

Improving Saline Soils and Sustaining Wheat Cultivation Using Plant Ash and Organic Residues

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Abstract

Soil salinity is among the important environmental problems that affect soil productivity. This study was undertaken to investigate the feasibility of using some local plant wastes (plant ash and compost) for improving the chemical makeup of saline soils and supporting the growth of plants, specifically wheat (*Triticum aestivum*). This study was done in laboratory conditions where the soil in the pots was salty loam soil. Treatments were made using plant ash, compost, ash and compost mixture, chemical fertilizer, and no fertilizer.

The impacts of these treatments were determined by assessing various soil chemical factors, namely, pH, electrical conductivity (EC), sodium exchangeability, calcium and magnesium exchangeability, chloride concentration, and organic matter content. The performance of plants was assessed in terms of plant height, root mass, and shoot dry weight.

Initial findings indicated that the application of plant ash and compost, particularly their combination, helped in reducing the levels of EC and soluble salts, brought about changes in soil pH to be within the optimum range for plant growth, and boosted soil organic matter. The positive effects were evident through enhanced wheat growth, relative to the control group without fertilizer use and chemical fertilizer treatment.

Keywords: Saline soils, Plant ash, Organic matter, Compost, Sustainable agriculture, Wheat yields.

Introduction

Soil salinity is one of the major problems faced by agriculture in arid and semi-arid areas [1]. Salt buildup in soil causes changes in soil chemistry and physics and negatively impacts the environment in which plants grow. Specifically, the increased salt content in the rooting area raises the osmotic pressure of the soil solution; hence, reducing the capacity of the plants to take in water and other vital minerals, leading to poor growth and crop production [2]. Excessive soil salinity has been found to impair nutrient-use efficiency and severely stifle the growth of plants, according

to one recent research [3]. In this context, previous scientific studies have revealed that the application of organic amendments like plant ash and organic waste can be helpful in remediation of saline soils through increased soil organic matter content, soil pH adjustment, and microbial activity [4]. Plant ash, especially, has the ability to contribute key elements to the soil composition, which includes important components like calcium and potassium and help regain ionic balance of the soil [5]. Wheat (*Triticum aestivum*) is an important cereal crop highly susceptible to salinity stress; therefore, wheat plants make a good choice to investigate the effect of saline

soil amended with plant ash [6]. In this study, efforts will be made to show that the use of treated plant residues can be considered an appropriate strategy for the rehabilitation of saline soils and improved productivity of wheat plants.

Materials and Methods

Experimental site and conditions

The experiment took place in a plastic greenhouse at College of Agriculture, Al-Qasim Green University, in the growing season of 2024.

The environmental factors inside the greenhouse-such as temperature, humidity, and lighting-were all controlled to allow optimum growth for the wheat.

Soil of the study

The experimental sample was taken from an agricultural field in the Al-Kifl area, which suffers from various problems related to soil salinity. The soil sample was dried and sieved through a 2 mm mesh to get rid of gravel particles before the experiment started. Physical and chemical properties of the soil were first identified according to standard methods [7].

[8]They include: the soil pH value measured using a pH meter in a soil solution (1:2.5); soil EC determined using a salinity meter; exchangeable sodium, calcium, and magnesium measured using 1N NHOAC (pH 7); chloride ions concentration measured using silver nitrate titration; and total organic matter measured using wet oxidation [9].

Preparation of organic amendments

a. Plant ash

Plant ash was generated through the combustion of crop residues (leaf, stem, and twig) under controlled temperatures of 500°C in a furnace, producing finely ground ash. The ash was dried, sieved, and stored in an airtight container in order to reduce the level of moisture content. The ash was grayish white in color, porous in nature, very basic, free flowing, with low moisture content and high

specific surface area, which means it could be reactive in soil environments. The analysis of elemental composition of the plant ash was performed by using Atomic Absorption Spectroscopy (AAS) method [10].

The major components of ash are in the form of oxides including Cao (20-30%), K₂O (5-10%), Na₂O (1-3%), P₂O₅ (1-5%), MgO (2-5%), Fe₂O₃ (0.5-2%), MnO (0.1-0.5%) and SiO₂ (10-15%). Such features have enabled it to provide soils with the ability to have Cation Exchange Capacity (CEC) ensuring that ionic equilibrium in.

b. Compost (organic treated waste)

The compost was made by mixing 70% cattle manure and 30% of plant debris like leaves, husk, and vegetable waste. The mixture was kept under aerobic condition for 60 days. It was turned thrice in every three days to facilitate proper aeration. Temperature was maintained between 50-60 °C to promote maturity and removal of weed seeds and disease-causing organisms. After treatment, the compost became brown, crumbly, moist but not wet, granular, and had an earthy odor without any bad smell.

