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Potential salinization of tropical soils formed from basement complex and sedimentary parent materials by sole and combined dried animal manures and wood ash

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Abstract
The hypothesis that sole and complementary application of dried animal manures and wood ash will affect electrical conductivity (EC) of some tropical soils under controlled and uncontrolled conditions was tested. Treatments: control, poultry manure at 90 kg P ha^{-1} (PM), cattle manure at 90 kg P ha^{-1} (CM), wood ash 5 t ha^{-1} (WA) and the mixtures of manure with wood ash (CMWA, PMWA) were applied to soil in incubation, screen house and field experiments. Samples were taken monthly (0, 4, 8, 12 weeks after incorporation/planting; WAI/WAP) for soil EC determination. For screenhouse and field experiments, maize seeds were sown in two cycles. Data on soil EC were analyzed and significant means separated. Result indicated that EC of soils were in the sequence of Soil 1 (0.16) > Soil 2 (0.13) > Soil 5 (0.12) > Soil 4 (0.08) > Soil 3 (0.05) > Soil 6 (0.02 dS m^{-1}). For amendments, the EC was in the order of WA (4.39) > PMWA (3.03) > CMWA (2.78) > PM (1.87) > CM (1.43 dS m^{-1}). In incubation experiment, application of CMWA increased EC by 126, 65, 79 % above control, CM and PM respectively in Soil 1 at 0WAI, by 338, 46, 218, 52 and 133 % than the control, CM, PM, PMWA and WA in Soil 6 at 4WAI, by 279, 77, 130, 66 and 61 % respectively than control, CM, PM, PMWA and WA in Soil 6 at 8WAI, by 67, 74, 188, 114 and 79 % than the control, CM, PM, PMWA and WA in Soil 3 at 12WAI. Salinization potential of the amendments was CMWA > PMWA > WA > CM > PM > Control in the incubation experiment. In the screenhouse experiment, the salinization potential of the amendments was CMWA > CM > WA > PMWA > PM > Control in the both cycles at 0WAP, CMWA > CM > WA > PMWA > PM > Control and WA > PM > CMWA > Control > CM > PMWA respectively in the first and second cycle respectively at 8WAP. In the field experiment, CMWA raised EC by 250, 232, 174, 152 and 174 % in comparison to control, CM, PM, PMWA and WA at 4WAP in the first cycle while a 185, 118, 76 and 118 % rise in EC was recorded above the control, PM, PMWA and WA at 12WAP in the second cycle. The salinization potential of the amendments was in the order of CMWA > CM > PMWA > WA > PM > Control and CMWA > PMWA > CM > WA > PM > Control repectively in the first and second cycle. The salinity of dried animal manures, wood ash and the potential secondary soil salinization induced by their application is greater in CMWA. The intensity of salinization among the soils was time cycle specific, and soils from basement complex parent material were more prone to salinization than soils from sedimentary parent material.

Keywords: *salinization, complementary application, Wood ash, nutrient uptake, basement complex.*

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Introduction

Soil electrical conductivity (EC) describes the capability of the soil liquid to carry electric current through its ion filled pores. It is an electrolytic process due to the ions in water, a measure of the cationic and anionic content of salts dissolved in soil liquid capable of and conducting electricity. Hence soil electrical conductivity (EC) is a measure of soil salinity or dissolved salt (Olowoboko *et al.*, 2018) as a function of the concentration of ions. Soil EC has been reported to be an indirect indicator of available nutrients and salinity levels which does not directly affect plant growth. Electrical conductivity has been used as a substitute degree of salt concentration (Azeez *et al.*, 2020) with high levels of EC been linked to high proportion of nitrates and salt forming cations used as nutrient by plant. However, most of our soils possess low EC as a result of continuous cropping due to decline in the concentration of dissolved salt forming ions that are also important macro and micro nutrient which tend to limit nutrient (Olowoboko *et al.*, 2018). Soil EC indirectly depicts the degree of soil organic matter mineralization and a measure of soluble nutrients (De *et al.,* 2000) therefore it tends to affect crop yield, biological activity due to nutrient solubility, availablity and uptake (Azeez and Van Averbeke, 2012). As a way of increasing soil nutrients and enhancing soil fertility and productivity of the soil, the use of animal manures therefore becomes a pertinent practice (Diacono and Montemurro, 2010). Consequently, the possible contamination of adding fresh farmyard manures to soil become worrisome due to environmental complications such as evolution of green house gases and streams and ground water contamination, hence their use agriculturally become limited (Alade *et al.*, 2019). Furthermore, weed seed content, heterogeneity, odour and nutrient imbalance in animal manure makes it compulsory for the growing need for efficient soil fertility management practices that comprise of alternatives ways of using animal manures manure. This makes drying of animal manure an important process before usage. The balanced nutrient content and organic matter of dried animal manure makes them a better organic fertilizer which improves soil water holding ability, soil tilth for aeration and development seed and plant (Roba, 2018). Pujanbanti et al. (2019) reported that organic manures were effective for crop production because they supplied mineral nutrients to the soil and decreased the need for the use of inorganic fertilizer. Due to the nutrient content of dried animal manures, they are applied to soil (Garbarino *et al.*, 2003; Jackson and Bertsch, 2001) after which they mineralize and release nutrients and salts to the soil (Azeez and Averbeke, 2015), these salts are usually from additives added to feed of ruminant animals or added directly for monogastrics animals as a feed flavour or for osmotic balance (Goff, 2006). Subsequently, the salts are excreted in the feaces which are used as manure for fertilizing the soil. When such manures are added to the soil, an increased salt concentration occurs and when in excess, tends to destroy the soil structure thereby negating the ameliorative purposes of manure addition. However, the salt content of animal manure and probable salinization of these manures to soil has been of much less concern in the recent past (Azeez and Averbeke, 2015). Recently, their environmental impact has become an issue of concern due to runoff of nitrogen and phosphorus from added manure which is considered a contributor to non-point pollution (Allen *et al.,* 2006; Anderson and Xia, 2001; Parker, 2000; Ekholm *et al.*, 2005). Furthermore, environmental implication of trace metals (copper, zinc, arsenic, etc) in animal manures and residue of feed additives, have been documented (Bednar *et al.,* 2003; Bolan *et al.,* 2004; Zhou *et al.,* 2005). Salinity induced by manure incorporation to soil has been reported, but results are inconsistent in the literature. Omeira et al. (2006) reported possible introduction of salts by the incorporation of chicken lirter with high EC in an experiment to compare pH and EC of different chicken gotten from varying production systems. Clark et al. (1998) reported no significant increase in EC levels for a study period of eight years after applying livestock manure. Conversely, a drastic improvement in soil salinity levels due to four years of livestock manure application was reported by Pratt (1984). Subsequently, Chang, Sommerfeldt, and Entz (1991) reported similar results after 11 years of cattle manure application. Hence the need to validate the information on sole effect of animal manure on soil EC becomes pertinent. Consequently, it has been reported that organic manures cannot sustainably lead to improved soil fertility and productivity (Zhang *et al.*, 2023; Bayu 2020), hence soil fertility management requiring combination of different management practices that can ensure good soil health and reduce environmental pollution is envisaged (Teressa *et al.*, 2004). One of such is the sole or complementary ap-

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plication of wood ash with dried animal manures since dried animal manures can supply the nutrient needs of a plant for a long term while wood ash is able to supply at immediate use for the plant. Wood ash is possibly an important soil fertilizer that is becoming popular as an alternative to inorganic fertilizer. Wood ash has been reported for its liming ability to substitute liming materials in combating soil acidity (Cruz-Paredes *et al.,* 2017; Dvořák *et al.,* 2017). The pH increase observed after wood ash application can influence soil water EC and increase nutrients such as K, S, B, Na, Ca, Mg, Si, Fe, and P (Augusto *et al.*, 2008). Wood ash is a by product of paper and pulp companies that use wood residues as a fuel source. Wood ash production can also be simulated when farmers convert the crop residues on their farm to ash as a way of returning back nutrient into the soil (Odelana *et al.*, 2024). An important disposal method of wood ash is application to soil as a liming agent; due to the formation of bicarbonates resulting from reaction between oxides and carbonate content of the ash (Brady and Weil, 2008). Ashes have been reported to have high levels of basic cations, micronutrient elements and some metals but a reduced carbon, sulphur and nitrogen content depending on the temperature of combustion (Ingerslev *et al.,* 2011). Contrary to the positive effects of wood ash, it has been reported that wood ash contains likely concentra tions of toxic substance and heavy metals, especially cadmium, based on the composition of wood stock (Pitmann, 2006). Several researches have been carried out on the effect of wood ash on soil pH, soil fertility and other component of soil, however, up to date, information on the sole effect of wood ash on soil electrical conductivity under controlled and uncontrolled environment is lacking, hence the necessity for this study. Azeez and Van Averbeke (2012) highlighted that soil electrical conductivity significantly increases with the incorporation of goat, cattle and poultry manures and the occurrence of soil salinization due to manure incorporation was very high with goat and poultry manure compared with cattle manure. Roy and Kashem (2014) reported that gradually increasing soil EC with incubation time was significant and the extent of increase was higher in the manure amended soil than the control soil. It was also reported by Eigenberg et al. (2002) that nitrogen content of soils may be monitored using EC measurements since significant positive relationship existed between soil EC and N contents. Dikinya and Mufwanzala (2010) revealed higher soil EC with increasing rates of poultry manure. Azeez et al. (2020) reported an increase in the pH and EC of soil with the incorporation of mixtures of poultry manure and other manures. While several studies on the sole effect of dried animal manures, wood ash have been carried out, scarcity of information on complementary effect of these organic fertilizers on changes in soil EC necessitates this research. Information regarding EC changes in soils amended with mixtures of dried manures and wood ash is scarce, hence this study becomes pertinent. It is therefore hypothesized that (i) sole application of wood ash can affect soil EC changes under different conditions (incubation, screen house and field experiment) (ii) sole and complementary incorporation of wood ash and dried animal manure (poultry manure and cattle manure) can influence EC changes in incubation, screenhouse and field experiments.

