Journal of Pure and Applied Agriculture (2020) 5(1): 11-19
ISSN (Print) 2617-8672, ISSN (Online) 2617-8680
http://jpaa.aiou.edu.pk/
RESEARCH PAPER

Impact of compost to produce rice-wheat crops from saline sodic soil

Ghulam Sarwar[1]*, Helge Schmeisky[2], Nazir Hussain[3], Muhammad Ashraf Malik[4], Muhammad Zeeshan Manzoor[1], Ayesha Zafar[1] and Ghulam Murtaza[1]

[1]Department of Soil & Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan
[2]Department of Landscape Ecology & Nature Conservation, University of Kassel, Germany
[3]Agriculture Ministry of Environment, Doha, Qatar
[4]Department of Education, Government of the Punjab, Pakistan

*Corresponding author: Ghulam Sarwar (ghulam.sarwar@uos.edu.pk)

Received: 30 March 2020; Accepted: 24 April 2020; Published online: 20 May 2020

Key Message: In this study, compost when integrated with mineral fertilizers at different rates improved production of rice-wheat crops in a saline stress environment. The compost not only increased production of rice-wheat crops, but also reclaimed saline sodic soil.

Abstract: A significant area of Pakistan is affected by high concentration of soluble and exchangeable salts that limit crop production. So, this study was planned to thrash positive effects of compost not only on yield of rice and wheat plants, but also on its role as a recovery agent. To achieve this purpose, a salt sodium field with pH = 8.63, TSS = 49.5 me L^{-1}, SAR = 18.99 was selected. Experiment consisted of 6 treatments that were repeated four times using a randomized complete block design. Treatments of experiment were; 1) control (no nutrition), 2) chemical fertilizers, 3) 12 tons/ hectare of compost, 4) 24 tons/ hectare of compost, 5) 2 + 3 combination and 6) 2 + 4 combination. Compost was applied 30 days before rice transplantation, since rice was first crop of rotation. All necessary cultural operations were carried out according to requirements. At time of ripening, data on various yield components such as plant height and other parameters were observed. Rice data of biomass, grains and then weight of 1000 grains from each plot was also recorded. Field was plowed again and wheat was sown and harvested until ripe. All desired wheat data were also noted. All data collected was tested statistically. Treatment (T6), however, proved superior to all others. Yield of rice and wheat was increased to level of 2.91 and 2.97 t ha^{-1}, respectively in T6. Similarly, soil pH, EC and SAR were decreased to the values of 8.1, 3.55 dSm^{-1} and 2.7, respectively for T6. Respective analyzed values for soil health parameters were 1.40% organic matter, 29.90 ppm Olsen's P and 2.59 me L^{-1} K for T6 after the end of experiment. In future, the compost can be used for reclamation of salt-affected soils in addition to maintain soil health.

Keywords: Chemical fertilizer, Compost, Rice and wheat, Saline sodic soil

To cite this article: Sarwar, G., Schmeisky, H., Hussain, N., Malik, M. A., Manzoor, M. Z., Zafar, A., & Murtaza, G. (2020). Impact of compost to produce rice-wheat crops from saline sodic soil. *Journal of Pure and Applied Agriculture*, *5*(1), 11-19.

Introduction

Compost is just like nutrient enriched energizer for crops and soils. Its application enhances the status of nutrients in the soil and also makes these nutrients more available to plants (Sarwar, 2005). Soil physical, chemical and biological properties are not only upgraded by the addition of compost to the soil but crop yield is also enhanced (Sarwar et al., 2008). Hence, it can be said that usage of compost is dire requirement of time in the current scenario of agriculture. Hussain et al. (2001) noted more crop growth when farm yard manure (FYM) was used as a source of organic matter. In general, rice yield and the inclusion of N, P and K showed that there was a fertilization plan with one of the FYM fertilizers or green manure or city compost coupled with the recommended doses. NPK would maximize yield and nutrient uptake as if only the recommended amounts of manure-free fertilizers were used (Jagadeeswari & Kumaraswamy, 2000).

Halima et al. (2019) used sugarcane compost and gypsum as an amendment on soils with diverse salinity levels and found that amendments are good pH buffer and nutrients sink even with soil salinization effect. The highest reduction in electrical conductivity was observed irrespective of the amendment used. Fang et al. (2020) suggested that application of organic amendments combined with inorganic fertilizers or gypsum in poorly structured soil is the best management practice aiming to ameliorate physicochemical constraints and improving soil carbon storage. In the same way, Nguyen-sy et al. (2020) found that the organic carbon and total nitrogen contents of the bulk soils were higher in the plots that were treated with inorganic fertilizers plus organic matter than in the PK and NPK plots. Yao et al. (2019) also found that growing leguminous green manure to replace summer fallow can raise the quantity and stability of soil organic carbon, suggesting that the proposed management practice could promote sustainable agriculture.

Smiciklas et al. (2002) conducted a research study on conservation of soil health through the use of compost prepared from various sources. It emerged from this study that the plots treated with compost showed a decline in the soil reaction values compared to control. The percentage of organic matter increased in almost all treatments with mature/ raw compost compared to the control. They also detected a decrease in CEC after spreading various organic materials and nitrogenous fertilizers. From these studies, they came to the conclusion that the use of mature compost did not change any measured soil parameters one to three years after the annual application, regardless of the application rate. Revegetation studies of salt deposits in the potash industry in Germany, consisting of sodium chloride (> 90%), showed that the use of compost (1-5 liters/ plant) in the plants (birch), Scotch, Aspen and Goat Willow) enhanced the growth and development of these plants. Compost and fertilizer also promoted the spread of grasses, without which they could no longer survive (Hofmann, 2004).

Similarly, Lim et al. (2020) also suggested that fertilization management as well as salinity management via drainage, gypsum application, tillage, and proper irrigation may be essential to improve rice production. Likewise, Rani et al. (2020) found that NPK availability in soil also enhances significantly with the integrated usage of FYM, compost and slurry biogas over control. This integrated approach can be used for the growth of wheat under semi-arid conditions of India. Hence, Cao et al. (2020) found that the beneficial results of hyper-thermophilic compost in soils and crops could reduce the use of mineral fertilizer for the sustainable production of vegetables. In another study, Shi et al. (2019) assessed the integrated effect between microbial communities and organic amendments in salt stress soil environment and reported that the addition of various amendments having organic origin increased fertility as well as enzymatic activities in saline sodic soils.

