24].

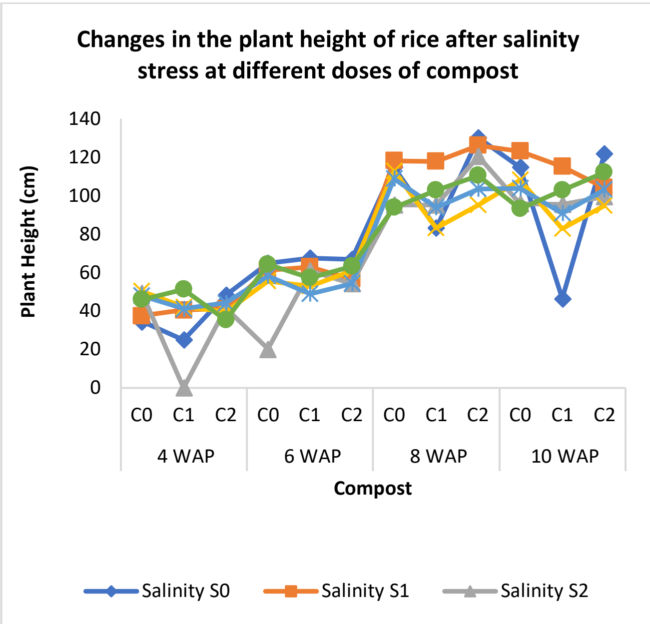

Fig. 3 Changes in the height of rice after salinity stress at different doses of compost. DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress

Fig. 3 shows a decrease in plant height with increasing salinity, with different levels of reduction at various doses of compost and without compost. The plant height decreased with increasing compost dosage and age at 18 WAP. Plant height was the highest in the treatment without salinity with 10 t ha^{-1} of compost. Then, it was followed by a salinity of 10,000 ppm at 10 t ha-1 compost and a salinity of 2000, 8000, and 6000 ppm. This shows a different response of Inpari 42 to plant height due to increasing salinity.

Fig. 3 also shows the increase in plant height with increasing doses of compost in different salinity stress. This is due to the ability of compost to neutralize salt compounds through organic acid compounds, which causes a decrease in salinity levels and an increase in plant height at older ages.

For example, at the age of 10 weeks, the height of the plants treated with salinity at 10.000 ppm at doses of 5.0 and 10.0 t ha^{-1} of compost had higher plant height compared to treatment with no compost applied. This is also caused by the ability of compost to increase plant resistance to various environmental stresses, which is also in line with research by [18], and [21], which stated that applying vermicompost to saline soils would increase plant vigor index and growth.

The number of tillers in rice given different doses of compost and different salinity stress. There was an increase in the number of rice plant tillers by applying compost 5.0-10.0 t ha^{-1} and C_2, which differed according to age and salinity level. The number of tillers at ten weeks after salinity stress treatment at 10.000 ppm was higher in the compost treatment because environmental conditions strongly influenced the number of tillers. There was an increase in water potential, which could have reduced the number of tillers, but it was independent of a disproportionate number of tillers for the best results. Even to overcome the high salt content. Rice requires many tillers so that salt can be translocated to the shoot, and a large number of tillers is not productive. This is in agreement with the results by [22], [23], [31], [32]. Also in line with the results of [33].

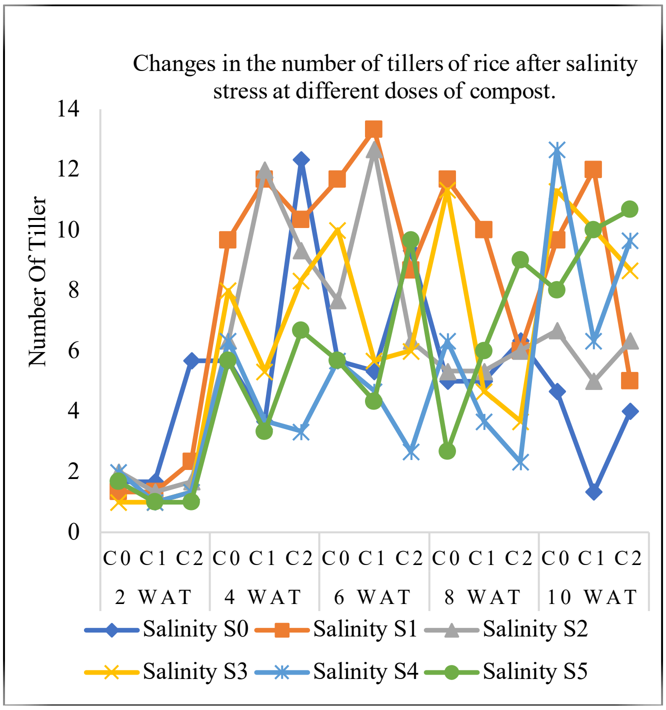

Fig. 4 Changes in the number of tillers of rice after salinity stress at different doses of compost. DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress)