Materials and Methods

Soil Sample collection and preparation

Surface soil samples from six locations chosen based on the type of parent materials, of which three location are basement complex parent materials (Soil 1; Alabata, Soil 5;Owode, Soil 6;Ojere) and the other three from sedimentary parent materials (Soil 2;Ijale Orile, Soil 4; Obada, Soil 3;Ikenne) were collected at a depth of 0 - 20 cm.

Animal manures, wood ash collection. Cattle manure and poultry manure were sourced from the University farms, Federal University of Agriculture, Abeokuta. Dried animal manures were made by air drying collected animal manures at room temperature to constant weight. Wood ash was collected from a renowned sawmill company at Odeda, Ogun state, Nigeria .

Analysis of soil samples, animal manures and wood ash. . Soil pH was determined in a 1:2 soil: water solution using glass electrode pH meter. The EC of Soil, dried manures and wood ash were measured in suspension by the method of Jackson (1973). Exchangeable bases were extracted with 1 N ammonium-acetate solution in 1:10 soil: solution ratio, sodium and potassium were determined by flame photometry, calcium and magnesium were determined using atomic absorption spectrophotometry according to method reported by Odelana et al. (2024). Dried manures were digested with nitric and perchloric acid at the ratio of 2:1 (Watanabe et al. 2013) and the digests were analyzed for exchangeable

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bases according to the method reported earlier.

Experimental design

The experiments were carried out under controlled (incubation and screen house experiments) and uncontrolled conditions (field experiment). Completely Randomized Design was used for the controlled experiments (screenhouse and incubation) while randomized complete block design was used for the field experiment with three replications and six treatments. Treatments were control, cattle manure at 90 kg P ha^{-1} (CM), poultry manure at 90 kg P ha^{-1} (PM), cattle manure at 90 kg P ha^{-1} and wood ash 5 t ha^{-1} (CMWA), poultry manure at 90 kg P ha^{-1} and wood ash 5 t ha^{-1} (PMWA) and wood ash at 5 t ha^{-1} (WA).

Experimental procedure

Incubation experiment. Soils collected from the six locations (Soil 1; Alabata, Soil 2; Ijale, Soil 3; Ikenne, Soil 4; Obada, Soil 5; Owode and Soil 6; Ojere were used for this experiment. Two hundred grams of air-dried sieved soil, were dispensed into 300 g incubation plastic, treatments were applied accordingly and mixed with the soil. The soil: treatment mixtures were watered and kept in a dark cupboard for twelve weeks. Soil samples were taken at 0, 4, 8, and 12 weeks after incorporation (WAI) for EC determination according to method mentioned earlier.

Screen house experiment. From the results of incubation experiment, soils from four locations (Soil 1; Alabata, Soil 5; Owode, Soil 2; Ijale Orile and Soil 4; Obada were used for the screen house experiment. This consisted of two cycles, the first cycle and second cycle were for 8 weeks each. Five kilograms (5 kg) of soil was dispensed into each experimental pot after which treatments were applied. Soil and treatment mixture were watered, maize seeds were sown at three seeds per pot and thinned to one plant per pot. Soil samples were collected at 0, 4, and 8 weeks after planting (WAP) for EC determination. After harvesting at the 8th week, maize seeds were sown again for the second cycle however with no treatment application. The second cycle was aimed at evaluating the residual effect of the treatments applied in the first cycle. Soil samples were collected at 0, 4 and 8WAP for EC determination for the second cycle.

Field experiment

This experiment was conducted at the Teaching and Research Farm of the Federal University of Agriculture Abeokuta in two cycles; first planting cycle was carried out between May and August and the second planting cycle was carried out between September and November. Pre planting practices were carried out on the field after which treatments were applied accordingly. A spacing of 75 cm by 25 cm was adopted for sowing the maize seeds, two weeks after which the plants were thinned to one plant per stand. The experiment lasted for 12 weeks and at 0, 4, 8 and 12 weeks after planting (WAP), soil samples were collected for EC determination. After harvesting at the 12th week, maize seeds were sown again for the second cycle however with no treatment application. The second cycle evaluated the residual effect of the treatments applied in the first cycle.

Statistical Analysis

Data collected were analyzed with the SAS package (2014). Significant treatments were separated at 5% level of probability using Duncan's Multiple Range Test.

Results and Discussion

Initial properties of soils and amendments used

Figure 1 shows the chemical characterization of soils, animal manure, mixtures of animal manures and wood ash, wood ash. The EC ranged from 0.02 – 0.16 dS m^{-1} in the experimental soils with the sequence of soil 1 (0.16 dSm^{-1}) > Soil 2 (0.13 dSm^{-1}) > Soil 5 (0.12 dSm^{-1}) > Soil 4 (0.08 dSm^{-1}) > Soil 3 (0.05 dSm^{-1}) > Soil 6 (0.02 dSm^{-1}). All the experimental soils were not saline according to salinity groupings., they were within the EC values recommended for agricultural soils. The cationic content of the amendments followed the sequence of Ca > Mg > Na > K. Calcium and potassium content were observed to be more in Soil 1 while Soil 6 possessed the highest potassium content. It was reported by Odelana et al. (2024) that the highest Ca content in Soil 1could be due to the type of parent material from which the soil was formed, land use history and differential impact of climate. Calcium, magnesium, potassium and sodium content were respectively between the ranges of 2.63 – 7.06 cmol kg^{-1}, 1.08 – 2.54 cmol kg^{-1}, 0.083 – 0.52 cmol kg^{-1} and 0.13 – 0.36 cmol kg^{-1}. According to fertility ratings, the calcium content of the soils were low to medium, magnesium content in the soils were medium whereas potassium and sodium content were between low and medium.

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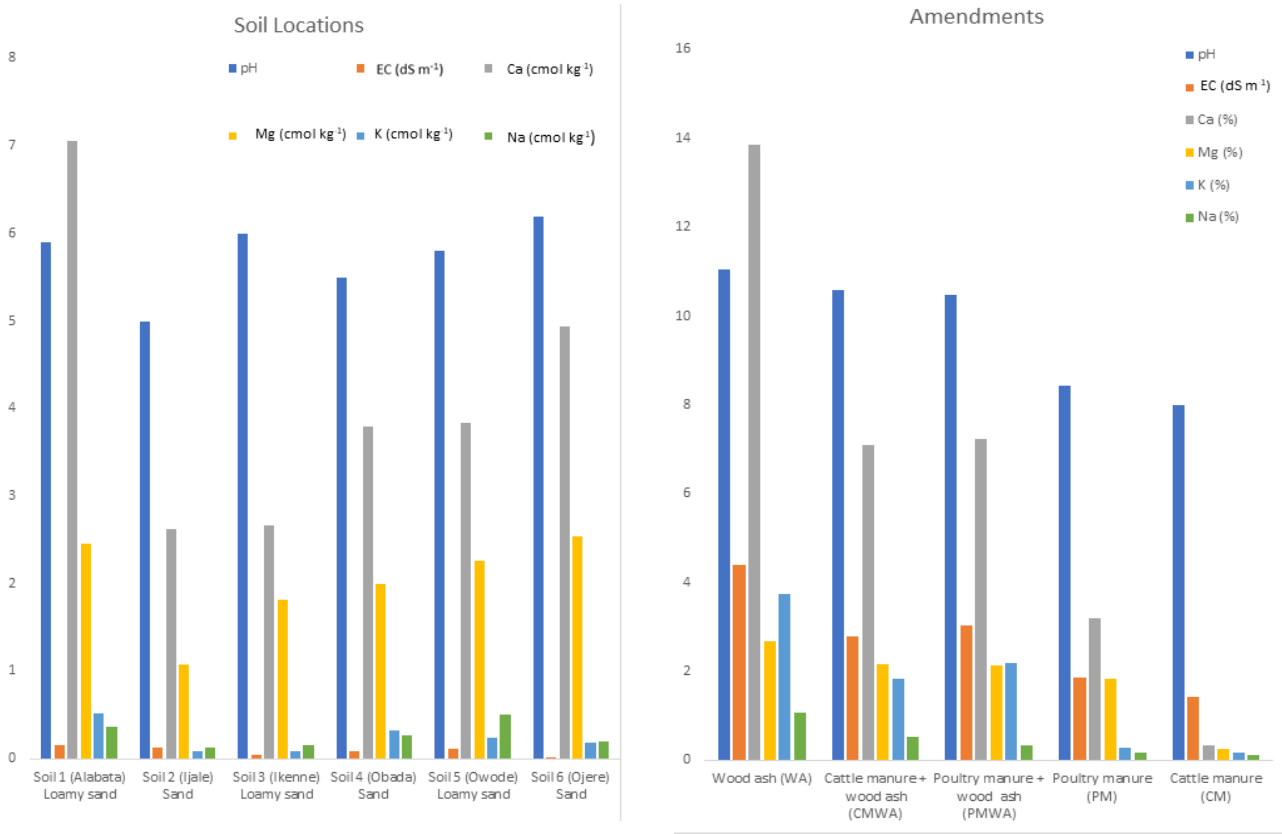