Addition of various organic amendments increased the maximum height of rice-wheat. The use of compost proved to be superior to that of sesbania green manure and farm yard manure. This tendency of increasing the plant height increased when the chemical fertilizer was combined with these organic materials. The combination of fertilizers and compost at the highest rate was the most successful treatment (Sarwar, 2005). Similarly, combining both amounts of compost + chemical fertilizers caused a maximum agglomeration in rice-wheat plants compared to FYM and sesbania. Using FYM proved to be superior to the control and led to a substantial rise in the number of rice-wheat crop growers. A comparison of compost and fertilizer showed the superiority of compost over chemical fertilizer in this regard, but the combination of these proved to be more successful than using compost alone (Sarwar et al., 2007).

Salinity leads to a deterioration of the natural resources of the soil, which affects the agricultural production (Ren et al., 2019). Increased salinity is a major cause of reduced yield in the economically important plants (Ivushkin et al., 2019). Therefore, excessively soluble salts and replaceable sodium are a major problem associated with salt in soils (Paz et al., 2019). Soil salinity is a global problem (Chen et al., 2019). Therefore, stopping salinity is a key to improve the plant productivity in arid and semi-arid regions (Wang et al., 2019). Plant growth is strongly influenced by nutrient imbalance, oxidative stress, osmotic effects and lack of water (Kim et al., 2016). The growth of most plants is reduced by the presence of salts in the soil (Zorb et al., 2019).

Nguyen et al. (2020) found an increase in methane emissions by the use of cow manure from paddy salt affected soils. However, the addition of biochar mitigated the methane emissions, reduced activities of methanogens while increased those of methanotrophs. Zhou et al. (2019) found that the combined application by aluminum sulfate with organic-inorganic compound fertilizer is an effective amendment of saline-sodic soils in Songnen Plain, Northeast China. These outcomes are likely due to sodium leaching and enhanced soil organic carbon leading to increased fertilizers retention. Application of vermicompost and humic acid fertilizer increased the nitrogen, phosphorus and potassium contents in maize. Therefore, the application of humic acid fertilizer and vermicompost can be integrated as a practice for improving coastal saline soil (Liu et al., 2019).

The residues from the rice and wheat harvest are mainly burned with the combine harvesters after the grain harvest. A vegetable and fruit waste from fruit and vegetable markets in major cities is also wasted, and contractors can collect, sort and compost it. If these materials are composted with the suitable composting technology, this huge waste of organic matter can be avoided. Keeping in view the present status of organic matter, low fertility and stagnant soil productivity, it is very important to encourage the use of organic matter. The present study was carried out with the objective to monitor the efficiency of compost to boost not only rice-wheat yield but also its impact on soil health after reclaiming the saline sodic soil.

Materials and Methods

Before starting the experiment, compost was prepared using farm waste materials and using hot method of compost preparation. After selecting the saline sodic field, desired layout was made according to randomized complete block design. Initial analysis of saline sodic soil was also performed (Table 1). Compost was also analyzed for its chemical composition before applying to the field (Table 2). Compost was applied to the field 30 days prior to transplanting rice nursery. Rice crop was grown till maturity and harvested. Necessary data were recorded and subsequent wheat was sown in respective treatments. Treatments of the experiment were: 1) control (no nutrition), 2) chemical fertilizers, 3) 12 tons / hectare of compost, 4) 24 tons / hectare of compost, 5) 2 + 3 combination and 6) 2 + 4 combination.

Rice was the first crop of rotation followed by wheat. The sources of chemical fertilizers were urea, simple superphosphate (SSP) and potassium sulfate for NPK. Dose of NPK for rice and wheat was 100, 70, 70 and 140, 110, 70 kg ha^{-1}. The total amount of a superphosphate and potassium sulfate was supplied at planting time on seedbed. On the other hand, 50% urea was given to both crops at the time of planting. The remaining 50% urea was applied after 30 days of transplant / sowing time. Soil samples were collected from each treatment plot and analyzed for chemical properties (pH_s, EC_e and SAR) and soil health parameters (organic matter, Olsen' Phosphorus and potassium content). Soil and compost samples were analyzed according to the USDA analysis methods Manual 60 (U.S. Salinity Laboratory Staff, 1969).

Table 1 Laboratory determination of soil

S. No.	Parameters/Property	Unit	Value
1	Soil saturation	%	42.00
2	Soil reaction	-	8.63
3	Total soluble salts	me L^{-1}	49.50
4	Sodium adsorption ratio	-	18.99
5	Organic carbon	%	0.12
6	Olsen's phosphorus	ppm	5.05
7	Water soluble potassium	me L^{-1}	0.49

Table 2 Laboratory determination of compost

S. No.	Parameters/Property	Unit	Value
1	Soil reaction	-	6.67
2	Total soluble salts	me L^{-1}	63.10
3	Organic matter	%	48.12
4	Organic carbon	%	28.00
5	C/N Ratio	-	13.33

Results

Plant height

Height is a very important parameter that indicates plant health and ultimately contributes to yield. The maximum height of the rice plants was affected by the use of chemical fertilizers and different amounts of compost alone or in combination significantly (Fig. 1). The height of the rice plants recorded for the control (110.0 cm) increased in all subsequent treatments and was maximum (128.0 cm) when the compost was used at the rate of 24 t ha^{-1} + fertilizer (T6). Treatments T5, T4, T2 and T3 with values of 120.8, 120.3, 119.5 and 117.8 cm, respectively followed it. These four treatments were not statistically significant with each other. Similarly, the height of the wheat plant also showed significant differences between treatments compared to the control after using compost and fertilizer (Fig. 1). In this case, the maximum height of the wheat plants (92.0 cm) was observed in T6, while T5 continued with a value of 89.7 cm and both treatments were equivalent in terms of statistics.

