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MITIGATION OF SALT STRESS IN RICE (*ORYZA SATIVA* L.) GROWTH AND YIELD IN COASTAL SALINE SOIL USING CROP RESIDUE-DRIVEN ORGANIC AMENDMENTS UNDER VARYING MOISTURE CONDITIONS

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Keywords: BRRI Dhan 28 and 47, growth and yield of rice, moisture conditions, organic amendments, saline soil, salt stress

Abstract

The increasing salinity in coastal areas due to climate change significantly hinders rice *(Oryza sativa L.)* production, a crucial food source for over half of the global population. This study evaluates the effects of organic amendments and moisture conditions on the vegetative growth and yield of rice varieties in a saline field in the Khulna district of Bangladesh. The field experiment was conducted from February to May 2020, using rice straw compost (RSC), sawdust (SD), rice husk (RH), and mustard seed meal (MSM) at varying rates (0, 5, 10, 15 t ha^{-1}) under moist (70% soil moisture) and saturated (>100% soil moisture) conditions. The experiment featured BRRI dhan 28 (salt-sensitive) and BRRI dhan 47 (salt-tolerant) varieties. Key metrics evaluated in the study included the productive to unproductive tillers ratio (PTR), spikelet sterility, percent filled grains, straw yield, and grain yield. Results indicated significant ($p \leq 0.05$) improvements in PTR, reduction in spikelet sterility, increased grain filling, and higher straw and grain yields with applying organic amendments, especially MSM. The highest PTR for BRRI dhan 47 (0.86) was achieved with MSM at 5 t ha^{-1} under moist conditions, while BRRI dhan 28 reached a PTR of 0.81 with RH at 10 t ha^{-1} under saturated conditions. Spikelet sterility was minimized (9/panicle) with MSM at 5 t ha^{-1} under saturated conditions for both varieties. Percent filled grains peaked (88.9%) with MSM at 5 t ha^{-1} for BRRI dhan 28. Enhanced straw yields were observed, with BRRI dhan 47 achieving 8.76 t ha^{-1} with MSM at 10 t ha^{-1}. Grain yield increased significantly, with BRRI dhan 28 yielding 5.75 t ha^{-1} under similar conditions. The study confirms that organic amendments of MSM > RSC > SD > RH can effectively mitigate salt and moisture stress, thereby improving rice productivity in saline soils.

Introduction

Due to climate change, the coastal area has been facing an increasing threat of salinity intrusion worldwide, hindering crop production and environmental sustainability. In Bangladesh, around 1.056 million hectares of cultivable coastal lands out of 2.86 million

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hectares are impacted by varying salinity levels at different depths, accounting for approximately 53% of the entire coastal area(1). Over 25 years, the prevalence of saline soils has escalated from 1 to 33%, primarily due to the encroachment of seawater in the coastal region of Bangladesh(2).

Rice *(Oryza sativa L.)* is not just a crop but a lifeline for over half of the global population, serving as a primary food source(3). However, its sensitivity to salinity poses a significant challenge to agricultural production. Salt stress is a major constraint on rice growth across all developmental stages, affecting germination, vegetative growth, reproductive development, and maturity(4,5,6,7). The decline in rice yield becomes evident when the electrical conductivity of the saturated paste extract of soil (EC_e) exceeds 3 dS m^{-1}, with a significant 50% reduction in yield occurring at EC_e levels ranging between 6 and 7 dS m^{-1} (8). Salt stress significantly hampers rice agronomic attributes, reducing tillering, shoot/root growth, panicle count, harvest index, leaf area, biomass production, grain yield, and increasing spikelet sterility(9,10,11).

Organic amendments have shown significant potential in alleviating salt stress in rice, improving growth and yield by modifying various physiological and biochemical processes(12). Therefore, this study aimed to determine the effectiveness of various organic amendments derived from crop residues such as rice straw compost, sawdust, rice husk, and mustard seed meal in reducing salt stress on different rice varieties. This research mainly focused on evaluating the impacts of organic amendments on the growth and yield of rice under different soil moisture conditions in a coastal saline field in Bangladesh.