Figure 1. *Initial characterization of soils and amendments*

The sequence of Calcium, Magnesium, potassium and sodium was Soil 1 > Soil 6> Soil 5 > Soil 4 > Soil 3 > Soil 2; Soil 6 > Soil 1 > Soil 5 > Soil 4 > Soil 3 > Soil 2; Soil 1> Soil 4 > Soil 5 > Soil 6 > Soil 3 > Soil 2; and Soil 5 > Soil 1 > Soil 4 > Soil 6 > Soil 3 > Soil 2. For amendments, the EC ranged from 1.43 to 4.39 dSm^{-1}, it was in the sequence of WA (4.39 dS m^{-1}) > PMWA (3.03 dS m^{-1}) > CMWA (2.78 dS m^{-1}) > PM (1.87 dS m^{-1}) > CM (1.43 dS m^{-1}). Poultry manure and Cattle manure were non saline, CMWA and PMWA are very slightly saline and wood ash was slightly saline. Bougnom et al. (2020) reported EC values of 2.01-2.19 dS m^{-1} for cattle manure wood ash compost. The higher EC value of poultry manure than cattle manure in this study conforms to the findings of Azeez and Van Averbeke (2012) who reported that EC was in the order of poultry manure > goat manure > cattle manure. The abundance of cations were Calcium > Magnesium > Potassium > Sodium. Calcium and potassium content of the amendments were in the sequence of WA (13.85, 3.75 cmol kg^{-1}) > PMWA (7.23, 2.19 cmol kg^{-1}) > CMWA (7.1, 1.85 cmol kg^{-1}) > PM (3.2, 0.28 cmol kg^{-1}) > CM (0.35, 0.17 cmol kg-1), while the magnesium and sodium content were in the order of WA (2.68, 1.07 cmol kg^{-1}) > CMWA (2.17, 0.52 cmol kg^{-1}) > PMWA (2.14, 0.34 cmol kg^{-1}) > PM (1.84, 0.18 cmol kg^{-1}) > CM (0.26, 0.11 cmol kg-1). Poultry manure used for this research was gotten from layer birds. These birds were managed under intensive system with all their nutritional needs in the form of compounded feeds. The higher proportion of calcium and potassium salts needed by the birds for egg production in the feeds, could have been the reason for the higher Ca and K content of poultry manure relative cattle manure which was gotten from cattle who scavenge for feed and might not have met their daily nutritional needs. According to fertility ratings, wood ash had very high Ca, Mg, K and high Na, PMWA and CMWA possessed medium Ca and Mg and very high K and Na. However, PM had low Ca, K, Na and medium content of magnesium whereas CM possessed low Ca, Mg, Na and very low K content.

Potential salinization of animal manure and wood ash in incubation experiment

Figure 2 shows the effect of animal manure and wood ash on soil electrical conductivity (EC) at 0 weeks after incorporation (WAI) in incubation experiment. In Soil 1, the lowest and highest EC was experimental

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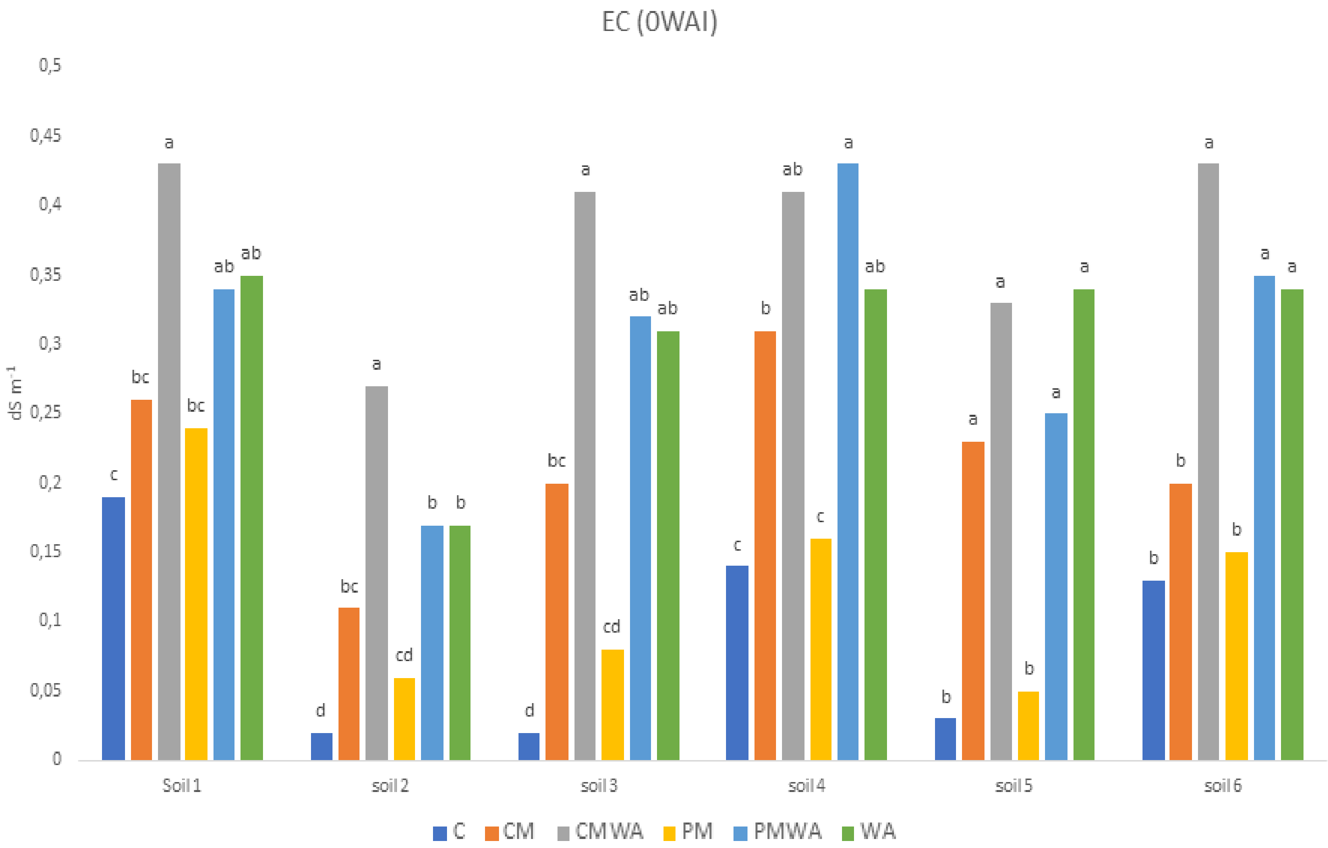

Means with the same letters within each soil are not significantly different at p ≤ 0.05 - C = Control - CM = Cattle manure - CMWA = Cattle manure + wood ash; PM = Poultry manure; PMWA = Poultry manure + wood ash - WA = Wood ash

Figure 2. *Effect of sole and combined animal manure and wood ash on EC at 0WAI (0 weeks after incorporation) in incubation experiment*

in control soil and CMWA amended soil respectively, the application of CMWA increased EC by 126, 65, 79 % above control, CM and PM whereas CMWA and PMWA did not differ. Amendment effect was significant on soil EC in Soil 2, as significantly higher EC was observed in amended soil relative the control. Subsequently, complementary application of animal manure and wood ash raised EC significantly than their sole application; EC increased by 145 % with CMWA compared to CM and 183 % with PMWA compared to PM. A drastic rise in EC by 1250 and 59 % was observed with CMWA relative to control and wood ash respectively. For Soil 3, the combined application of wood ash and dried animal manure increased EC drastically than the sole application of the manure, a significant increase by 1950, 105 and 413 % was recorded with the incorporation of CMWA in comparison with control, CM and PM respectively. The significant capacity of dried manure on soil EC was a reflection of the dissolved salt content of the manures (Azeez and Van Averbeke, 2012), with the salts content of the manures obtained from additives being added to their feeds especially for poultry manures (Goff 2006). For Soil 4, the lowest and highest EC was observed with control and PMWA respectively, EC increased by 207, 39 and 169 % with PMWA in comparison to control, CM and PM, though CMWA, PMWA and WA had similar effect on EC. Cattle manure, CMWA, PMWA and WA had similar effect on EC in Soil 5 despite that the highest EC produced by CMWA was 1000 and 560 % more than that in the control and PM amended soil respectively. In Soil 6, significantly higher EC was observed in amended soil relative the control. Subsequently, co-application of animal manure and wood ash raised EC significantly than their sole application; EC increased by 115 % with CMWA compared to CM and 133 % with PMWA compared to PM. The intensity of salinization among the soils was in the order of Soil 1 > Soil 4 > Soil 6 > Soil 3 >