Tillers of rice and wheat plants

When compost and fertilizer were applied, an improvement in tillers of the rice plant was observed. The different treatments differed from the control, which indicates statistically significant differences (Fig. 2). The maximum tillers (23.2) were recorded using compost at the rate of 24 t ha^{-1} + fertilizer (T6) against minimum of 16.0 in control. Treatment T5 followed the maximum value shown by 21.2 tillers. Treatments T2, T3 and T4 were considered to be non-significant when compared statistically. In case of wheat, number of tillers were more when compared with control (Fig. 2). The number of tillers in wheat plants increased from the minimum (5.3) for control to the maximum of 8.1 in T6, followed by T5 and T4, which were 7.4 and 7.2, respectively. Both treatments were observed statistically at the same level of non-significance.

1000 grain weight

Grain weight is an indication of seed health and disease resistance. Highest weight improvement of 1000 rice grains (22.2 g) was observed when using compost only 12 t ha^{-1} (T3) against the minimum weight of 17.4 g for the control (Fig. 3). Usage of chemical fertilizers or in amalgamation with compost worsened weight of 1000 grains of rice. The T4 and T5 treatments were non-significant statistically. The same trend was observed for T1 and T2. The weight of 1000 wheat grains also showed a significant improvement in subsequent treatments compared to the control (Fig. 3). The weight of 1000 wheat grains were maximum (36.4 g) for T3 compared to the lowest weight of 31.7 g in the control. The T5 treatment followed the maximum of 36.5 g. All treatments except the control were not significant to each other.

Total biomass

Treatment T6 produced highest rice biomass (14.08 t ha^{-1}) in comparison to lowest of 8.91 t ha^{-1} for control (Fig. 4). The T5 with a value of 12.42 t ha^{-1} was next to T6, while treatments T2 and T4 were determined to be equivalent and non-significant statistically. The differences between the different treatments compared to the control remained statistically significant. The values for other treatments were between T1 and T6. Similarly, the biomass of the wheat harvested using compost and fertilizer improved significantly (Fig. 4). The use of fertilizer alone (T2) was on a par with the control.

Grain weight

Rice yield was positively affected by the use of fertilizers and various amounts of compost, alone or in combination, and several treatments differed from the control and showed statistically significant differences (Fig. 5). The lowest rice yield (1.98 t ha^{-1}) recorded for the control improved in all subsequent treatments and was maximized to the 2.91 t ha^{-1} level using 24 t ha^{-1} compost + fertilizer (T6). This was followed by T5 and T4 with values of 2.64 and 2.47 t ha^{-1}. Similarly, it was observed that T2, T3 and T4 treatments were the same when statistically examined. An almost similar trend to improve wheat grain yield was observed because the treatments differed from the control and showed significant differences (Fig. 5). Similarly, maximum increase in rice and wheat yield when calculated after comparing with control treatment remained 48.5 and 84.5 % respectively (Fig. 6).

Chemical characteristics of soil

Soil pH_s

Soil pH_s is an important chemical characteristic of soil as it classifies the soil into normal and sodic categories. After harvesting rice and wheat crops, in soil samples collected alone or integrated use of compost with mineral fertilizers reduced value of pH_s in the soil (Table 3). Maximum value of soil pH_s (8.6) estimated for control after rice harvest reduced to the level of 8.2 in T6 (combination of 2 + 4) and the application of compost alone at the same rate was the next treatment that reduced pH_s value to 8.2. The values of pH_s for other treatments were in between T1 and T6 and none of the treatment was non-significant with each other. After wheat crop, the highest pH_s (8.6) analyzed for control reduced in all subsequent treatments and was the minimized in T6 to the level of 8.1. The use of chemical fertilizer alone followed the control with pH_s value of 8.5 and thus remained inferior to compost.

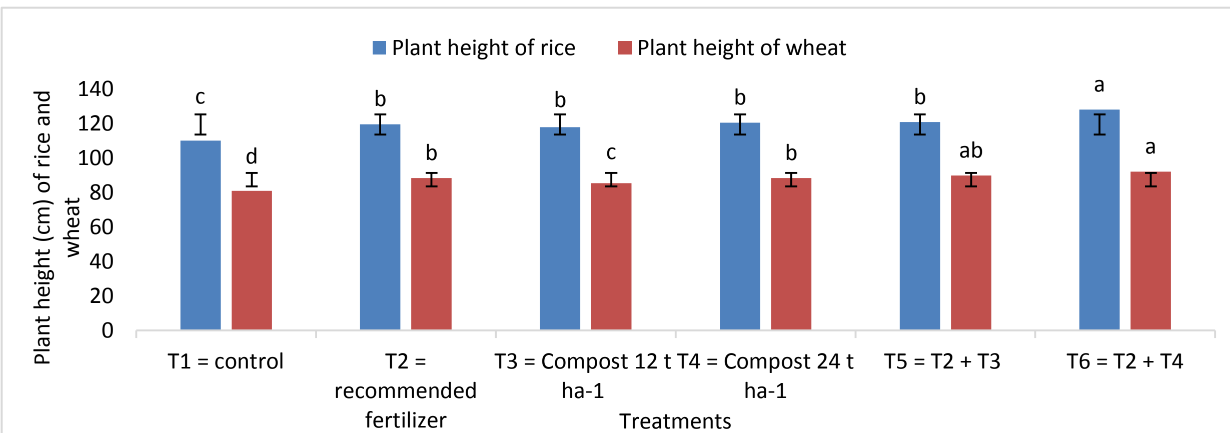

Fig. 1 Effect of compost and chemical fertilizer on plant height (cm) of rice and wheat