Fig. 4 shows the number of tillers at the ages of 2, 4, 6, and 10 WAT at different salinity and compost dosages. There was an increase in the number of tillers with increasing compost dosage at various plant ages which was influenced by the salinity level. At the age of 10 WAT, the number of tillers was higher in the no-compost treatment, followed by 10 t ha-1, and the lowest at 5 t ha^{-1}, likewise at salinity levels of 4000 and 6000 ppm. But, at 6000 ppm there was a decrease in the number of tillers with an increase in the dose of compost. In the treatment without compost, the number of tillers was higher followed by 10 t ha^{-1} and 5 t ha^{-1}, while in 8000 ppm there was an increase of tillers at 10 WAT with increasing compost dosage. The lowest tillers number was in the treatment without compost.

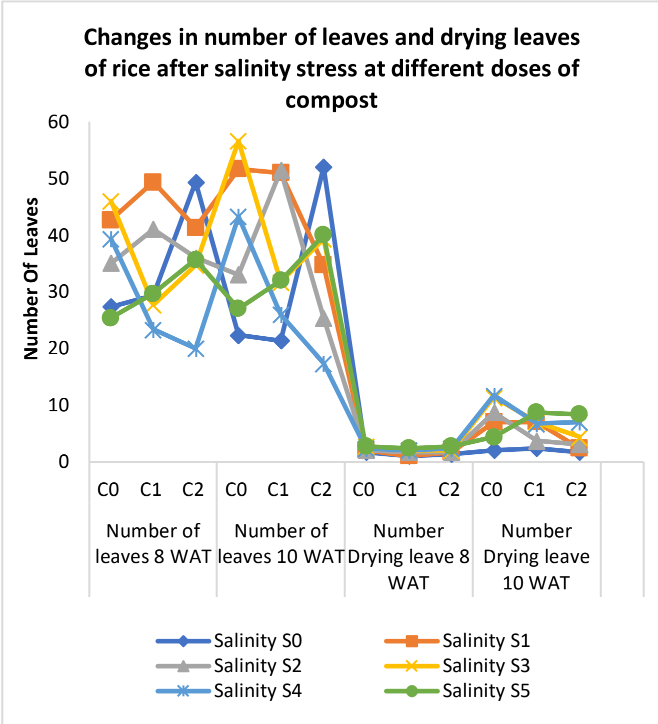

Fig. 5 Changes in the number of leaves and number of drying leaves of rice after salinity stress at different doses of compost. DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress)

The number of leaves increased with increasing doses of compost in the treatment without salinity stress, but with increasing salinity stress the decrease in leaf number varied according to salinity stress. At the age of 8 weeks after treatment, the number of leaves was higher in the treatment given at 10 t ha^{-1} compared to that without compost and 5.0 t ha^{-1}. The number of leaves is very dependent on the level of cell turgidity, which is influenced by the water potential of the soil and plants. This is influenced by various factors, such as the presence of various osmolytes that can maintain cell turgidity to handle environmental stress. This is in agreement with the research by [22], [23], [31], [32]. Adding vermicompost to saline soils can increase branching and plant height.

Fig. 5 shows the number of fresh and dry leaves at different salinity levels, ages, and compost doses. It shows that the number of leaves increases with the increase of compost doses at different salinity levels at various ages. At 10 WAT in the treatment without salinity, the leaves were highest in 10 t ha^{-1} compost. Meanwhile, at 2000 ppm, the number of leaves was highest at the 5 t ha^{-1} compost dose, likewise at 4000 ppm. The highest number of leaves was in the treatment without salinity, at 8000 ppm. The highest number of leaves was obtained in the 10 t ha^{-1} compost treatment. The drying leaves decreased with increased compost dosage at salinity level and age. At 10 WAT in the treatment without salinity, the number of drying leaves was the lowest, while at 2000 ppm with drying leaves was the same as at 4000, 6000, and 8000 ppm of NaCl. However, at 10000 pm, the number of dry leaves increased with the increase of compost dosage. This shows differences in the response of Inpari 42 and different levels of salinity.