Materials and Methods

A field experiment was conducted on a saline field at Par-Batiaghata, Batiaghata (GPS: 22°43′49.4″N, 89°28′00.1″E), Khulna, Bangladesh, during February 2020 to May 2020 in Boro season. The soil of the studied site belongs to the medium lowland and saline phase of the Bajoa soil series, having properties of pH 7.8, EC_e 8.2 dS m^{-1}, $SAR_{1:5}$ 7.4, and ESP 20.0%. The salt-affected soil was amended with four different indigenous crop residues driven organic amendments viz., rice straw compost (RSC), sawdust (SD), rice husk (RH), and mustard seed meal (MSM) each at the rates of 0, 5, 10 and 15 t ha^{-1} under moist (ML_{70}=70% soil moisture level) and saturated (ML_{100}=>100% soil moisture level) conditions. The treatment combinations are denoted throughout the paper as T_1=$RSC_0SD_0RH_0MSM_0ML_{100}$ (Control soil, >100% soil moisture), T_2=RSC_5ML_{100} (Rice straw compost at 5 t ha^{-1}, >100% soil moisture), T_3=$RSC_{10}ML_{100}$ (Rice straw compost at 10 t ha^{-1}, >100% soil moisture), T_4=$RSC_{15}ML_{100}$ (Rice straw compost at 15 t ha^{-1}, >100% soil moisture), T_5=SD_5ML_{100} (Sawdust at 5 t ha^{-1}, >100% soil moisture), T_6=$SD_{10}ML_{100}$ (Sawdust at 10 t ha^{-1}, >100% soil moisture), T_7=$SD_{15}ML_{100}$ (Sawdust at 15 t ha^{-1}, >100% soil moisture), T_8=RH_5ML_{100} (Rice husk at 5 t ha^{-1}, >100% soil moisture), T_9=$RH_{10}ML_{100}$ (Rice husk at 10 t ha^{-1}, >100% soil moisture), T_{10}=$RH_{15}ML_{100}$ (Rice husk at 15 t ha^{-1}, >100% soil moisture), T_{11}=MSM_5ML_{100} (Mustard seed meal at 5 t ha^{-1}, >100% soil moisture), T_{12}=$MSM_{10}ML_{100}$ (Mustard seed meal at 10 t ha^{-1}, >100% soil moisture), T_{13}=$MSM_{15}ML_{100}$ (Mustard seed meal at 15 t ha^{-1}, >100% soil moisture), T_{14}=$RSC_0SD_0RH_0MSM_0ML_{70}$ (Control soil, 70% soil moisture), T_{15}=RSC_5ML_{70} (Rice straw compost at 5 t ha^{-1}, 70% soil moisture), T_{16}=$RSC_{10}ML_{70}$ (Rice straw compost at 10 t ha^{-1}, 70% soil moisture), T_{17}=$RSC_{15}ML_{70}$ (Rice straw compost at 15 t ha^{-1}, 70% soil moisture), T_{18}=SD_5ML_{70} (Sawdust at 5 t ha^{-1}, 70% soil moisture), T_{19}=$SD_{10}ML_{70}$ (Sawdust at 10 t ha^{-1}, 70% soil moisture), T_{20}=$SD_{15}ML_{70}$ (Sawdust at 15 t ha^{-1}, 70% soil moisture), T_{21}=RH_5ML_{70} (Rice husk at 5 t ha^{-1}, 70% soil moisture), T_{22}=$RH_{10}ML_{70}$ (Rice husk at 10 t ha^{-1}, 70% soil moisture), T_{23}=$RH_{15}ML_{70}$ (Rice husk at 15 t ha^{-1}, 70% soil moisture), T_{24}=MSM_5ML_{70} (Mustard seed meal at 5 t ha^{-1}, 70% soil moisture), T_{25}=$MSM_{10}ML_{70}$ (Mustard seed meal at 10 t ha^{-1}, 70% soil moisture), and T_{26}=$MSM_{15}ML_{70}$ (Mustard seed meal at 15 t ha^{-1}, 70% soil moisture). The effects of the treatments were measured on the ratio of productive to unproductive tillers (PTR), spikelet sterility $panicle^{-1}$, percent filled grains $panicle^{-1}$, straw yield, and grain yield of BRRI dhan 28 and BRRI dhan 47, a salt-sensitive and a salt-tolerant variety, respectively after the harvest.

The study used a split-plot design with three replications. The main plots were assigned for moist (70% soil moisture) and saturated (over 100% soil moisture) soil moisture conditions, using frequent irrigation with saline water (EC 1.5 dS m^{-1}, SAR 2.36) when required to maintain the soil moisture levels. In each main plot, specific RSC, SD, RH, and MSM dosages and two selected rice varieties were randomly assigned to the subplots for different treatments. Each main plot consisted of 13 subplots (2m × 2m). The pH of the soil was determined on a 1:2.5 soil-to-water suspension by a glass electrode(13). The electrical conductivity of saturated paste extract (EC_e), sodium absorption ratio of a 1:5 soil-to-water suspension ($SAR_{1:5}$), and exchangeable sodium percentage (ESP) of the soil were determined by following standard methods(14).

The general linear model analysis for different factors and Tukey's range test to detect significant differences ($p \leq 0.05$) between means were performed using Minitab Statistics 20. All graphs were prepared using Microsoft Excel 2016.