Results of chemical analysis indicated that the compost had a neutral to slightly alkaline pH (6.5-7.5). It was also high in organic matter content (30-40%) and other vital nutrients such as nitrogen (N, 1.5-2.5%), available phosphorus (P₂O₅, 0.8-1.5%), and potassium (K₂O, 1.5-2.5%). Besides, it showed high capacity for holding water and cation exchange capacity (CEC).

Experimental design

A randomized complete block design (RCBD) was used, consisting of five main treatments with three replications each. In total, 15 experimental pots were prepared, each containing 5 kg of soil.

Treatments

Treatment type	Code
Control (soil only, no amendments)	T1
Plant ash at 5% (w/w) of soil	T2
Compost at 10% (w/w) of soil	T3
Combination of ash (5%) + compost (10%)	T4
Chemical fertilizer NPK at recommended rates	T5

Wheat cultivation

A local wheat cultivar (*Triticum aestivum*) was used. Seeds were surface-sterilized with 1% sodium hypochlorite for 5 minutes, rinsed thoroughly, and sown immediately. Five seeds were planted per pot, and after emergence, seedlings were thinned to three plants per pot.

Crop management and irrigation

Plants were irrigated as needed with low-salinity water ($EC < 1 \text{ ds m}^{-1}$)

No pesticides or additional inputs were applied during the experimental period.

Measurements

Treatment effects were assessed through both plant and soil parameters. Plant growth indicators: plant Length(cm), number of tillers, dry weight of the shoot (g), leaf chlorophyll concentration, and a biomass index.

Soil properties after harvest: pH, EC, exchangeable Na^+ , Ca^{2+} , Mg^{2+} , Cl^- and organic matter.

Statistical analysis

The collected data were processed using SPSS software. A one-way analysis of variance (ANOVA) was conducted to examine significant differences among the treatments. To identify differences between treatment means, Duncan's Multiple Range Test (DMRT) was applied at a significance level of $p \leq 0.05$.

Results and Discussion

Table 1. Chemical properties of soil before applying treatments (pre-planting)

Property	Value
EC (ds/m^{-1})	7.5
pH	8.20
Na^+ (meq/L^{-1})	15.5
Ca^{2+} (maq/L^{-1})	4.8
Mg^{2+} (meq/L^{-1})	3.1
Cl^- (meq/L^{-1})	12.8
Organic matter (%)	0.70

The initial soil analysis (Table 1) characterized the site as moderately saline and alkaline, conditions that typically impede plant development. However, the application of treatments, particularly T4 (Ash +Compost), led to a significant reduction in EC (from 7.5 to 4.8 ds/m^{-1}) and pH (from 8.20 to 7.65) These findings are consistent with [11], who reported

that organic amendments facilitate salt leaching by improving soil hydraulic conductivity. The decrease in pH observed in T4 can be attributed to the release of organic acids during compost decomposition, which neutralizes alkalinity—a mechanism further supported by [12] in their study on integrated soil fertility management in arid zones .

Table 2. Effect of treatments on soil chemical properties after harvest.

Treatment	Organic matter (%)	Cl^- (meq/L^{-1})	Mg^{2+} (meq/L^{-1})	Ca^{2+} (meq/L^{-1})	Na^+ (meq/L^{-1})	pH	EC (ds/m^{-1})
T1	0.70	12.8	3.1	4.8	15.5	8.20	7.5
T2	0.92	10.3	3.4	6.2	12.2	7.95	6.1
T3	1.45	9.2	3.5	6.8	11.3	7.80	5.4
T4	1.72	7.4	3.6	7.3	9.9	7.65	4.8
T5	0.78	11.1	3.3	5.4	13.5	8.00	6.7

One of the important findings in Table 2 is the marked decrease in concentration of Na^+ (from 15.5 to 9.9 meq/L^{-1}) in T4. This variation in concentration supports the "displacement phenomenon," in which the divalent ions Ca^{2+} and Mg^{2+} , supplied by the ash, replace mono-

valent ions such as Na^+ at the exchange sites. According to [13], recent studies have highlighted the ability of wood and plant ash as liming and reclaiming materials in sodic soils due to their calcium content.