The number of dry leaves decreased with increasing doses of compost depending on the different doses of compost. This is due to the ability of the compost to reduce the salt content, which affects the soil Ec value due to the ability of the compost to absorb Na and Cl and the ability of rice roots to translocate to shoot. So, the chlorophyll damage decreases and the number of dry leaves decreases. This is in line with research by [18], [19].

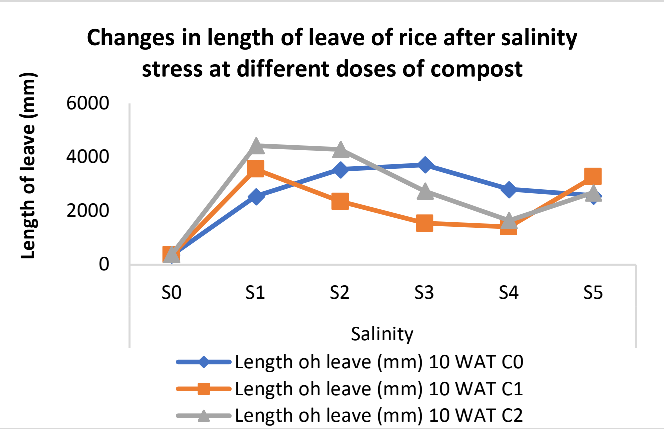

Fig. 6 Changes in the length of leave of rice after salinity stress at different doses of compost. DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress)

Fig. 6 shows differences in leaf length due to differences in salinity and compost dosage. Leaf length in the treatment without compost increased with increasing salinity up to a salinity level of 6000 ppm. Then leaf length decreased at salinity levels 8000 and 10000 ppm. Whereas in the 5 t ha^{-1} compost treatment, there was an increase in leaf length and at 2000 and 10000. Likewise at 4000 and 8000 which are longer than without salinity. Whereas at this dose of 10 t ha^{-1} of compost, there was an increase in Leaf length with increasing salinity. This shows that there was a different response to Inpari 42 and compost dose.

Fig. 6 shows Leaf length increases with increasing doses of compost with different levels of increase according to the level of salinity. It is related to leaf turgidity which is influenced by leaf water potential which affects leaf cell elongation, influenced by sugar and salt content in leaves. Cell turgidity influences cell solution which balances the cell water potential of leaves that affect cell elongation. This is in line with research by [18], [19], [24].

Fig. 7 shows the number of panicle hill^{-1} due to different doses of compost and salinity levels. In the treatment without compost, the number of panicles increased at 2000 ppm, then decreased with increasing salinity, whereas at the 5 t ha^{-1} compost dose, the number of panicles was highest in the treatment without salinity and there was a decrease in the number of panicles with increasing salinity, but the decrease was smaller with the addition of compost. While the application of compost on 5 t ha^{-1} and without are lower number of panicles.

Fig. 8 shows the differences in the number of grains at different levels of salinity and compost dosage. In the treatment without compost, the number of grains decreased with increasing salinity. With a lower grain number than the 5 t ha^{-1} compost treatment. Whereas in the 5 t ha^{-1} compost treatment, there was also a decrease in the amount of grain with an increase in salinity compared to without adding compost and adding 10 t ha^{-1} compost.

Fig. 9 shows the yield potential reduction in Inpari 42 with increasing salinity in various compost dose treatments. The yield potential at treatment without compost decreased with increasing salinity with a low level of yield potential from treatment 5 and 10 t ha^{-1}. At salinity levels of 6000 and 8000 ppm, the yield potential was higher in treatments of 5 and 10 t ha^{-1} followed by treatments without compost.

Fig. 7, 8, and 9 show changes in the panicle number of grains and yield potential at different levels of salinity and different doses of compost. The number of panicles decreased with increasing salinity, although the dose of compost increased. It was because the level of salinity affected the number of tillers. The number of tillers determines the number of panicles. This is influenced by the turgidity of cells at different salinity stresses. This is in agreement with the results of [20], and [34] research which resulting that the level of salinity affects soil and water EC, and affects the relative water content. Which ultimately affects plant growth, this is in agreement with the results of studies by [35], [36].