Results and Discussion

The ratio of productive to unproductive tillers (PTR): In a general linear model analysis, the productive tiller ratio of salt tolerant genotype BRRI dhan 47 was found to respond significantly to the different application rates of organic amendments ($p \leq 0.001$) and variable moisture practices ($p \leq 0.001$), but their interactions were not found significant (Table 1). The highest value (0.86) of PTR of BRRI dhan 47 was obtained by amending the saline soil with mustard seed meal at the rate of 5 t ha^{-1} under moist conditions, succeeded by MSM at 5 t ha^{-1} (0.84), MSM at 10 t ha^{-1} (0.84) under saturated moisture practice, MSM at 10 t ha^{-1} (0.83) under moist condition and RH at 15 t ha^{-1} (0.83) under saturated moisture practice (Fig. 1). In contrast, the lowest PTR value (0.68) was observed in T_{14}, where the rice plant underwent moisture stress without receiving any organic amendments, followed by the control (T_1: 0.71). The PTR count of salt-sensitive genotype BRRI dhan 28 was found to significantly differ by different rates of organic amendments ($p \leq 0.001$), where the effects of moisture variation were found insignificant (Table 1). However, the combined effects of organic amendment and moisture conditions were found to be significant ($p \leq 0.05$). The rice husk at 10 t ha^{-1} under saturated moisture practice endorsed the highest PTR value (0.81) in BRRI dhan 28, followed by MSM at 10 t ha^{-1} (0.80) under saturated condition, MSM at 5 t ha^{-1} (0.80) under moist condition and RSC at 15 t ha^{-1} (0.79) under moist condition (Fig. 1). Whereas, productive tiller production was attenuated in BRRI dhan 28 with the least PTR value of 0.67 as impacted by moisture stress in the saline environment without receiving any organic amendment (T_{14}) succeeded by the control (T_1: 0.70). The number of tillers in rice determines plant structure. Having too many tillers reduces photosynthetic efficiency due to mutual shading, while too few tillers result in low biomass production(15). It is desirable to have a high ratio of productive to unproductive tillers (PTR) for high-yield performance in rice. However, it is evident that these organic amendments have the potential to increase the productivity of tillers of the varieties by counteracting both the salt and moisture stresses in the saline environment. The enhanced PTR in both the salt-sensitive and salt-tolerant genotypes may be attributed to the adequate nourishment of rice from the initial supply of essential macro and micronutrients in the soil and the alleviation of salt stress in the plants due to organic amendments. These amendments have likely facilitated improved translocation of carbohydrates from the mother stem to the tillers(15). A similar outcome was observed in another study, with increased productive tillers in rice after incorporating crop residue-driven organic amendments into coastal saline soil under varying moisture conditions(16).

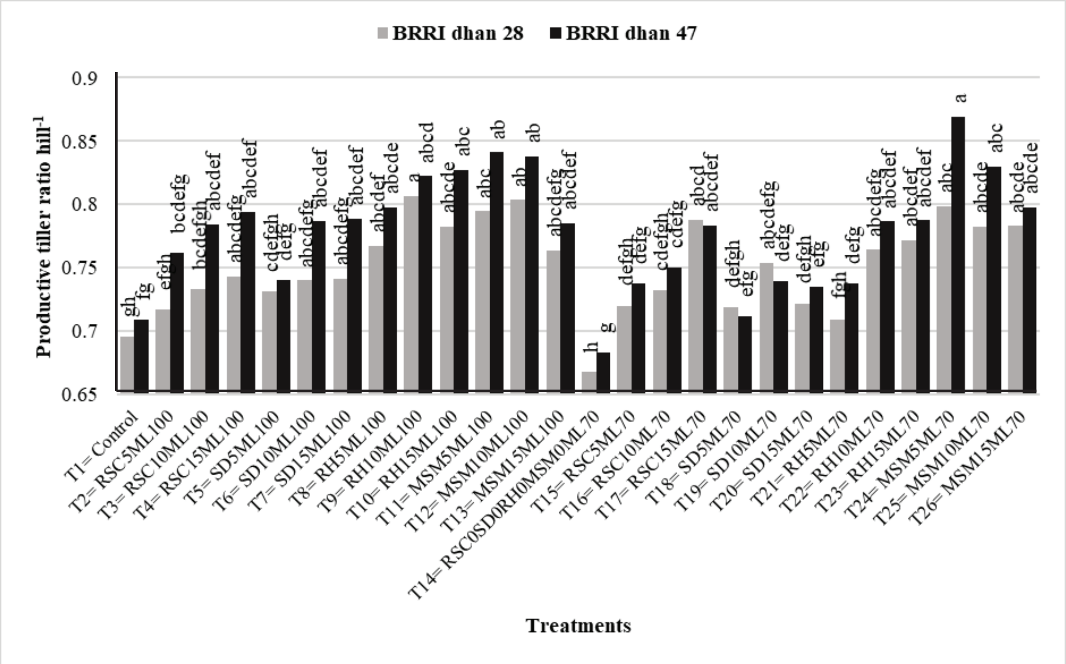

Fig. 1. Effect of organic amendments and moisture levels on the productive tiller ratio of salt-sensitive and salt-tolerant rice varieties in saline soil