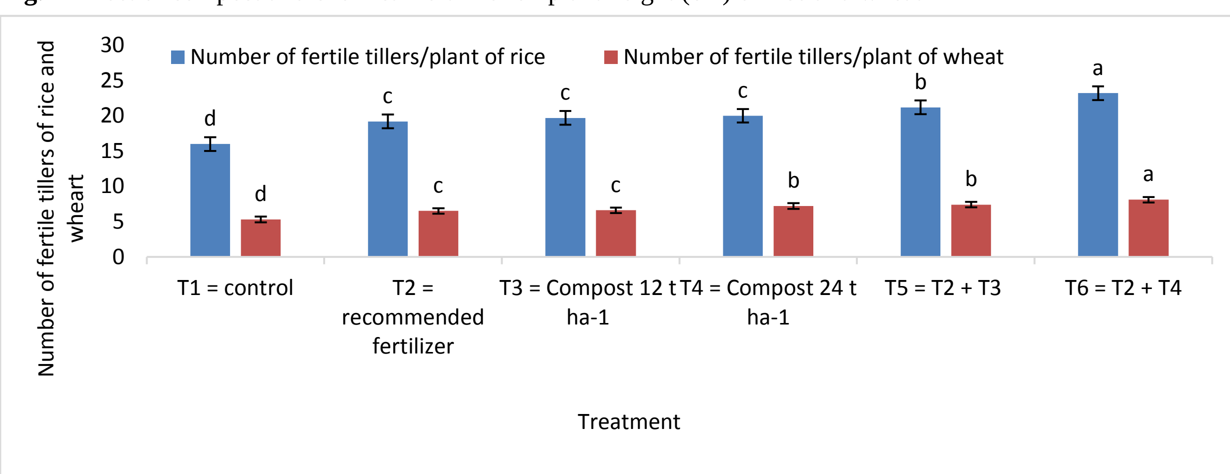

Fig. 2 Effect of compost and chemical fertilizer on number of fertile tillers of rice and wheat

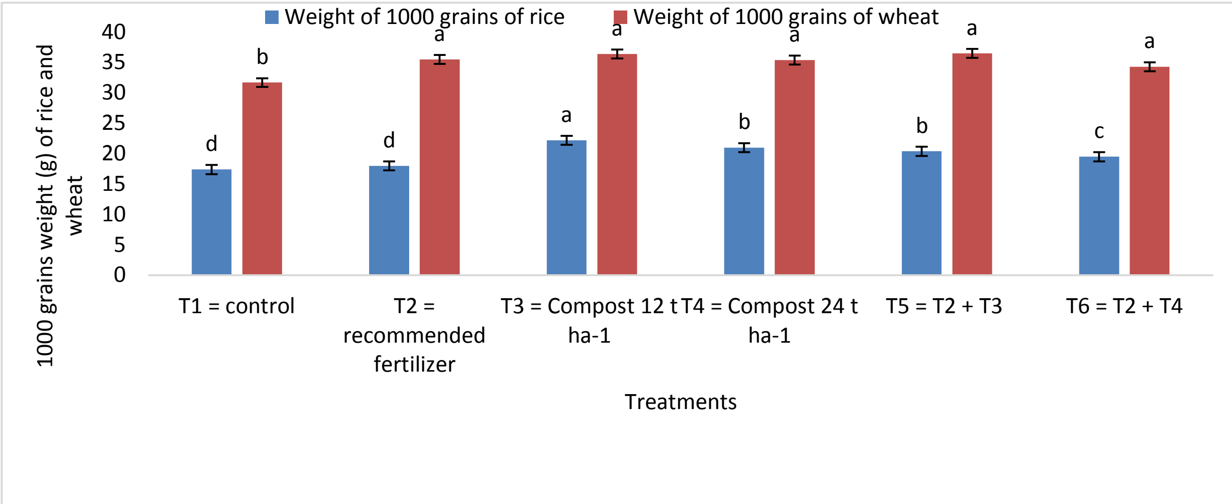

Fig. 3 Effect of compost and chemical fertilizer on1000 grains weight (g) of rice and wheat

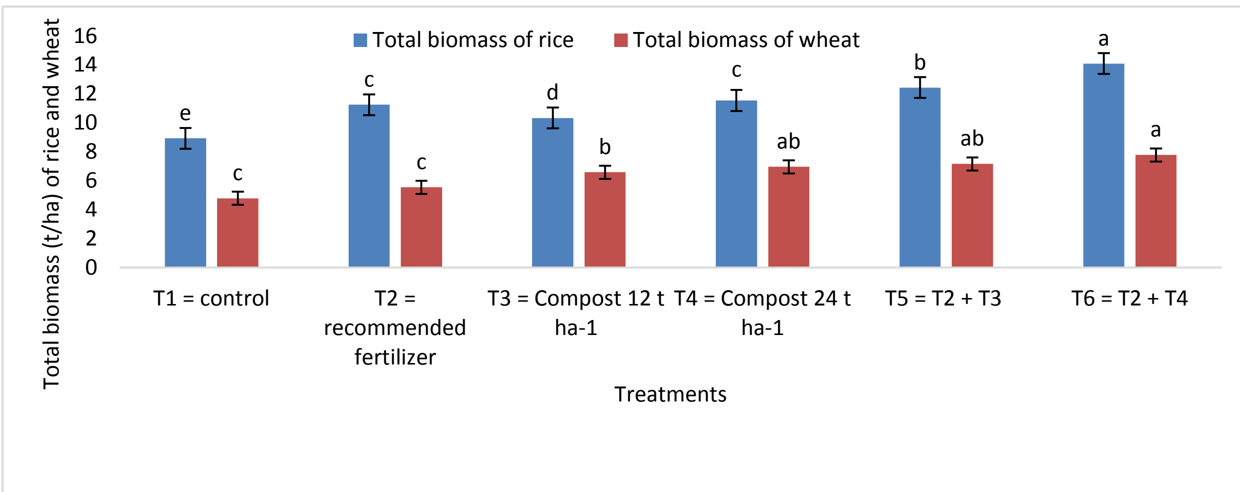

Fig. 4 Effect compost and chemical fertilizer on total biomass (t/ha) of rice and wheat