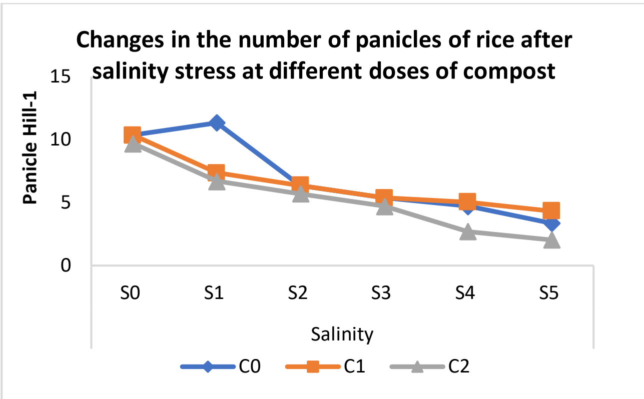

Fig. 7 Changes in the number of rice panicles after salinity stress at different doses of compost. DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress)

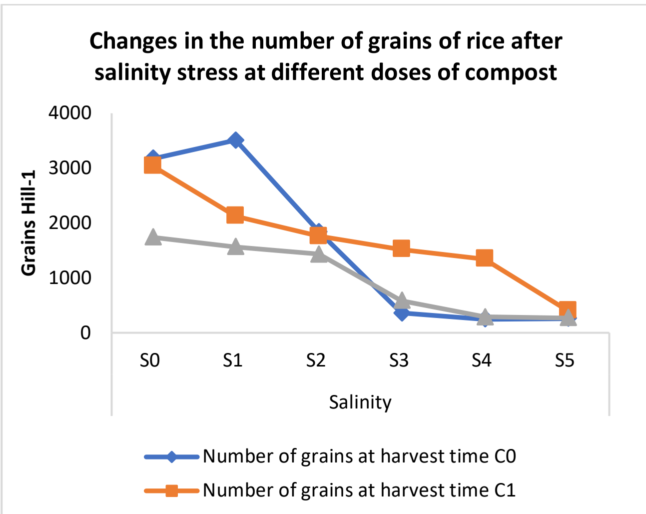

Fig. 8 Changes in the number of grains of rice after salinity stress at different doses of compost. DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress)

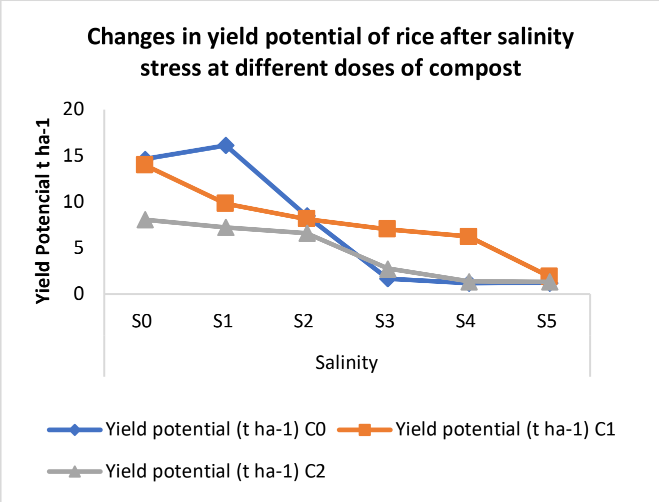

Fig. 9 Changes in the yield potential of rice after salinity stress at different doses of compost. DAT (day after treatment) WAT (week after treatment) test. C (compost), S (salinity stress)

Compost from a comparison of the results of the use of organic amendment, by other researchers and the research and our results of compost at different salinity stresses which affect rice morphogronomic, SPAD value which indicates physiological leaf health and soil EC value, compost can be recommended to reduce salinity stress and increase rice growth and yield. Compost is a soil amendment that is very likely to be used because it can be self-produced from eco-friendly rice waste. The rate of growth decreased with increasing compost dosage from 5.0 to 10.0 t ha^{-1} Likewise, rice yields were mitigated by reducing yields due to increased salinity by increasing the dose of compost.

IV. Conclusion

Application of compost can reduce soil EC with different levels of reduction at different salinity stress and compost dosage. Application of 5.0 t ha^{-1} of compost resulted in a change in soil EC compared to no compost application, the higher the dose of compost the lower the soil EC with different values according to the level of salinity. The SPAD of rice plant leaves increased with increasing doses of compost compared to no compost. The SPAD value varied according to the level of salinity and compost dosage. Applying 5.0-10.0 t ha^{-1} of compost can decrease soil EC and change rice leaf SPAD values. The application of compost has an effect on the morpho-agronomic of rice, with different levels of influence depending on the level of salinity. Increasing the dose of compost increases rice plant height, number of tillers, leaves, panicles, grains, leaf length, and yield potential. Increasing the dose of compost decreases the number of drying leaves. Applying 5.0-10.0 tha-1 of compost can be recommended to decrease soil EC and increase leaf SPAD value and rice.

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