Table 3. Influence of the treatment methods on wheat growth parameters (height of plant, tiller count, SPAD chlorophyll index).

Treatment	leaf chlorophyll content(SPAD)	tiller number	plant height(cm)
T1	32.1	2.3	23.4
T2	35.4	2.8	27.8
T3	38.9	3.2	31.2
T4	42.6	3.6	34.7
T5	36.8	3.0	28.5

The supremacy of T4 in plant height (34.7 cm) and chlorophyll concentration (42.6 SPAD) indicates the existence of synergy between nutrients from the compost and ions from the ash treatment method. According to [14], the decrease in salinity stress positively relates to the increase in SPAD because of low osmotic

pressure and the subsequent efficient absorption of Magnesium (Mg) ions, which act as the nucleus of the chlorophyll compound. Higher nutrients (N, P, and K ions from compost) may have stimulated enzyme functions, which, according to [15], are vital for wheat tolerance to salt stress.

Table 4. Biomass Index (Dry weight/Tiller number)

Treatment	Biomass index	Tillers (no.)	Dry weight (g)
T1	1.22	2.3	2.8
T2	1.25	2.8	3.5
T3	1.31	3.2	4.2
T4	1.36	3.6	4.9
T5	1.27	3.0	3.8

The Biomass Index (Table 4), which hit the maximum of 1.36 in T4, is not only about increased growth, but also efficient growth. Efficiency here is because of the capacity of plants to allocate dry matter efficiently when the stress is mitigated. [16] has recently pointed out that the combination of bio-waste such as ash and compost leads to a "reservoir rich in nutrients" that reduces physiological drought in cereals. This is consistent with your findings, where the combination approach has proven superior compared to singular applications.

Recommendations

Considering the considerable changes that have been made concerning the soil characteristics and wheat production, the below recommendations are made:

1. Use Combined Application of Plant Ash and Compost (T4): The use of T4 is very advisable and considered the best eco-friendly technique for decreasing EC (by 36%) and improving the wheat biomass yield in comparison with other methods.
2. Substitute for Chemicals in Saline Regions: It is recommended that agricultural extension services encourage the utilization of plant ash and compost to substitute expensive fertilizers, especially in saline lands. The reason is the effect of Cat in the displacement of Nat in the cations analysis.
3. Adopt the Principles of Circular Economy: Increase the recycling of crop waste materials by utilizing them for producing compost and bio-ash. This helps in reducing the loss caused to the environment while improving the quality of the soil by increasing its organic matter up to its maximum level of 1.72% achieved in this study.

4. Comprehensive Ionic Analysis Practice: Any future studies concerning saline soils will need to pay attention to performing tests with both Cl and Nat ions alongside EC. Based on the results obtained through the current analysis of the data, it is clear that measuring the changes in the specific ions is important for determining the effectiveness of the soil amendments used.

5. Perform Cumulative Experiments: While the current results are positive, it is advisable to conduct such experiments throughout several growing seasons.

Conclusion

Conclusions drawn from the results of this study prove that the use of plant ash, compost, and their combined action represent an extremely efficient approach towards increasing the fertility of saline-alkaline soils. Among other things, this experiment has yielded the following important results:

1. Efficient Reduction of Salinity: Combination treatment with plant ash and compost (treatment T4) proved to be extremely efficient in lowering the levels of Electrical Conductivity (EC), bringing them down from 7.5 ds/m^{-1} (characteristic of saline soils) to 4.8 ds/m^{-1} . This occurred in combination with a reduction in the levels of toxic ions (Na^+ and Cl^-) as well as changes in the soil pH, dropping it from 8.20 to 7.65. This contributed significantly to improving the conditions of the rhizosphere, thus enabling plants to absorb nutrients from the soil much better.
2. Enhancement of Soil Fertility: Compost helped raise the share of organic substances in the soil, growing it from 0.70% to 1.72%.

3.Optimum Yield of Wheat: The enhancement of the chemical properties of the soil had a favorable impact on the agro-ecological suitability of the soil. T4 treatment showed optimum growth performance, with optimum plant height at 34.7 cm and Biomass Index at 1.36. From the study, it is clear that the combination of ash and compost has proven to be effective in overcoming salt stress. In summary, the use of locally available ash from plants and compost from organic waste materials offers a dual benefit. On one side, it acts as an alternative to traditional chemical fertilizers, and on the other, it is a way of revitalizing salty soils.

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