Spikelet sterility: The highest sterility of spikelet was counted in the present experiment as 17/panicle and 16/panicle in BRRI dhan 28 and BRRI dhan 47, respectively, where salt stress was imposed with moisture stress (T_{14}) on the genotypes in a saline environment. Conversely, the amendments made in the salt-affected coastal soil with the selected organic materials substantially reduced spikelet sterility in both the salt-sensitive and tolerant genotypes regardless of moisture practices (Fig. 2). The least sterile spikelet was counted as 9/panicle in both the BRRI dhan 47 and BRRI dhan 28 varieties as influenced by mustard seed meal at 5 t ha^{-1} under saturated moisture practice. The least count of the sterile spikelet in BRRI dhan 47 was followed by 10/panicle with a statistically identical count as influenced by T_9, T_{10}, T_{12}, T_3, T_4, T_7, T_{17}, and T_{24}. The impact of amendment of the saline soil on spikelet sterility in salt-sensitive genotype BRRI dhan 28 was observed to be quite sharp. The least count was followed by 10/panicle with a statistically identical count as influenced by the RSC at 15 t ha^{-1}, RH at 15 t ha$^{-1,}$ and MSM at 10 t ha^{-1} under saturated moisture practice. Furthermore, the sterility of spikelet of both the genotypes BRRI dhan 28 and BRRI dhan 47 was found to be significantly varied by the different rates of organic amendments applied ($p \leq 0.001$) and variable moisture practices ($p \leq 0.001$). In contrast, their combined effects were not found significant in a general linear model analysis (Table 1). Salt-affected soil can lead to spikelet sterility, resulting in fewer grains per panicle and reduced rice yields(9). It was observed that as soil salinity increases, there is a linear reduction in the K^+ content in the shoot and the K^+/Na^+ ratio, while grain sterility and Na^+ content in the shoot increase(17). This suggests that the decrease in spikelet sterility may be due to the reduced osmotic stress in plants and the increased supply of essential nutrients influenced by the organic amendments.

Percent filled grains: The amendments with organic residues to the salt-affected soil under different moisture practices substantially improved grain filling in BRRI dhan 28 and BRRI dhan 47. It is evident statistically from the results of the present study that the percent filled grains per panicle significantly differed among the treatment combinations by different rates of organic amendments ($p \leq 0.001$) and variable moisture practices ($p \leq 0.001$). However, their combined effects on both genotypes were insignificant (Table 1). Among the treatments, mustard seed meal at 5 t ha^{-1} promoted the highest (88.9%) percent filled grains per panicle in BRRI dhan 28, succeeded by MSM at 10 t ha^{-1} (88.30%), SD at 15 t ha^{-1} (87.6%) under saturated moisture practice, MSM at 5 t ha^{-1} under moist condition (87.0%) and RSC at 15 t ha^{-1} under saturated moisture practice (86.1%). However, the increased rate of application of MSM at 10 t ha^{-1} was not found to make a significant change over 5 t ha^{-1} under saturated moisture practice (Fig. 3). Furthermore, MSM at 5 t ha^{-1} under less water input produced a statistically identical response in BRRI dhan 28. Almost similar results were observed in SD at 15 t ha^{-1}, implying that these amendments could alleviate moisture stress in the saline environment regarding grain filling of the salt-sensitive genotype.

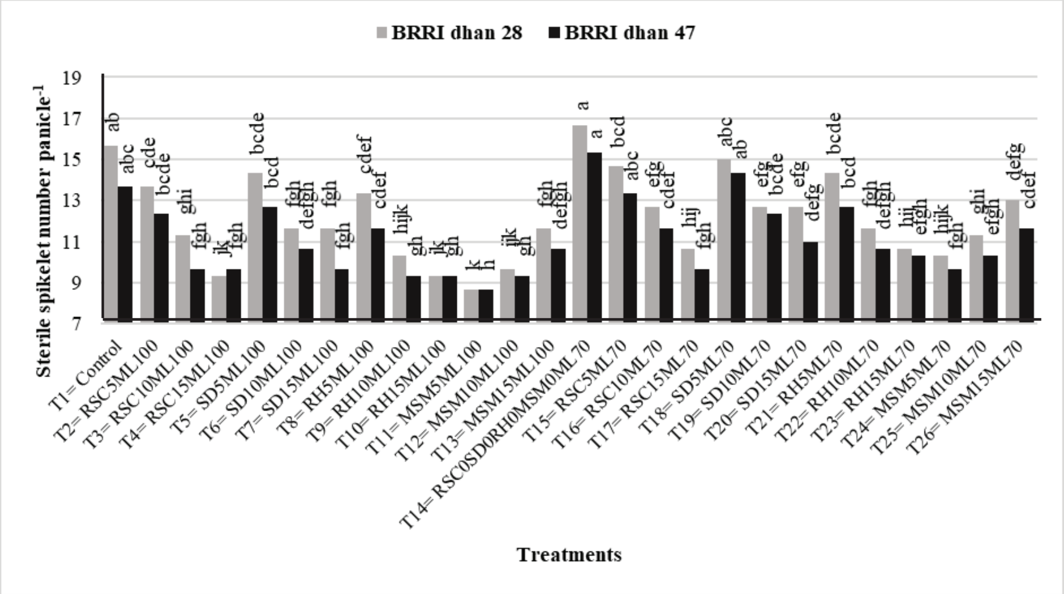

Fig. 2. Effect of organic amendments and moisture levels on the sterile spikelet number panicle^{-1} of salt-sensitive and salt-tolerant rice varieties