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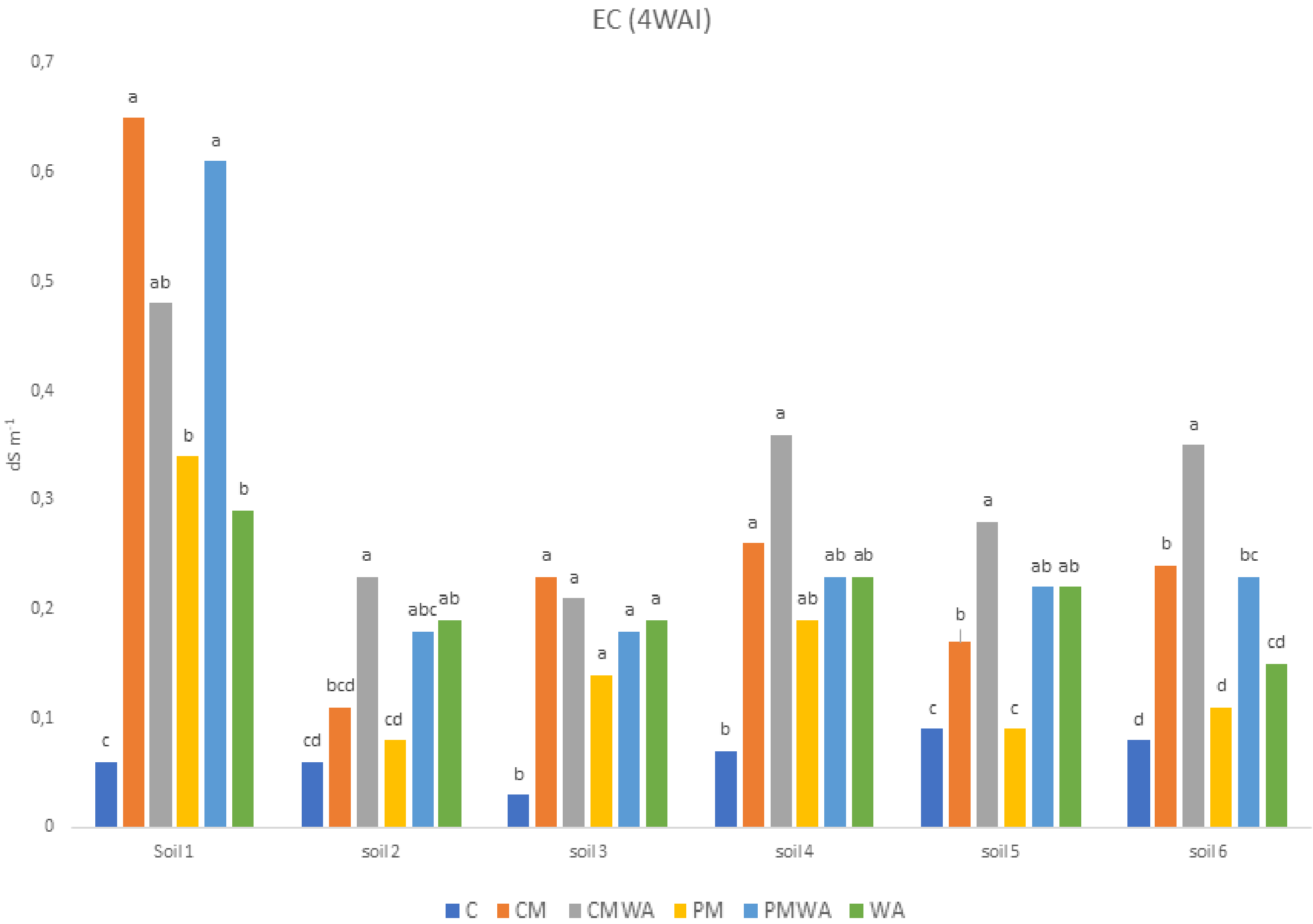
Soil 5 > Soil 2 whereas the salinization potential of the amendments were CMWA > PMWA > WA > CM > PM > Control. The effect of dried animal manures and wood ash on EC at 4WAI is presented on Figure 3. In Soil 1, the highest EC observed with the sole application of CM which was 983 and 124 % higher than that of the control and WA amended soil, though CMWA and CM did not differ, PMWA raised the EC of soil by 79 % above PM. Contrary to our findings, Azeez and Van Averbeke (2012) reported that effect of animal manures on soil EC was in PM was greater than CM , however, the reason for the greater effect of CM on soil EC than PM in this study could be due to the greater amount of cattle manure applied to the soil since the rates of application were P rates and CM had lower P compared PM, hence more CM in terms of weight were applied to achieve. the rate, this might have likely correspond to more salts being added to the soil .

The complementary application of dried manures and wood ash raised EC drastically than their sole application in Soil 2, CMWA and PMWA increased EC by 109 and 125 % respec-tively than CM and PM whereas the highest increase in EC by 283 % was observed with CMWA relative the control. Amendment effect on EC in Soil 3 was significant as all amended soil had similar EC was significantly higher than the control soil. The incorporation of CMWA led to the significant increa-se of 414 % in EC above the control for Soil 4, all sole and complemen-tary application of amendments had similar effect on EC. Conversely, in Soil 5, complementary application: CMWA and PMWA in-crease soil EC respectively by 65 and 144 % when compared to sole applications; CM and PM. Further-more, the lowest EC in the control soil did not differ from PM amended soil but was 211 % lower than the highest EC in CMWA amended soil.



Means with the same letters within each soil are not significantly different at p ≤ 0.05 - C = Control - CM= Cattle manure – CMWA= Cattle manure + wood ash - PM = Poultry manure - PMWA = Poultry manure + wood ash – WA=Wood ash

Figure 3. *Effect of sole and combined animal manure and wood ash on EC at 4WAI (4 weeks after incorporation) in incubation experiment*

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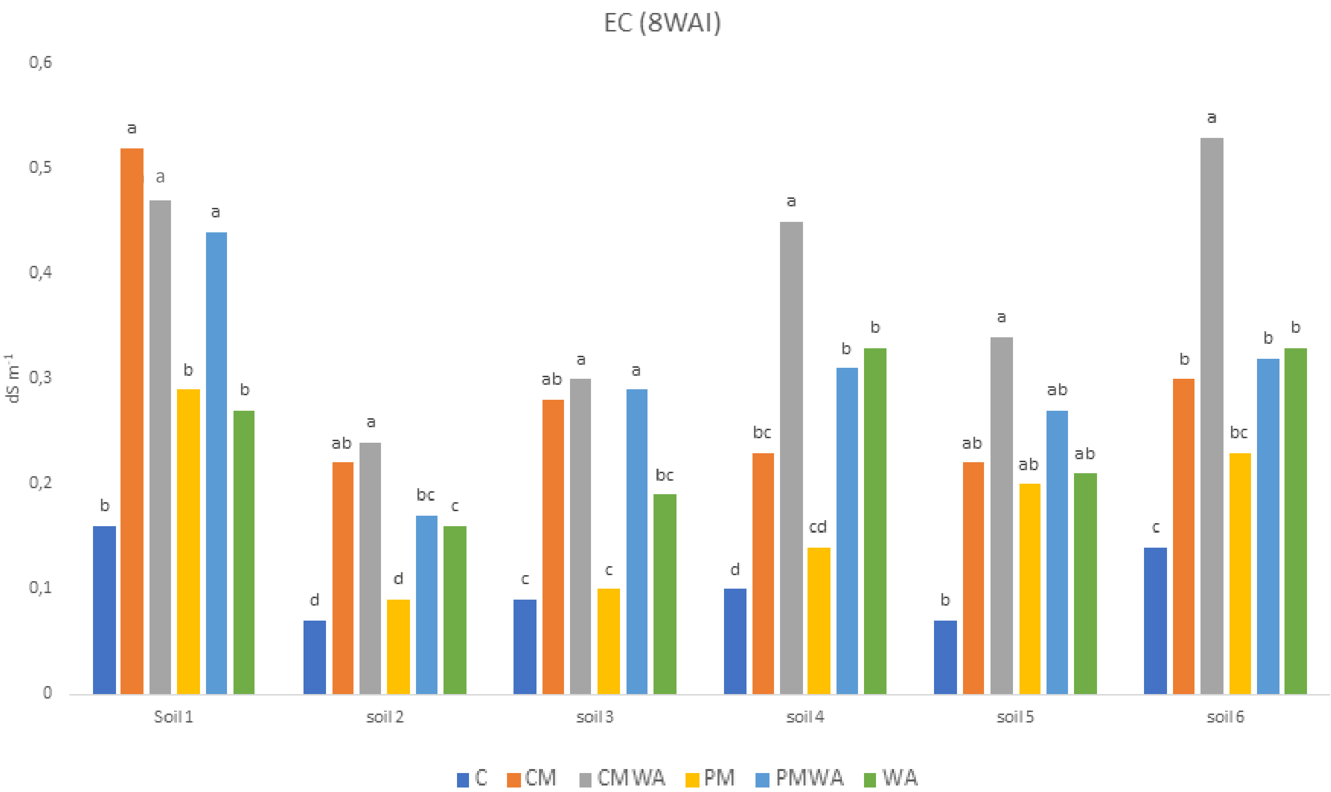
In Soil 6, the incorporation of CMWA increased EC drastically by 133, 52, 218, 46 and 338 % than WA, CM, PM, PMWA and control respectively. All the mixtures of dried manures and wood ash had greater effect on Soil EC than their dried manure counterparts. The intensity of salinization among the soils was in the order of Soil 1 > Soil 4 > Soil 6 > Soil 5 > Soil 3 > Soil 2 whereas the salinization potential of the amendments were CMWA > CM > WA > PMWA > PM > Control. Electrical conductivity can serve as a measure of soluble nutrients for both cations and anions (Roy and Kashem, 2014). Figure 4 shows the effect of animal manure and wood ash on Soil electrical conductivity (EC) at 8 weeks after incorporation (WAI) in incubation experiment. In Soil 1, the lowest and highest EC was observed in control soil and CM amended soil, the application of CM increased EC by 225, 79 and 93 % respectively above control, PM and WA whereas CM, CMWA and PMWA did not differ. Applying manures with high EC in large mounts can the increase the soil EC and salt content which could later destroys the soil structure and overthrow the ameliorative purposes of manure incorporation. Azeez and Van Averbeke (2020) reported that salinity of animal manures and potential secondary soil salinization as a result of their application is greater in poultry manure and goat manure than cattle manure. Amendment effect was significant on soil EC in Soil 2, as significantly higher EC was observed in amended soil relative the control. Subsequently, complementary application of poultry manure and wood ash (PMWA) raised EC significantly than its application (PM) ; EC increased by 89 % with PMWA compared to PM. A drastic rise in EC by 243 and 50 % was observed with CMWA relative to control and wood ash. Similar effect was observed in Soil 3, such that EC increased by 190 % with PMWA compared to PM whereas CMWA amended soil possessed the highest EC at 233, 200 and 58 % than the control, PM and WA. Amendment effect was significant on soil EC in Soil 4, as significantly higher EC was observed in amended soil relative the control. Subsequently, complementary application of dried manures and wood ash raised EC significantly than their sole application; EC increased by 97 % with CMWA compared to CM and 121 % with PMWA