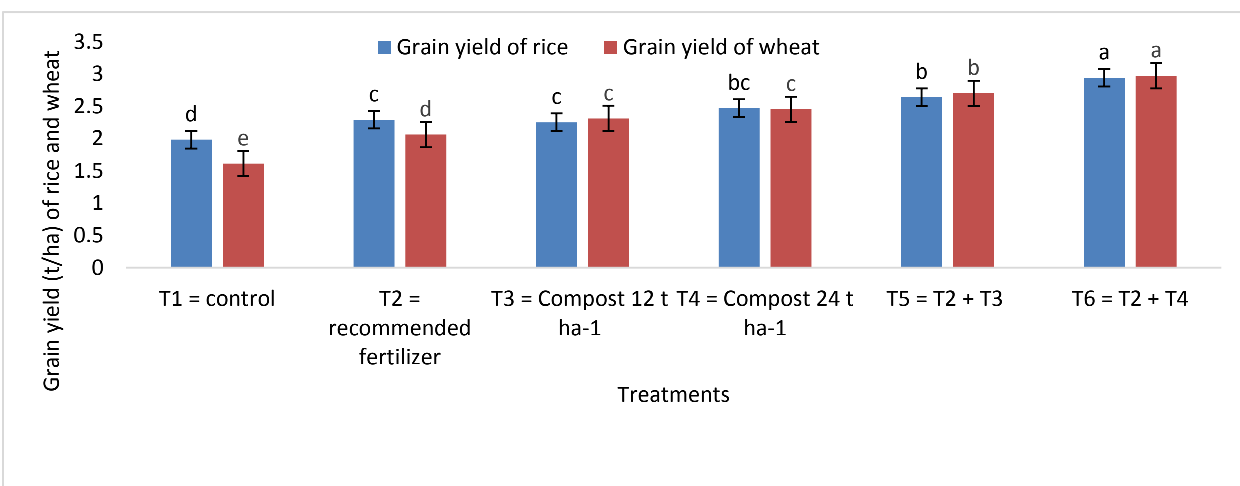

Fig. 5 Effect of compost and chemical fertilizer on grain yield (t/ha) of rice and wheat

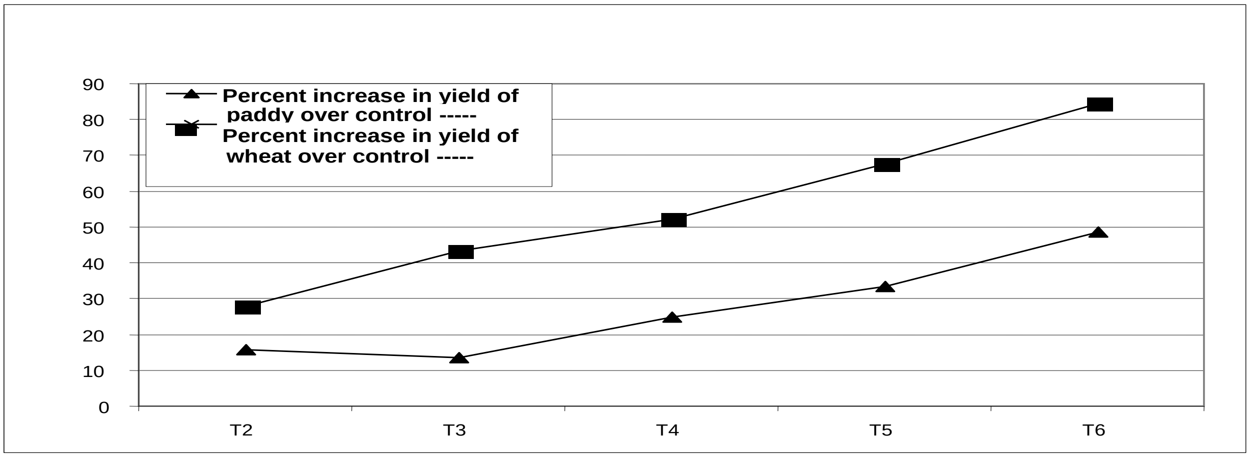

Fig. 6 Percent increase in yield of paddy and wheat over control

Electrical conductivity

Electrical conductivity (EC_e) of soil decreased with the addition of chemical fertilizer and compost at various levels. The use of compost proved best in reducing soil EC_e from saline range to normal indicating the ability of compost to neutralize soil. Treatments differed from each other indicating trend of significance statistically after both rice and wheat crops (Table 3). The highest value of EC_e (4.72 $dS.m^{-1}$) estimated for control after rice harvest lowered to the minimum value of 3.03 $dS.m^{-1}$ with the use of 24 t ha^{-1} compost (T4) and this treatment was non-significant with T5 and T6. The use of chemical fertilizer alone (T2) followed the control exhibiting EC_e of 4.40 $dS.m^{-1}$ and was also at par with T1. After wheat harvest, the EC_e of soil reduced from the maximum value of 4.74 $dS.m^{-1}$ for control to the 3.55 $dS.m^{-1}$ in T6. The control was once again followed by T2 with value of 4.12 $dS.m^{-1}$. The treatments T4 and T5 were assessed as non-significant with each other statistically.

Sodium adsorption ratio (SAR)

Soil SAR is important parameter of classification and addition of compost at both levels reduced it very promptly after rice-wheat. The treatments differed from control significantly after both crops (Table 3). The value of SAR (14.2) estimated for control after rice crop reduced in all subsequent treatments to the level of 2.2 for T6 (combination of 2 + 4). Use of fertilizer alone (T2) followed the control with SAR value of 11.0 and remained non-significant with control. After wheat harvest, almost same trend of reduction in SAR values was noticed. The lowest value of SAR determined for T6 remained 2.7 against the highest level of 18.5 in control. Compost proved its superiority for lowering soil SAR significantly.

Organic matter

Compost is a form of organic matter, and organic matter status of soil was enhanced with its application. The differences among treatments after both crops remained significant when compared with control (Table 4). The use of compost combined with fertilizer remained beneficial than alone application of compost after rice crop. The organic matter status of soil after rice enhanced to the maximum level of 1.28 % with the use of 24 t ha^{-1} compost + fertilizer (T6) against the minimum value of 0.52 % for control. The treatments T4 and T5 followed the maximum value indicating 1.16 and 1.14 % respectively. Application of chemical fertilizer alone was assessed as inferior to compost in this regard. The treatments differed from each other significantly with regard to organic matter percentage after wheat crop and none of the treatment was at par with each other. The lowest percentage of organic matter (0.54%) for control improved in all subsequent treatments and approached the highest level of 1.40 % in T6 and was followed by T4 with organic matter content of 1.26 %. The values for other treatments remained in between T1 and T6. Similar results were recorded for soil nitrogen.