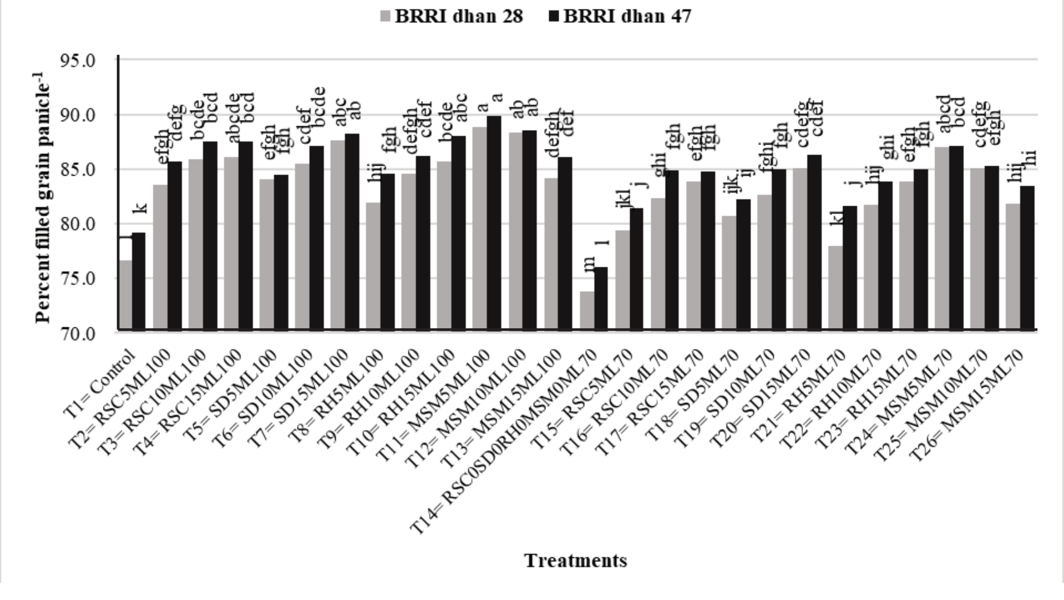

Fig. 3. Effect of amendments of saline soil under different moisture levels on the percent filled grain panicle^{-1} of the salt-sensitive and salt-tolerant rice varieties

The findings of the present study align with those of a previous study, which observed a significant enhancement in rice grain filling by using compost and sugarcane filter cake to amend salt-affected soil(18). These results suggest that organic amendments could effectively enhance grain filling by improving mineral nutrition and reducing salt stress, thereby potentially enhancing photosynthesis and the transport of photosynthates to the grains of rice plants.

Straw yield: The straw yield of the salt-sensitive BRRI dhan 28 in the study was substantially improved by the organic amendments to the salt-affected soil (Fig. 4). A general linear model analysis showed that the straw yield response of BRRI dhan 28 was significantly varied with the different doses of organic amendments ($p \leq 0.001$), variable moisture practices ($p \leq 0.001$), and their combinations ($p \leq 0.01$). A markedly higher straw yield (7.11 t ha^{-1}) of BRRI dhan 28 was obtained from the salt-affected soil which received mustard seed meal at 10 t ha^{-1} under saturated moisture practice succeeded by SD at 15 t ha^{-1} (6.49 t ha^{-1}) with a statistically identical yield response to MSM at 5 t ha^{-1} (6.29 t ha^{-1}), SD at 10 t ha^{-1} (6.18 t ha^{-1}) and RSC at 15 t ha^{-1} (6.10 t ha^{-1}) under saturated moisture practice. The mustard seed meal at 10 t ha^{-1} under less water input enhanced straw yield of 5.84 t $ha^{-1,}$ which showed a statistically similar response of BRRI dhan 28 to the treatment scenarios of $T_{11} > T_6 > T_4 > T_{13} > T_{10} > T_9$ under saturated moisture practice. Whereas the least straw yield (3.37 t ha^{-1}) of BRRI dhan 28 was observed in the soil where the plant received limited irrigation water supply without any organic amendment (T_{14}) succeeded by the control (T_1: 4.24 t ha^{-1}). Similarly, quite striking impacts of amendments on straw yield of BRRI dhan 47 were observed and differed significantly ($p \leq 0.001$) by the different organic amendments, variable moisture practices, and their combinations (Table 2). A relatively poor straw yield of 4.06 t ha^{-1} was attained in T_{14} where the rice plant underwent moisture stress without any organic amendments as anticipated. Mustard seed meal at 10 t ha^{-1} under saturated moisture practice promoted a vigorous growth in BRRI dhan 47 with a yield of 8.76 t ha^{-1} followed by MSM at 5 t ha^{-1} (7.76 t ha^{-1}), RSC at 10 t ha^{-1} (7.33 t ha^{-1}) with a statistically equal response to RSC at 15 t ha^{-1} (7.10 t ha^{-1}) and MSM at 15 t ha^{-1} (7.02 t ha^{-1}) under saturated moisture practice. Meanwhile, MSM at 10 t ha^{-1} promoted a straw yield of 6.75 t ha^{-1} under less irrigation input, which was a statistically identical response to $T_4 > T_{13}$ (Fig. 4).