Means with the same letters within each soil are not significantly different at p ≤ 0.05 - C = Control - CM= Cattle manure – CMWA= Cattle manure + wood ash - PM = Poultry manure – PMWA=Poultry manure + wood ash – WA= Wood ash

Figure 4. *Effect of sole and combined animal manure and wood ash on EC at 8WAI (8 weeks after incorporation) in incubation experiment*

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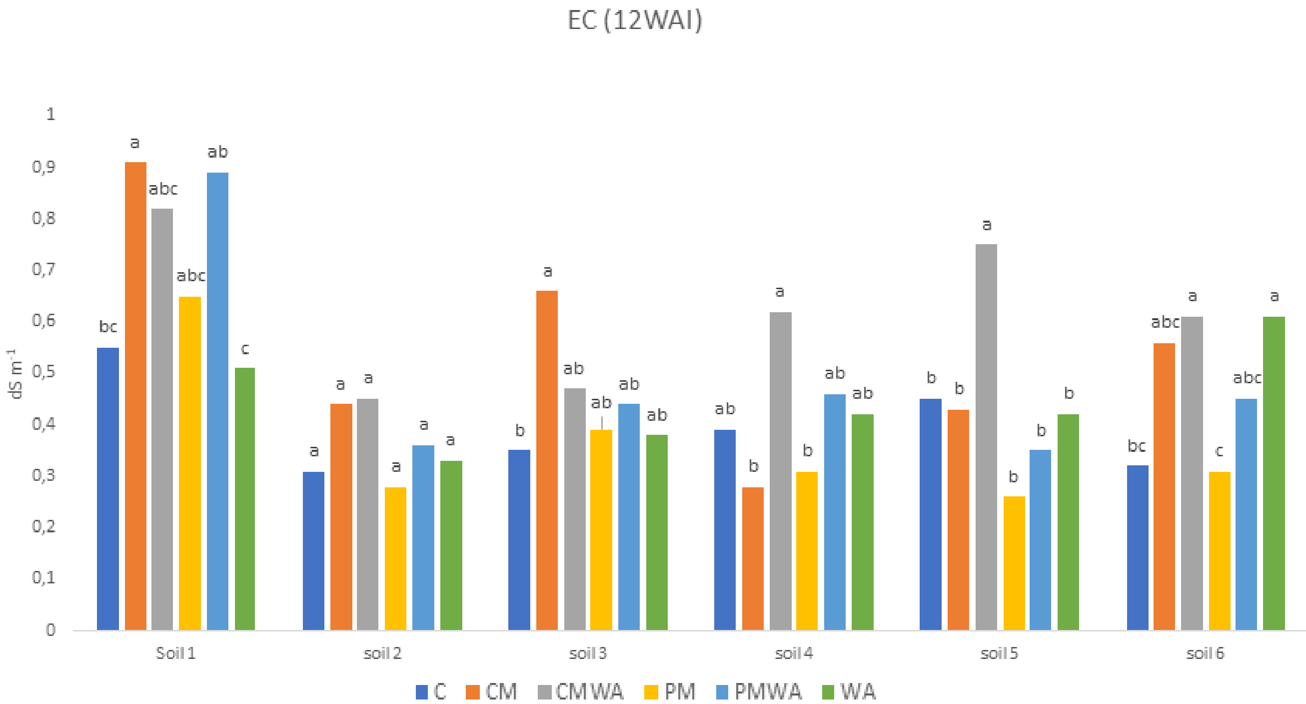
compared to PM. Azeez et al. (2020) highlighted that in the soil from Osiele, the incorporation of poultry-manure ash led to a significant increase in EC compared to its dried manure across the weeks. A drastic rise in EC by 350 and 36 % was observed with CMWA relative to control and wood ash. For Soil 5, amendments except CMWA significantly differed from the control with a 386 % higher EC, however, PMWA and CMWA led to similar EC as their counterparts PM and CM. Electrical conductivity of soil improved by 279, 77, 130, 66 and 61 % with the application of CMWA in comparison to control, CM, PM, PMWA and WA respectively in Soil 6. Furthermore, CMWA and PMWA increased EC by 77 and 39 % than CM and PM respectively. The higher content of sodium in the CMWA used for this experiment could be the reason for the higher significant increase in soil EC as compared to CMWA, PM and CM. The intensity of salinization among the soils was in the order of Soil 1 > Soil 6 > Soil 4 > Soil 5 > Soil 3 > Soil 2 whereas the salinization potential of the amendments were CMWA > PMWA > WA > CM > PM > Control. n Soil 1, the highest EC observed with the sole application of CM was 65 and 78 % higher than that that of the control and WA amended soil, though CM and CMWA did not differ, PMWA raised the EC of soil by 37 % above PM (Figure 5). In Soil 2, the control soil did not differ from amended soil though the highest EC was observed with the usage of CMWA. Amendment effect on EC in Soil 3 was significant as all amended soil had similar EC, and only CM treatment significantly raised EC than the control soil 89 %. Similar result was reported by Azeez et al. (2020) that the incorporation of dried cattle manure significantly increased the electrical conductivity of soils during weeks of incubation than other dried manures. Complementary application of cattle manure and wood ash produced the highest soil EC which was only significantly higher than CM by 121 % and PM by 100 % for Soil 4. In Soil 5, the incorporation of CMWA increased EC drastically by 67, 74, 188, 114 and 79 % than the control, CM, PM, PMWA and WA respectively. The incorporation of CMWA led to the highest increase of 91 % in EC above the control for Soil 6, all sole and complementary application of amendments except PM had comparable effect on EC. Roy and Kashem (2014), reported that at the terminal end of the incubation experiment, a significant EC increase by 33 % was observed in soils amended with combined cowdung and chicken manure relative to the control



Means with the same letters within each soil are not significantly different at p ≤ 0.05 - C = Control - CM= Cattle manure – CMWA= Cattle manure + wood ash - PM = Poultry manure – PMWA= Poultry manure + wood ash – WA= Wood ash

Figure 5. *Effect of sole and combined animal manure and wood ash on EC at 12WAI (12 weeks after incorporation) in incubation experiment*