Available phosphorus

An improvement in concentration of available phosphorus of soil was noted when mineral fertilizer and compost were used singly or in an integrated form. The treatments indicated significant differences for control after rice and wheat crops (Table 4). After rice, the highest level of available P (27.74 mg Kg^{-1}) was estimated with the use of 24 t ha^{-1} compost + fertilizer (T6) in contrast to the lowest value of 5.14 mg Kg^{-1} for control. Mineral fertilizer was noted as non-significant when compared with compost alone @ 12 t ha^{-1} whereas T5 followed T6 possessing 17.71 mg Kg^{-1} available P. Similarly, concentration of available P enhanced after wheat as maximum value of 29.90 mg Kg^{-1} was noted for T6 against minimum of 5.53 mg Kg^{-1} for control. None of the treatment after wheat harvest was examined as non-significant with each other statistically. The treatment T5 followed T6 exhibiting value of 18.76 mg Kg^{-1}.

Soil potassium content

Application of compost and fertilizer alone or combined increased water-soluble potassium in soil after rice-wheat crops. All treatments of the experiment differed from each other in significant manner in terms of statistics, (Table 4). After rice harvest, the minimum content of water-soluble K (0.53 $mmol_c\ L^{-1}$) estimated for control improved in all subsequent treatments and was approached the highest level of 2.51 $mmol_c\ L^{-1}$ with the use of 24 t ha^{-1} compost + fertilizer (T6). This was followed by T5 indicating the value of 1.51 $mmol_c\ L^{-1}$. The treatments T2 and T3 were assessed as at par with each other in terms of statistics. Similarly, after wheat crop the minimum value (0.52 $mmol_c\ L^{-1}$) was maximized up to the level of 2.59 $mmol_c\ L^{-1}$ in T6 while T5 and T4 was following it showing 1.73 and 1.67 $mmol_c\ L^{-1}$ respective values. Both these treatments were non-significant statistically. Likewise, T2 & T3 proved at par with each other when examined statistically.

Table 3 Effect of compost on soil chemical properties after rice and wheat crops

Treatment	pH_s	EC_e (dS m^{-1})	SAR	pH_s	EC_e (dS m^{-1})	SAR
	After rice crop			After wheat crop		
Control (zero nutrition)	8.6^{a}	4.72^{a}	14.2^{a}	8.6^{a}	4.74^{a}	18.5^{a}
Chemical fertilizers	8.5^{b}	4.40^{ab}	11.0^{ab}	8.5^{b}	4.12^{b}	12.6^{b}
12 ton/hectare compost	8.4^{c}	3.81^{bc}	8.70^{bc}	8.4^{c}	3.86^{c}	11.8^{b}
24 ton/hectare compost	8.2^{e}	3.03^{d}	6.50^{c}	8.2^{e}	3.73^{d}	4.20^{d}
Combination of 2 + 3	8.3^{d}	3.43^{cd}	6.20^{c}	8.3^{d}	3.64^{de}	6.80^{c}
Combination of 2 + 4	8.2^{e}	3.46^{cd}	2.20^{d}	8.1^{f}	3.55^{e}	2.70^{e}

Table 4 Effect of compost on soil health parameters after rice and wheat crops

Treatment	Organic matter (%)	Olsen P (mg kg^{-1})	Water soluble K^{+} ($mmol_c\ L^{-1}$)	Organic matter (%)	Olsen P (mg kg^{-1})	Water soluble K^{+} ($mmol_c\ L^{-1}$)
	After rice crop			After wheat crop		
Control (zero nutrition)	0.52^{e}	5.14^{e}	0.53^{e}	0.54^{f}	5.53^{f}	0.52^{d}
Chemical fertilizers	0.91^{d}	9.85^{d}	0.75^{d}	1.07^{e}	10.56^{e}	0.73^{c}
12 ton/hectare compost	1.05^{c}	9.33^{d}	0.85^{c}	1.14^{d}	12.98^{d}	0.75^{c}
24 ton/hectare compost	1.16^{b}	13.73^{c}	1.25^{c}	1.26^{b}	16.24^{c}	1.67^{b}
Combination of 2 + 3	1.14^{b}	17.71^{b}	1.51^{b}	1.19^{c}	18.76^{b}	1.73^{b}
Combination of 2 + 4	1.28^{a}	27.74^{a}	2.51^{a}	1.40^{a}	29.90^{a}	2.59^{a}

Discussion

Ultimate objective of crop production is to get maximum yield or profit from a given piece of land throughout the globe. In the current study, compost performed its role efficiently in enhancing and improving the different yield components like tillers, height of plants, total biomass and weight of 1000 grains. All these components when improved indicate more yield resultantly. Integration of compost with mineral fertilizer proved superior than its sole application. No doubt, compost application at both levels were admirable but its application at higher rate resulted more yield either alone or when integrated with chemical fertilizers. This trend was almost same and uniform for rice & wheat crops. Maximum increase in rice and wheat yield when calculated after comparing with control treatment remained 48.5 and 84.5 % respectively. The sole addition of chemical fertilizer was also superior to control. Phenomenon of growth increase of rice-wheat after compost is the result of series of given chain process.

Soil reaction (pH) is the property of soil that determines its suitability for plant growth in connection with nutrition supply and salinity/sodicity status. Like other arid and semi-arid regions, pH of majority of soils ranges from 7.0 - 10.0. Therefore, any techniques that can lower soil pH is desirable. Addition of compost lowered soil pH of saline sodic soil due to its acidifying effect by producing and subsequently releasing different organic acids during mineralization process of the nutrients. The pH of alkaline soil is controlled by Na. When compost is used as source of nutrients, it makes free Ca that leads to reduction in soil pH. Resultantly, Na ions are released in the soil solution that are leached down the soil profile (Brady & Weil, 2005).