The findings of the current study align closely with those of several earlier investigations, illustrating that the use of organic amendments significantly enhances aboveground biomass production in saline soils(16,18,19). It was reported that the highest straw yield of BRRI dhan 48 was achieved through the combined application of rice straw compost, rice husk, and sawdust in coastal saline soil under saturated moisture conditions(16). Thus, it can be argued that applying organic amendments either aids in reducing salinity through improved soil physical and structural properties or promotes the availability of nutrients in the soil, thereby enhancing plant mineral nutrition or both. In such conditions, the plant is more capable of handling the energy needed to continuously produce organic solutes necessary to maintain osmotic balance and counteract salinity(20). This results in improved vegetative growth of rice.

Grain yield: The salt stress, together with less moisture input, impaired grain yield in both the BRRI dhan 28 and BRRI dhan 47 by 10.59% and 10.69% yield loss, respectively (Table 2). Meanwhile, the amendments of the saline soil with organic materials under variable moisture practices profoundly impacted grain yield in salt-sensitive and salt-tolerant genotypes. The salt-sensitive genotype showed significant grain yield response to the different rates of organic amendments ($p \leq 0.001$), variable moisture practices ($p \leq 0.001$), and their combinations ($p \leq 0.01$), as revealed in a general linear model analysis (Table 1). Furthermore, all the treatment combinations significantly ($p \leq 0.05$) increased the grain yield of BRRI dhan 28 over T_{14} and T_1. The highest increase (67.64% over control) of grain yield as 5.75 t ha^{-1} of BRRI dhan 28 was attained by the mustard seed meal at 10 t ha^{-1} applied as an amendment for the salt-affected soil under saturated moisture condition with a statistically identical yield response to MSM at 5 t ha^{-1} (5.67 t ha^{-1}) and SD at 15 t ha^{-1} (5.5 t ha^{-1}) under saturated moisture practice succeeded by SD at 10 t ha^{-1} (5.1 t ha^{-1}), RSC at 10 t ha^{-1} (5.0 t ha^{-1}) and RSC at 15 t ha^{-1} (4.9 t ha^{-1}) under saturated moisture practice. Under less irrigation water input, the maximum grain yield (4.86 t ha^{-1}) of BRRI dhan 28 was obtained by MSM at 10 t $ha^{-1,}$ succeeded by MSM at 5 t ha^{-1} (4.8 t ha^{-1}), which was found statistically identical to the response of the genotype to the treatments as $T_6 > T_3 > T_4 > T_{10} > T_5 > T_9 > T_8$ under saturated moisture practice (Table 2). That implies MSM at 5 t ha^{-1} might alleviate moisture stress in rice grain production in the saline environment over these doses of organic amendments. Furthermore, it was observed that the application of MSM at the higher rate (10 t ha^{-1}) could not exert a significant effect on grain yield over the lower rate (5 t ha^{-1}) under saturated moisture practice. The responses were similar to sawdust and rice straw compost applied at 10 t ha^{-1} and 15 t ha^{-1} under saturated moisture practice. Whereas the lowest grain yield of 3.06 t ha^{-1} of BRRI dhan 28 was obtained in the soil where no amendment was made and the rice plant underwent moisture stress (T_{14}) followed by the control (T_1: 3.43 t ha^{-1}). The salt-tolerant genotype BRRI dhan 47 responded strikingly to the amendments made in the saline soil. The grain yield of BRRI dhan 47 was found to differ significantly ($p \leq 0.001$) by the different doses of organic amendments, variable moisture practices, and their interactions (Table 1). Among the amendments, mustard seed meal applied at 10 t ha^{-1} under saturated moisture practice endorsed maximum grain yield intensification (55.5% over control) of BRRI dhan 47 as 6.73 t ha^{-1} in the saline soil succeeded by the RSC at 10 t ha^{-1} (6.2 t ha^{-1}) with a statistically identical response to MSM at 5 t ha^{-1} (6.0 t ha^{-1}), RSC at 15 t ha^{-1} (5.96 t ha^{-1}), SD at 15 t ha^{-1} (5.9 t ha^{-1}) and RH at 15 t ha^{-1} (5.82 t ha^{-1}) under saturated moisture practice. In contrast, a satisfactory grain yield of 5.62 t ha^{-1} was achieved by the MSM at 10 t ha^{-1} under less irrigation water input in the soil, which was a statistically similar response to $T_{11} > T_4 > T_7 > T_{10} > T_9$ (Table 2).