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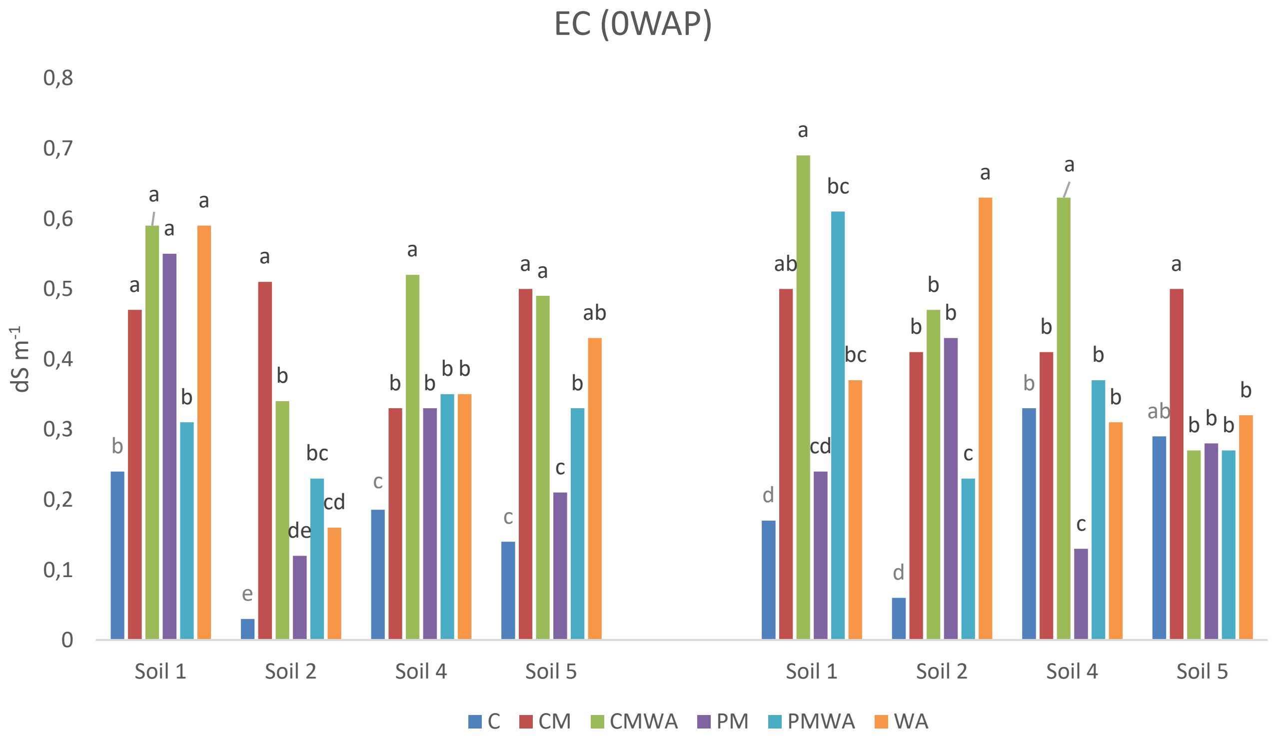
soil. Subsequently, a significant rise in EC by 97 % was observed with CMWA incorporation relative PM. The intensity of salinization among the soils was in the order of Soil 1 > Soil 6 > Soil 3 > Soil 5 > Soil 4 > Soil 2 whereas the salinization potential of the amendments were CMWA > PMWA > WA > CM > PM > Control.

Potential salinization of animal manure and wood ash in screen house experiment

Figure 6 presents the sole and combined effect of dried animal manures and wood ash on soil EC at 0 weeks after planting (0WAP). An increase in soil EC was observed with the incorporation of amendments except PMWA in Soil 1 relative to the control, subsequently, CM, CMWA, PM and WA did not differ in the first cycle. In Soil 2, PMWA increased EC by 92 % above PM while significantly lower EC was observed in CMWA amended soil relative CM. Furthermore, highest EC of CM amended soil was 667 and 44 % more than control and wood ash respectively. Conversely, in Soil 4, all amendments except CMWA increased EC similarly and significantly more than the control though CMWA produced the highest increase of 173 % relative the control. Sole cattle manure andits combination with wood ash similarly affected soil EC in Soil 5, however, a significant increase in EC by 257, 138 and 51 % above the control, PM and PMWA was recorded with CM incorporation. In an experi- ment to determine the effects of organic manures in changes of some soil properties, Roy and Kashem (2000) reported that the magnitude of EC increases was more in manure amended soils than the control soils. In the second cycle, CM, CMWA and PMWA produced similar effect on EC, though PMWA improved EC by 154 % than PM in Soil 1. Furthermore, the greatest EC in CMWA treated soil was 259, 154, and 65 % more than that observed in the control, PM and WA. Wood ash incorporation led to significantly higher EC than the control by 950 % and other amended soils, despite that CM and CMWA did not differ, PM improved EC than PMWA by 87 % in Soil 2. For Soil 4, complementary application of treatments performed significantly than sole treat- ments as CMWA and PMWA improved EC by 54 and 185 % than their dried manure counterparts. Subsequently, an higher EC by 91 and 103 % was recorded with CMWA incorporation relative control and wood ash. Electrical conductivity in the control



Means with the same letters within each soil are not significantly different at p ≤ 0.05 - C = Control - CM= Cattle manure – CMWA=Cattle manure + wood ash - PM = Poultry manure – PMWA= Poultry manure + wood ash – WA= Wood ash

Figure 6. *Effect of sole and combined animal manure and wood ash on soil EC at 0WAP (0 weeks after planting) in screen house experiment*

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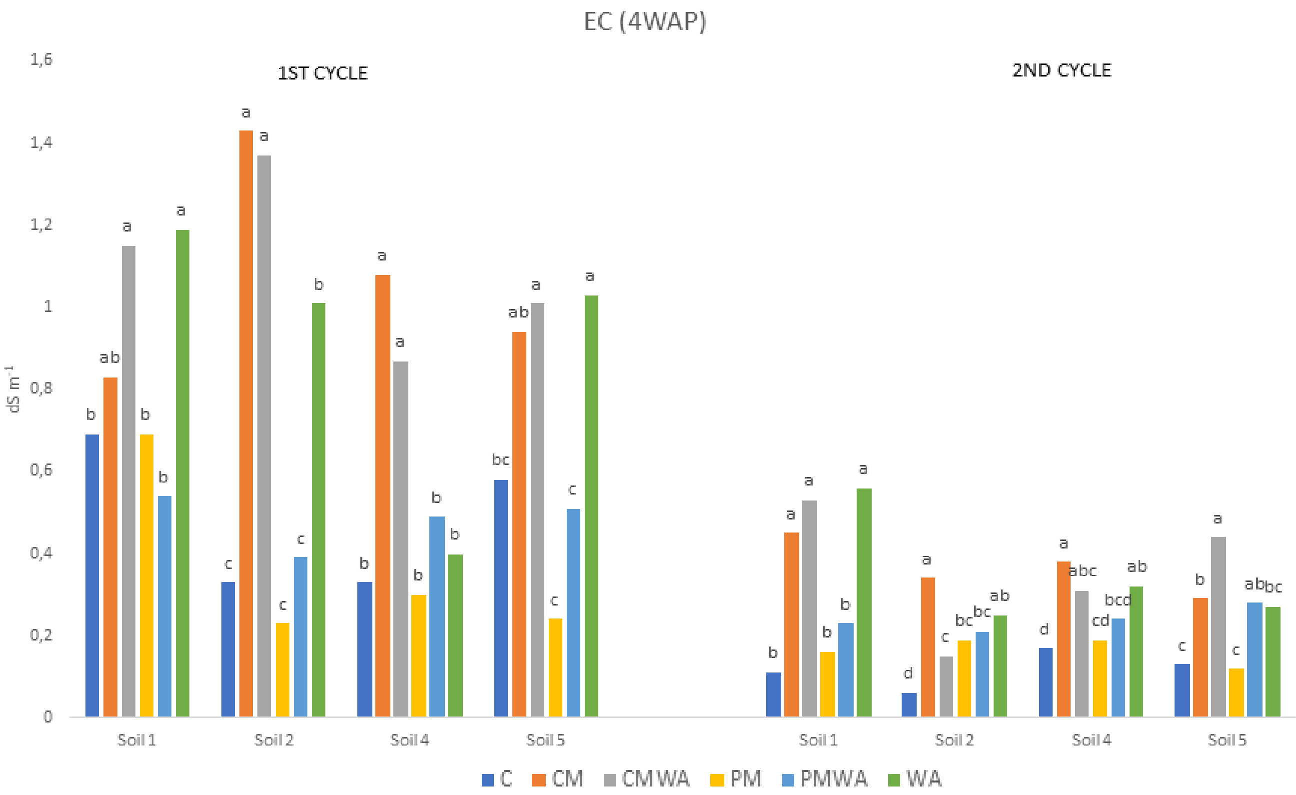
and amendments except CMWA did not differ though the highest EC in CMWA amended soil was significantly higher than other amended soil for Soil 5. The intensity of salinization among the soils was in the order of Soil 1 > Soil 5 > Soil 4 > Soil 2 and Soil 1 > Soil 2 > Soil 4 > Soil 5 in the first and second cycle respectively whereas the salinization potential of the amendments were CMWA > CM > WA > PMWA > PM > Control in the first and second cycle respectively. The single and combined effect of dried animal manures and wood ash on soil EC at 4WAP shows that an increase in soil EC was observed with the incorporation of only CMWA and WA in Soil 1 relative to the control, though CM, PM and PMWA did not differ in the first cycle (Fig. 7), the highest increase in EC was produced as 72% over the control with the application of WA. In Soil 2, single and combined incorporation of dried animal manure and wood ash had similar effect on EC, the highest EC produced with CM incorporation was 333, 521, 267 and 42 % respectively more than WA, control, PM and PMWA. Similar effect was observed in Soil 4, such that CM increased EC above control, WA, PM and PMWA by 227, 258, 260, and 120 % respectively. For Soil 5, WA application produced significantly higher EC by 78, 329 and 102 % relative the control, PM and PMWA respectively, sole dried manures did not differ from their complementary counterparts. Singh and Sukul (2019) reported during an experiment to determine the effect of organic manure, inorganic fertilizer and fly ash on some soil properties, that a significant increase in soil EC was observed in amended soils in comparison to the control. In the second cycle, CM, CMWA and WA produced similar effect on EC, though WA improved EC by 409, 250 and 143 % than the control, PM, and PMWA respectively in Soil 1. Furthermore, sole dried manure had similar effect on EC as their complementary application with wood ash. However, in Soil 2, PM and PMWA did not differ whereas CM incorporation increased EC by 127 % above CMWA. The highest EC produced with CM was 467, 79. 62 % more than control, PM, and PMWA. Similar response was observed for Soil 4 where CM increased EC by 124, 100 and 58 % than control, PM and PMWA. For Soil 5, complementary application of dried manures and wood ash increased EC significantly than their sole application, CMWA and PMWA increased EC at 52