Soil salinity or high concentration of total soluble salts is major issue of agriculture around the globe. Due to this problem, plants have issues of water uptake linked with osmotic effect. Plants also have limited uptake of nutrients that is caused by specific ion effect. When compost is added to the soil, it produces plenty of acid forming substances that show their reaction with partially soluble salts present natively in the soil and change these into highly soluble ones. These highly soluble salts are leached down and soil properties are improved. Still quantity of this improvement is linked the amount of compost applied (Sarwar, 2005). Sodicity status of a soil is assessed by measuring its SAR (sodium adsorption ratio) value that indicates Na content in soil. High sodium content is harmful for plant growth. Addition of compost decreased values of soil SAR. Usage of other amendments (rice straw, FYM and green manures) also lowered numerical value of SAR in the soil. This reduction in SAR values is coupled with the release of various useful substances in soil. Hence, concentration of Ca is enhanced in the soil that leads to reclaim lowering SAR (Zaka et al., 2003). Such decrease in SAR occurs either due to increase in Ca content or decrease in Na concentration (Sarwar, 2005).

As all types of microbial activity and nutrients is linked with concentration of organic matter in soil, so it is single parameter that controls all other growth production parameters in soil. In salt affected soils, quantity of organic matter was raised with usage of compost at either rate. Reason of this improvement is very obvious as organic matter was applied to the soil in form of compost. Hence, organic matter status of soil has direct relationship with the applied quantity of its source (Sarwar et al., 2003). Availability of phosphorus to plants is directly linked with pH level of the soil. As explained earlier, use of compost lowered soil pH values, so resultantly phosphorus availability was enhanced and more P content was estimated in soil samples collected after both crops (Brady & Weil, 2005). Similarly, concentration of water-soluble potassium increased in the soil as a result of compost application. This positive change is also attributed as the result of organic acids production due to use of compost. The H^+ ions are released from the exchange site of clay which lead to improve K content in the soil (Sarwar et al., 2009).

Similarly, results of early scientists also favored these findings. Addition of farm yard manure in saline sodic soil yielded more rice production due to above explained phenomenon. These positive effects of FYM were also carried over to the subsequent wheat crop (Tiwari et al., 2001). In the same way, findings of Sarwar (2005); Ahmad et al. (2002); Sarwar et al. (2009); Parmer and Sharma (2002) were also in the same direction and favored the above phenomenon and hypothesis.

Conclusion

It was concluded from this study that use of compost is beneficial for enhancing yield of rice-wheat production grown from salt affected soil environment. Application of compost also reclaimed saline sodic soil by indicating an improvement in chemical properties of soil. Further, fertility status/soil health was also strengthened with the use of compost as source of nutrition.

Author Contribution Statement: Ghulam Sarwar planned, designed, conducted and carried out this research study. Helge Schmeisky supervised this research work being program leader. Nazir Hussain acted as a co-supervisor and provided different research facilities. Muhammad Ashraf Malik performed statistical analysis and assisted in excel work. Muhammad Zeeshan Manzoor helped in conducting the research project and wrote the manuscript. Ayesha Zafar contributed in laboratory analysis of various parameters prescribed in the manuscript. Ghulam Murtaza contributed in data analysis, description and edited the manuscript. All the authors read and approved the manuscript to be published in Journal of Pure and Applied Agriculture.

Conflict of Interest: The authors declare that they have no conflict of interest.

Acknowledgments: The authors are thankful to the Department of Soil & Environmental Sciences, College of Agriculture, University of Sargodha and Soil Salinity Research Institute, Pindi Bhattian District Hafizabad for providing all facilities and platform for this research study.

References

Ahmad, S. I., Abbasi, M. K., & Rasool, G. (2002). Integrated plant nutrition system (IPNS) in wheat under rainfed conditions of Rawalakot Azad Jammu and Kashmir. *Pakistan Journal of Soil Science*, *21*(1-2), 79-86.

Brady, N. C., & Weil, R. R. (2005). *The Nature and Properties of Soil* (13th Edition). New York, Macmillan Publishing Company.

Cao, Y., Huang, H., Wang, J., Qian, Y., Wang, L., Xu, Y., & Chang, Z. (2020). Crop response and quality of soil as affected by hyperthermophilic compost in Tai-Lake region of China. *Journal of Plant Nutrition*, *43*(7), 1000-1015.

Chen, M., Zeng, W., Arthur, E., Gaiser, T., Lei, G., Zha, Y., & Huang, J. (2019). Relating soil salinity, clay content and water vapour sorption isotherms. *European Journal of Soil Science*, https://doi.org/10.1111/ejss.12876

Fang, Y., Singh, B. P., Collins, D., Armstrong, R., Van Zwieten, L., & Tavakkoli, E. (2020). Nutrient stoichiometry and labile carbon content of organic amendments control microbial biomass and carbon-use efficiency in a poorly structured sodic-subsoil. *Biology and Fertility of Soils*, *56*(2), 219-233.

Halima, O. I., Azzouzi, M. E., Douaik, A., Azim, K., & Zouahri, A. (2019). Organic and inorganic remediation of soils affected by salinity in the Sebkha of Sed El Mesjoune–Marrakech (Morocco). *Soil and Tillage Research*, *193*, 153-160.

Hofmann, H. (2004). Rekultivierung von Rückstandshalden der kaliindutrie. Untersuchungen zur Begrünung und zur Sukzession auf einer anhydritisch geprägten Rückstandshalde der Kaliindustrie in Werragebiet. Ökologie und Umweltsicherung. 24/2004. Universität Kassel, Fachgebiet Landschaftsökologie und Naturschutz, Witzenhausen, Germany.

Hussain, N., Hassan, G., Arshadullah, M., & Mujeeb, F. (2001). Evaluation of amendments for the improvement of physical properties of sodic soil. *International Journal of Agriculture and Biology*, *3*(3), 319-322.

Ivushkin, K., Bartholomeus, H., Bregt, A. K., Pulatov, A., Franceschini, M. H., Kramer, H., & Finkers, R. (2019). UAV based soil salinity assessment of cropland. *Geoderma*, *338*, 502-512.

Jagadeeswari, P. V., & Kumaraswamy, K. (2000). Long-term effects of manure-fertilizer schedules on the yield of and nutrient uptake by rice crop in a permanent manurial experiment. *Journal of the Indian Society of Soil Science*, *48*(4), 833-836.

Kim, H., Jeong, H., Jeon, J., & Bae, S. (2016). Effects of irrigation with saline water on crop growth and yield in greenhouse cultivation. *Water*, *8*(4), 127-135.