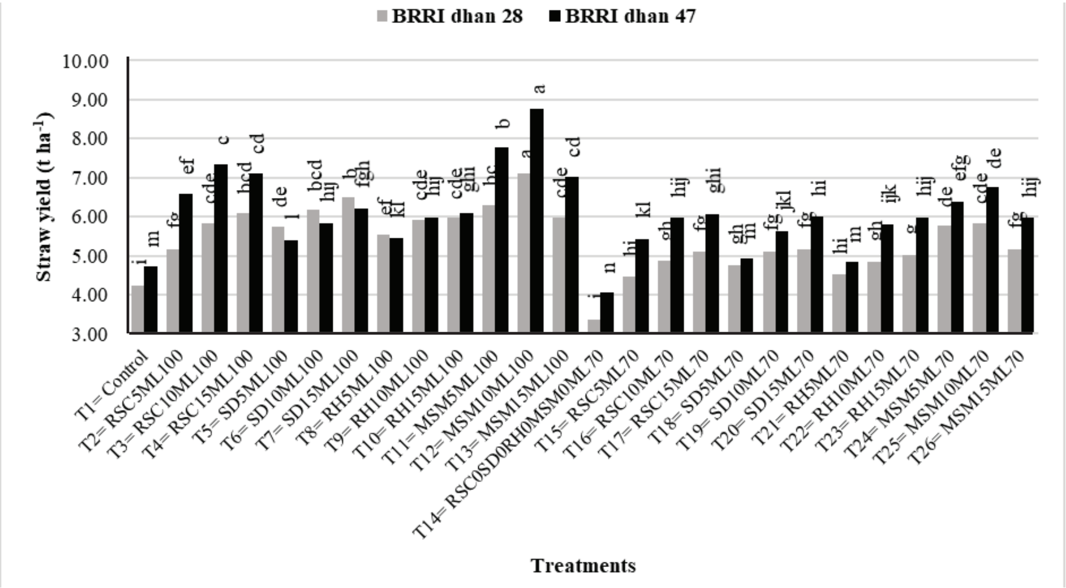

Fig. 4. Effect of organic amendments and moisture levels on the straw yield response of BRRI dhan 28 and BRRI dhan 47

However, the increased rate (15 t ha^{-1}) of rice straw compost, rice husk, and sawdust was not found to make any significant improvement in the grain yield of BRRI dhan 47 over relatively lower rates of application (10 t ha^{-1}) under saturated moisture practice. The least grain yield (3.86 t ha^{-1}) of BRRI dhan 47 was found where no organic amendment was made, and the rice plant received less irrigation water input (T_{14}) followed by the control (T_1: 4.33 t ha^{-1}) as anticipated. Furthermore, between the varieties, the salt-tolerant BRRI dhan 47 was found to perform better than the salt-sensitive BRRI dhan 28 in response to organic amendments as reflected in grain production under both moisture conditions (Table 2). The results of the current study are consistent with prior studies that also showed an increase in rice grain production by using organic amendments in salt-affected soils(16, 18). The combined findings of these studies indicate that the improved grain yields obtained by applying different organic materials to address the problematic soils may be attributed to an overall enhancement of the physical, chemical, and biological properties of soil. This improvement results in a better supply of essential macro and micro-nutrients and helps mitigate plant salt stress.

Table 1. General linear model analysis to assess the effects of organic amendments, moisture levels, and their interaction on the growth and yield attributes of BRRI dhan 28 and BRRI dhan 47

Variable and source of variation	df	F	P	Variable and source of variation	df	F	P
PTR (BRRI dhan 28)				PTR (BRRI dhan 47)			
[a]OA	12	13.84	0.000	OA	12	14.46	0.000
[b]ML	1	2.70	0.107	ML	1	16.75	0.000
OA × ML	12	2.17	0.027	OA × ML	12	1.27	0.262
Spikelet sterility (BRRI dhan 28)				Spikelet sterility (BRRI dhan 47)			
OA	12	64.63	0.000	OA	12	37.34	0.000
ML	1	73.63	0.000	ML	1	64.97	0.000
OA × ML	12	0.33	0.981	OA × ML	12	0.86	0.588
Percent filled grains (BRRI dhan 28)				Percent filled grains (BRRI dhan 47)			
OA	12	80.83	0.000	OA	12	132.17	0.000
ML	1	202.04	0.000	ML	1	438.45	0.000
OA × ML	12	1.02	0.447	OA × ML	12	1.66	0.105
Straw yield (BRRI dhan 28)				Straw yield (BRRI dhan 47)			
OA	12	100.59	0.000	OA	12	322.66	0.000
ML	1	743.72	0.000	ML	1	882.50	0.000
OA × ML	12	2.76	0.006	OA × ML	12	35.40	0.000
Grain yield (BRRI dhan 28)				Grain yield (BRRI dhan 47)			
OA	12	65.74	0.000	OA	12	118.96	0.000
ML	1	208.77	0.000	ML	1	478.73	0.000
OA × ML	12	2.65	0.008	OA × ML	12	4.27	0.000

[a]Organic amendments, [b]Moisture level.