Means with the same letters within each soil are not significantly different at p ≤ 0.05 - C = Control - CM= Cattle manure – CMWA= Cattle manure + wood ash - PM =Poultry manure – PMWA= Poultry manure + wood ash – WA= Wood ash

Figure 7. *Effect of sole and combined animal manure and wood ash on soil EC at 4WAP (4 weeks after planting) in screen house experiment*

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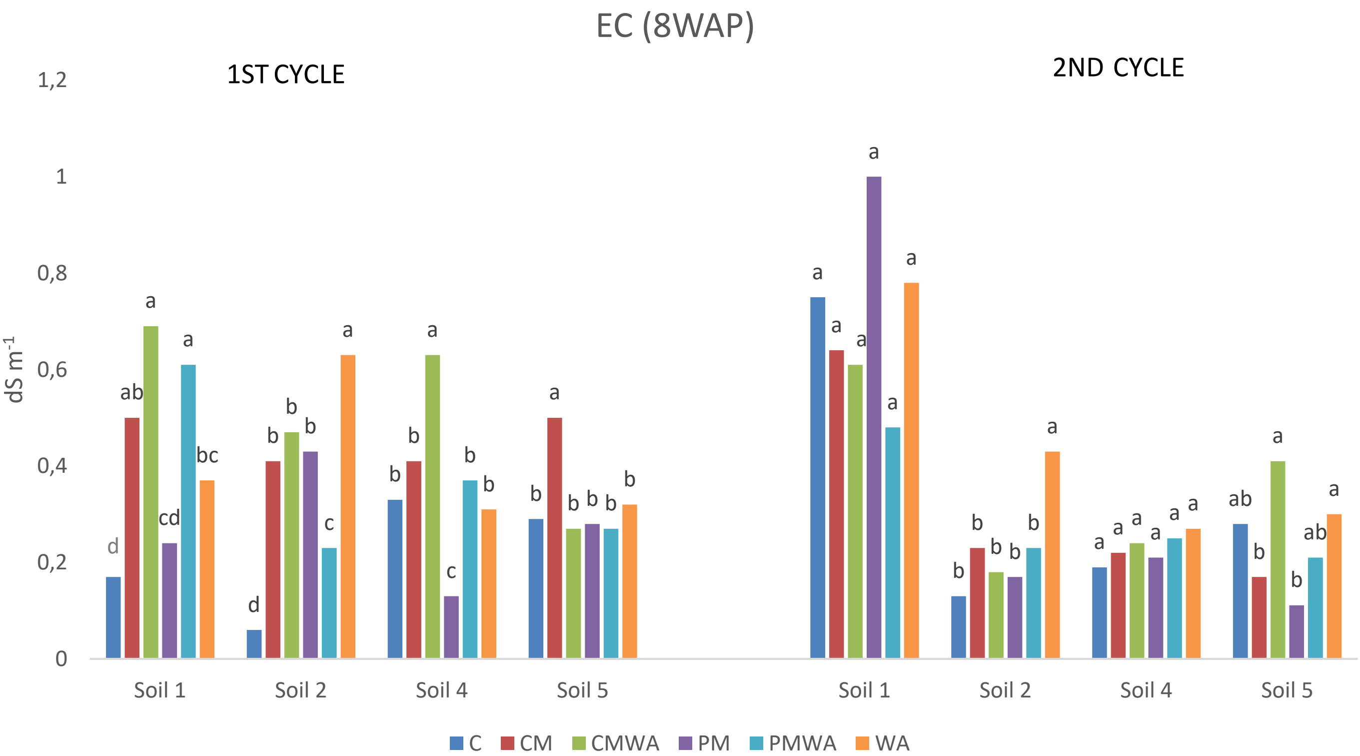
and 133 % above CM and PM respectively, subsequently the CMWA increased EC by 238 % compared to control. A drastic increase in soil EC has been reported with incorporation of organic manures, inorganic fertilizers and fly ash, as they are rich in soluble salts (Singh and Sukul, 2019). The intensity of salinization among the soils was in the order of Soil 1 > Soil 2 > Soil 5 > Soil 4 and Soil 1 > Soil 4 > Soil 5 > Soil 2 in the first and second cycle respectively whereas the salinization potential of the amendments were CMWA > CM > WA > PMWA > Control > PM and CM > CMWA > WA > PMWA > PM > Control respectively in the first and second cycle respectively. Figure 8 presents the single and combined effect of wood ash and dried animal manures on soil EC at 8WAP. An increase in soil EC was recorded with the incorporation of amendments in comparison to the control in Soil 1. However, CMWA and CM did not differ but PMWA increased EC by 154 % above PM. Furthermore, the EC produced with the incorporation of CMWA was higher by 306, 188 and 86 % than the control, PM and WA. Das et al. (2013) highlighted that the incorporation of fly ash led to significant increases in soil EC. The incorporation of WA to Soil 2 improved EC by 950, 54, 34, 47, and 174 above the control, CM, CMWA, PM and PMWA despite that PMWA increased EC significantly than PM, cattle manure and CMWA did not differ. For Soil 4, CMWA increased EC by 91, 54, 385, 70, 103 % than the control, CM, PM, PMWA and WA, subsequently, CMWA and PMWA significantly improved EC than CM and PM respectively. In Soil 5, sole application of cattle manure led to higher EC by 90, 104, 96, 104 and 72 % above control, CMWA, PM, PMWA and PMWA. Electrical conductivity indicates the mineralization of organic matter in soil and serves as a measure of soluble nutrients (De et al. 2000). During the second cycle, the highest and least EC was produced with PM and PMWA respectively though EC of the control and amended soil were not significantly different. Similar response was observed for Soil 4 though the highest EC was produced with WA. For Soil 2, sole incorporation of wood ash improved soil EC significantly than the control at 231 % and CM, CMWA,PM and PMWA at 87, 139, 153 and 87 % respectively.



Means with the same letters within each soil are not significantly different at p ≤ 0.05 - C = Control - CM= Cattle manure – CMWA=Cattle manure + wood ash – PM= Poultry manure – PMWA= Poultry manure + wood ash – WA= Wood ash

Figure 8. *Effect of sole and combined animal manure and wood ash on soil EC at 8WAP (8 weeks after planting) in screen house experiment*