Lim, S. S., Yang, H. I., Park, H. J., Park, S. I., Seo, B. S., Lee, K. S., Lee, S. H., Lee, S. M., Kim, H. Y., Ryu, J. H., Kwak, J. H., & Choi, W. J. (2020). Land-use management for sustainable rice production and carbon sequestration in reclaimed coastal tideland soils of South Korea: a review. *Soil Science and Plant Nutrition*, *66*(1), 60-75.

Liu, M., Wang, C., Wang, F., & Xie, Y. (2019). Maize (*Zea mays*) growth and nutrient uptake following integrated improvement of vermicompost and humic acid fertilizer on coastal saline soil. *Applied Soil Ecology*, *142*, 147-154.

Nguyen, B. T., Trinh, N. N., & Bach, Q. V. (2020). Methane emissions and associated microbial activities from paddy salt-affected soil as influenced by biochar and cow manure addition. *Applied Soil Ecology*, *152*(2020), 1-9.

Nguyen-Sy, T., Cheng, W., Kimani, S. M., Shiono, H., Sugawara, R., Tawaraya, K. & Kumagai, K. (2020). Stable carbon isotope ratios of water-extractable organic carbon affected by application of rice straw and rice straw compost during a long-term rice experiment in Yamagata, Japan. *Soil Science and Plant Nutrition*, *66*(1), 125-132.

Parmer, D. K., & Sharma, V. (2002). Studies on long-term application of fertilizers and manure on yield of maize-wheat rotation and soil properties under rainfed conditions in Western-Himalayas. *Journal of the Indian Society of Soil Science, 50*(3), 311-312.

Paz, A. M., Castanheira, N., Farzamian, M., Paz, M. C., Gonçalves, M. C., Santos, F. A. M., & Triantafilis, J. (2019). Prediction of soil salinity and sodicity using electromagnetic conductivity imaging. *Geoderma*, *361*(2020), 1-10.

Rani, S., Satyavan, Kumar, A., & Beniwal, S. (2020). Integrated nutrient management as a managerial tool for applying saline water in wheat crop cultivated under sub-tropic and semi-arid conditions of North-Western India. *Journal of Plant Nutrition*, *43*(4), 604-620.

Ren, D., Wei, B., Xu, X., Engel, B., Li, G., Huang, Q., & Huang, G. (2019). Analyzing spatiotemporal characteristics of soil salinity in arid irrigated agro-ecosystems using integrated approaches. *Geoderma*, *356*(2019), 113935.

Sarwar, G., Hussain, N., Mujeeb, F., Schmeisky, H., & Hassan, G. (2003). Biocompost for the improvement of soil characteristics and dry matter yield of Lolium perenne (grass). *Asian Journal of Plant Sciences. 2*(2), 237-241.

Sarwar, G. (2005). Use of compost for crop production in Pakistan. (Doctoral dissertation). Retrieved from Okologie und Umweltsicherung. 26/2005. Universität Kassel, Fachgebiet Landschaftsökologie und Naturschutz, Witzenhausen, Germany.

Sarwar, G., Hussain, N., Schmeisky, H., & Muhammad, S. (2007). Use of compost an environment friendly technology for enhancing rice-wheat production in Pakistan. *Pakistan Journal of Botany, 39*(5), 1553-1558.

Sarwar, G., Hussain, N., Schmeisky, H., & Muhammad, S. (2008). Efficiency of various organic residues for enhancing rice-wheat production under normal soil conditions. *Pakistan Journal of Botany*, *40*(5), 2107-2113.

Sarwar, G., Schmeisky, H., Hussain, N., Muhammad, S., Tahir, M. A., & Saleem, U. (2009). Variations in nutrient concentrations of wheat and paddy as affected by different levels of compost and chemical fertilizer in normal soil. *Pakistan Journal of Botany, 41*(5), 2403-2410.

Shi, S., Tian, L., Nasir, F., Bahadur, A., Batool, A., Luo, S. & Tian, C. (2019). Response of microbial communities and enzyme activities to amendments in saline-alkaline soils. *Applied Soil Ecology*, *135*, 16-24.

Smiciklas, K. D., Walker, P. M., & Kelley, T. R. (2002). Utilization of compost (Food, paper, landscape and manure) in row crop production. Retrieved from ww:/E:/utilization% 20 conipost% 20 (Food%20 paper,%20 lands scape% 20 M and% 20l : Department of Agriculture and Health Sciences, Illinois State University.

Tiwari, V. N., Singh, H., & Upadhyay, R. M. (2001). Effect of biocides, organic manure and blue green algae on yield and yield attributing characteristics of rice and soil productivity under sodic soil conditions. *Journal of the Indian Society of Soil Science*, *49*(2), 332-336.

U.S. Salinity Laboratory Staff. (1969). Diagnosis and improvement of saline and alkaline soils. USDA Hand Book No. 60. USDA. U.S. Govt. Printing Office, Washington, DC, USA.

Wang, Z., Fan, B., & Guo, L. (2019). Soil salinization after long-term mulched drip irrigation poses a potential risk to agricultural sustainability. *European Journal of Soil Science*, *70*(1), 20-24.

Yao, Z., Xu, Q., Chen, Y., Liu, N., Huang, L., Zhao, Y. & Zhai, B. (2019). Enhanced stabilization of soil organic carbon by growing leguminous green manure on the Loess Plateau of China. *Soil Science Society of America Journal*, *83*(6), 1722-1732.

Zaka, M. A., Mujeeb, F., Sarwar, G., Hassan, N. M., & Hassan, G. (2003). Agromelioration of saline sodic soils. *OnLine Journal of Biological Sciences, 3*(3), 329-334.

Zhou, M., Liu, X., Meng, Q., Zeng, X., Zhang, J., Li, D. & Ma, X. (2019). Additional application of aluminum sulfate with different fertilizers ameliorates saline-sodic soil of Songnen Plain in Northeast China. *Journal of Soils and Sediments*, *19*(10), 3521-3533.

Zorb, C., Geilfus, C. M., & Dietz, K. J. (2019). Salinity and crop yield. *Plant Biology*, *21*(1), 31-38.