Table 2. Effects of different treatments of organic amendments and moisture levels on the grain yields (t h^{-1}) of BRRI dhan 28 and BRRI dhan 47

Treatments		Grain yield (t ha^{-1})			
ID	Combinations and Denotations	BRRI dhan 28	^{f}IOC (%)	BRRI dhan 47	IOC (%)
T_1	Control ($^{a}RSC_0{}^{b}SD_0{}^{c}RH_0{}^{d}MSM_0{}^{e}ML_{100}$)	3.43 j	-	4.33 m	-
T_2	RSC_5ML_{100}	4.53 defghi	32.17	5.50 efghi	27.02
T_3	$RSC_{10}ML_{100}$	5.00 cd	45.77	6.20 b	43.19
T_4	$RSC_{15}ML_{100}$	4.93 cd	43.83	5.97 bc	37.80
T_5	SD_5ML_{100}	4.83 cde	40.91	5.13 ijkl	18.55
T_6	$SD_{10}ML_{100}$	5.10 bc	48.69	5.53 defgh	27.79
T_7	$SD_{15}ML_{100}$	5.50 ab	60.35	5.90 bcd	36.26
T_8	RH_5ML_{100}	4.62 cdefg	34.61	5.17 hijkl	19.40
T_9	$RH_{10}ML_{100}$	4.80 cdef	39.94	5.65 cdef	30.48
T_{10}	$RH_{15}ML_{100}$	4.87 cde	41.89	5.83 bcde	34.57
T_{11}	MSM_5ML_{100}	5.67 a	65.21	6.00 bc	38.57
T_{12}	$MSM_{10}ML_{100}$	5.75 a	67.64	6.73 a	55.50
T_{13}	$MSM_{15}ML_{100}$	4.60 defg	34.11	5.50 efghi	27.02
T_{14}	$RSC_0SD_0RH_0MSM_0ML_{70}$	3.07 j	-10.59	3.87 n	-10.69
T_{15}	RSC_5ML_{70}	4.07 i	18.56	4.93 kl	13.93
T_{16}	$RSC_{10}ML_{70}$	4.43 efghi	29.25	5.40 fghij	24.71
T_{17}	$RSC_{15}ML_{70}$	4.63 cdefg	35.07	5.47 efghij	26.25
T_{18}	SD_5ML_{70}	4.33 fghi	26.34	4.50 m	3.93
T_{19}	$SD_{10}ML_{70}$	4.65 cdefg	35.57	5.10 jkl	17.78
T_{20}	$SD_{15}ML_{70}$	4.70 cdefg	37.03	5.47 efghij	26.25
T_{21}	RH_5ML_{70}	4.10 hi	19.53	4.40 m	1.62
T_{22}	$RH_{10}ML_{70}$	4.41 efghi	28.67	5.25 ghijkl	21.25
T_{23}	$RH_{15}ML_{70}$	4.57 defgh	33.14	5.42 fghij	25.10
T_{24}	MSM_5ML_{70}	4.80 cdef	39.94	5.30 fghijk	22.40
T_{25}	$MSM_{10}ML_{70}$	4.87 cde	41.89	5.62 cdefg	29.79
T_{26}	$MSM_{15}ML_{70}$	4.30 ghi	25.36	4.90 l	13.16

[a]Rice straw compost, [b]Sawdust, [c]Rice husk, [d]Mustard seed meal, [e]Moisture level, [f]Increase over control. In a column, means that do not share a letter differ significantly at the 5% level according to Tukey's Range Test.

Conclusion

This study highlights the significant benefits of using organic amendments to enhance the growth and yield of rice varieties in saline soils under different moisture conditions. The findings demonstrate that rice straw compost, sawdust, rice husk, and mustard seed meal effectively improved the ratio of productive tillers, reduced spikelet sterility, increased grain filling, and enhanced both straw and grain yields. Particularly, it is noteworthy that mustard seed meal applied at 10 tons per hectare under saturated conditions emerged as the most effective treatment, significantly benefiting both BRRI dhan 28 and BRRI dhan 47 varieties. The amendments followed the order of their effectiveness in mitigating salt stress, as MSM > RSC > SD > RH. These results underscore the potential of organic amendments to mitigate the adverse effects of salinity and moisture stress, thereby promoting sustainable rice production in salt-affected regions. Future research should focus on investigating the long-term impacts and economic feasibility to facilitate broader adoption of these practices.

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