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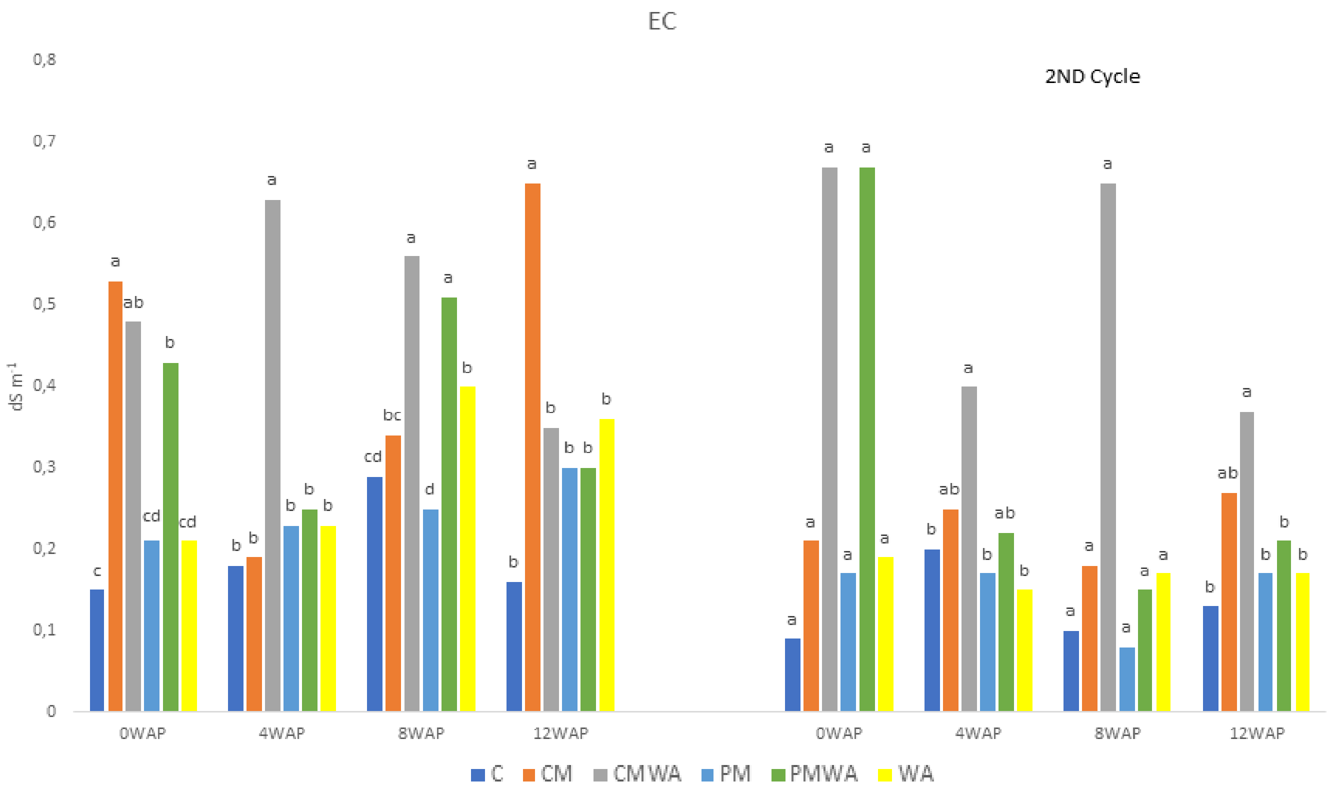
The control soil did not differ from amended soils but a significant higher EC by 141 and 269 % was observed with the incorporation of CMWA relative CM and PM. The intensity of salinization among the soils was in the order of Soil 1 > Soil 2> Soil 4 > Soil 5 and Soil 1 > Soil 5 > Soil 4 > Soil 2 in the first and second cycle respectively whereas the salinization potential of the amendments were CMWA > CM > WA > PMWA > PM > Control and WA > PM > CMWA > Control > CM >PMWA respectively in the first and second cycle respectively.

Potential salinization of soil with animal manure and wood ash in field experiment

Soil EC has an indirect effect on plant growth and is used as an indirect indicator of the amount of nutrients available for plant uptake, and salinity levels (USDA 2011). Figure 9 shows the effect of single and combined wood ash and dried animal manures on soil EC in field experiment. In the first cycle, the incorporation of CM raised EC by 253, 152, 152 and 23% above the control, WA, PM, PMWA and wood ash respectively, CM and CMWA had similar effect whereas PMWA raised EC by 105 % above its sole counterpart PM at 0WAP. Asare (2009) reported a higher EC in bone meal treated area compared to the control area. At 2WAP, the control soil had similar effect with all amendments except CMWA which raised EC by 250, 232, 174, 174, and 152 % relative to control, CM, WA, PM and PMWA at 4WAP. The complementary application of dried animal manures and wood ash led to drastic change in soil EC when compared to the dried manures at 8WAP. It was highlighted by Azeez et al. (2020), that at two weeks after planting, animal manure ashes incorporation to soil in a field experiment significantly increased EC relative to their dried manures. Furthermore, the highest change in EC was 93 % above the control with the incorporation of CMWA, whereas PMWA and CMWA raised EC by 65 and 104% relatively to CM and PM. Bougnom et al. (2020) highlighted that increasing the amount of wood ash in compost led to greater values in EC, this could be the reason for the significant increase in EC of CMWA and PMWA amended soil relative CM and PM amended soil. Though EC values were compatible to agricultural soil EC levels 0 - 4 dS m^{-1} (Brady and Weil, 1996), the incorporation of wood ash in tropical agriculture



Means with the same letters within each WAP are not significantly different at p ≤ 0.05 - C = Control - CM= Cattle manure – CMWA= Cattle manure + wood ash - PM = Poultry manure – PMWA= Poultry manure + wood ash – WAP = Weeks after planting

Figure 9. *Effect of Sole and combined animal manure and wood ash on soil EC in field experiment*

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should be handled with care, espe- cially if the salt content of the amended soil is above 4 dS m-1. Sole application of CM increased EC significantly above the control and all treatments at 12WAP; 306, 86, 117, 117 and 81% increases in EC were recorded with the use of CM when compared respectively to control, CMWA, PM, PMWA, and WA. In the second cycle, the highest and least EC was recorded in the CMWA amended soil and control respectively though EC difference in control and all amended soil were not significant at 0WAP and 8WAP. The incorporation of cattle-manure ash led to a drastic increase in the soil electrical conductivity at all weeks of observation except 0WAP during a field experiment as reported by Azeez et al. (2020). At 4WAP, only WA, PM and the control significantly led to lower soil EC relative other amendments, the highest EC in CMWA amended soil was by 100, 135 and 167 % higher than the control, PM amended soil and WA amended soil respectively. The combined incorporation of dried cattle manure and wood ash (CMWA) increased EC significantly than the control and all other amended soil except CM, a 185, 76, 118 and 118 % rise in EC was recorded with the usage of CMWA relative to control, PMWA, PM, and WA at 12WAP. Bougnom et al. (2020) reported that EC of soils applied with cattle manure wood ash compost increased signi- ficantly in comparison to the control soil due to the increase in salt content. Generally, EC in the first cycle was higher than that in the second cycle depicting that EC reduced across the cycle, this signifying a reduction in the amount of soluble salts content as the plants grow, mature and are harvested such that some of the nutrient forming salts have been mined up into their tissue. When comparison was made within cycles, EC at the 8WAP was the highest and EC at 4WAP was the least in the first cycle while EC at 0WAP was highest and the least was recorded at 12WAP in the second cycle. The salinization potential of the amendments were in the order of CMWA > CM > PMWA > WA > PM > Control in the first cycle and CMWA > PMWA > CM > WA > PM > Control in the second cycle.

Conclusions

EC was in the sequence of Soil 1 > Soil 2 > Soil 5 > Soil 4 > Soil 3 > Soil 6. All the experimental soils we- re not saline according to salinity groupings. For a- mendments, EC was in the sequence of WA > PMWA > CMWA > PM > CM. Poultry manure and Cattle manure were non saline, CMWA and PMWA are very slightly saline and wood ash was slightly saline. The abundance of cations were Calcium > Magnesium > Potassium > Sodium. Calcium and potassium content of the amendments were in the sequence of WA > PMWA > CMWA > PM > CM, while the magnesium and sodium content were in the order of WA > CMWA >PMWA > PM > CM. Amendment effect was significant on EC in incubation experiment, least EC observed in the control soil. Complementary application of wood ash and dried animal manure drastically enhance soil EC than sole incorporation in incubation experiment. The incorporation of CMWA significantly increased EC than other amendments. The salinization ability of the amendments was highest at 12WAI whereas the least was at 4WAI. Electrical conductivity increased across the weeks in the incubation experiment. The intensity of saliniza-tion among the soils was time specific, and soils from basement complex parent material were more prone to salinization than soils from sedimentary parent material whereas the salinization potential of the amendments were CMWA > PMWA > WA > CM > PM > Control as observed in incubation experiment. Amendment effect was significant on EC in screen-house experiment, with least EC in the control soil. Complementary application of animal manure and wood ash drastically enhance soil EC than sole incorporation. The application of CMWA significantly increased EC than other amendments. The potential salinization ability of the amendments were cycle spe-cific as salinization was observed to be more pro-nounced at 4WAP and least at 0WAP in the first cycle whereas in the second cycle salinization was more at 8WAP and least at 0WAP. The order of intensity of salinization among the soils and salinization ability of the amendments were time and cycle specific, and soils from basement complex parent material were more prone to salinization than soils from sedimen-tary parent material whereas the most pronounced salinization potential of the amendments were CMWA > CM > WA > PMWA > PM > Control.

In the field experiment, an increase in EC was re- corded with the sole and complementary application of dried animal manures and wood ash, EC decreased across the cycle. The greatest effect on EC was obser- ved with complementary application of dried animal manures and wood ash especially CMWA. When comparison was made within cycles, EC at the 8WAP was the highest and EC at 4WAP was the was the

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highest and EC at 4WAP was the least in the first cycle while EC at 0WAP was highest and the least was recorded at 12WAP in the second cycle. The salinization potential of the amendments were in the order of CMWA > CM > PMWA > WA > PM > Control in the first cycle and CMWA > PMWA > CM > WA > PM > Control in the second cycle.

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