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Growth and Yield response of Tomato (*Solanum lycopersicum*) as Impacted by Fertilization on the Saline and Sodic soils of Kano River Irrigation Project

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ABSTRACT

Crop growth is impacted by soluble salts that determine the normalcy or salinity of soils and natural waterways. Salt-affected soils have a critical role in land deterioration in irrigated areas. In view of this, a field experiment was conducted in the 2020 and 2021 wet and dry seasons in the eastern and western sectors of the Kano River Irrigation Project (KRIP), Garun Mallam and Kura local government areas, Kano (11°45'N and 12°05'N; 8°45E' and 9°05'E) in the Sudan savanna agro-ecology of Nigeria to evaluate the effect of organic manure on the growth and yield of tomato in the saline and sodic soils of KRIP. Treatments consisted of farmer practice, recommended fertilizer rates (100:30:30), poultry manure, and cow dung, which were laid out in a randomized complete block design in which a farmer constitutes a replication. Soil data (pre-planting and post-harvest) were taken, and plant data were taken on plant height, leaf area index, days to 50% flowering, number of fruits, fruit yield, and an economic analysis was performed to determine the profitability of the treatments. Plant height, number of fruits, and fruit yield show significant differences ($P<0.05$) with the application of treatments. Results showed that application of poultry manure increased plant height, the number of fruits, and fruit weight. However, leaf area index, number of days to 50% flowering, and number of days to first fruit were not significantly affected. Results also revealed that poultry manure was more economical when compared to the other treatments. The application of poultry manure was also found to increase the level of pH in the soil, reduce the electrical conductivity, and increase the effective cation exchange capacity as a result

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of the increase in Ca^{2+}, Mg^{2+}, and K^+ in the exchangeable sites relative to Na^+. It can be recommended that the application of organic manure in areas affected by salinity be encouraged for tomato production.

***Keywords*:** Response, tomato, sodic, saline, soil, amendments

1. INTRODUCTION

The buildup of salts that are soluble in water in the top layers of the soil is referred to as salinity, and it has detrimental effects on both crop productivity and environmental health. Conversely, sodicity pertains to the amount of sodium present in the soil. Excessive sodium can cause detrimental effects on soil structure and impede plant growth when applied to the soil (Gebrehiwot, 2022). One of the main reasons for soil salinity is saline irrigation water and poor land management practices (Sanon *et al*., 2015). While the development of saline soils worldwide can be attributed to natural causes, poor soil and water management regimes in irrigated areas (Mohanavelu *et al*., 2021) most often lead to salt accumulation over many years within the top soils of arid and semi-arid regions (Shrivastava and Kumar, 2015).

Such soils are considered to be saline when the electrical conductivity (EC) of the soil solution reaches 4 dS m^{-1} which is associated with an osmotic pressure of about 0.2 MPa, known to eventually result in significant reduction in yields of most crops (Munns and Tester, 2008). Soil salinity affects agricultural crops, including vegetable crops, reducing productivity. However, increasing vegetable production and consumption is a global priority due to their importance in human nutrition and health. A diet low in vegetables can result in micronutrient deficiencies, which can cause nutritional diseases that are widespread (GAIN, 2018). More water and irrigation are needed for vegetable crops, particularly in arid regions with high temperatures and low rainfall often leading to a rise in the salt content of the soil and water.

The most important cause of land degradation in irrigated areas is salt-affected soils, which are mostly found in arid and semi-arid climates throughout more than 100 nations (Hussain *et al*., 2019; Nachshon and Levy, 2023). Plant development is reduced by salinity in a time-dependent manner, with a rapid phase brought on by a water deficit and a gradual phase brought on by a buildup of harmful salt in the shoot. By lowering the amount of CO_2 available and the amount of photosynthetic pigment in many crops, salinity also has an impact on photosynthesis (Atta *et al*., 2021; 2022a and b; 2023). An accumulation of salt in root zones causes osmotic stress, disturbs cell ion homeostasis, prevents the uptake of necessary nutrients, and causes Na^+, Cl^- and other heavy metals to build up (Atta *et al*., 2021). Crop production decline is mostly caused by fertility degradation and soil nutrient depletion. Soil fertility can be decreased by using improper farming techniques, such as continuous cropping. It is therefore very important to fertilize saline- sodic soils to mitigate nutrient deficiency due to salinity. Hence organic manure with its low cost and slow nutrient release is increasingly preferred (AGRA, 2007; Agegnehu, and vanBeek, 2014; Amare and Melkamu, 2020).

It has been discovered that adding organic soil amendments has positive impacts on the following: reduced bulk density of the soil, enhanced capacity to hold water, aggregate stability, saturated hydraulic conductivity, rate of water infiltration, and biochemical activities (Karami *et al*., 2012; Aytenew and Wolancho, 2020). Using organic materials such as crop leftovers, animal manures, and green manures enhances the physical properties, microbiological activity, and fertility of the soil while lowering heavy metal toxicity through complexation (Khan *et al.*, 2024). To sustain crop production in salt-affected soils, it is imperative to lower salinity by leaching salts, maintaining the water balance in the root zone and providing adequate drainage. It is also crucial to reclaim the soil by applying gypsum prior to leaching. Therefore, this trial was initiated with the aim of evaluating the impact of soil amendment on the growth and yield of tomatoes as well as the physico-chemical properties of saline - sodic soils of Kano River Irrigation Sheme in Nigeria.

2. MATERIALS AND METHODS

2. 1. Experimental site

The experiment was carried out in the East and Western sector of Kano River Irrigation Sheme (KRIS). It lies within latitudes 11°45'N - 12°05'N and longitudes 8°30'E - 9°05'E in the Sudan Savanna Agro-ecology of Nigeria. The elevation of the project site is 440 m above sea level. The project area covers land between Kano and Hadejia Rivers; stretching from Tiga dam (S.E. of Kano) to the landmass on both banks of River Hadejia. It is bordered to the northeast by rivers Hadejia, to east by rivers Garanga, Goriba and Guska Rivers to the south east and south by villages of Kulluwa, Cirin, Gora, Barnawa and Garun Babba.

2. 2. Treatments and Experimental design

The experiment consisted of four (4) treatments, Farmer's practice (FP), recommended fertilizer for tomato (250 kg/ha of NPK 15:15:15 2 weeks after planting (WAP) and 100 kg/ha of Urea 4 weeks after NPK application), Poultry manure (15 t/ha at transplanting), and Cow dung (15 t/ha at transplanting) and replicated 20 times in which a farmer constitutes a replication. The treatments were laid out in a Randomized complete block design (RCBD). Each plot size was 10 × 10 m divided into four (4) equal parts and separated by 1.0 m unplanted area to serve as discard. The tomato variety used for the experiment was UC82B which was provided to the farmers by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). UC82B is a super high yielding plant, firm, and square-shaped red fruit with excellent quality fruit. Germinates within 7-14 days and reaches maturity at 80-90 days.

2. 3. Cultural practices

2. 3. 1. Nursery establishment

Seeds were sown in an area of 225 m^2. A raised bed was prepared by well-decomposed FYM mixed at 3 kg FYM per m^2 of nursery bed. A fertilizer dose of 0.5 kg N, P, and K per bed was also mixed in the soil. Formalin solution in a 500 ml/m^2 area of the nursery bed was used in sterilization. 10% formaldehyde was also used for fumigation. After fumigation, the beds were covered with polythene for 24 hours. Seeds were sown 4 to 5 days after the removal of polythene sheets. Seeds were drilled at 7.5 cm spacing between the rows and covered lightly with soil straw used as mulch till the seeds germinated. Seedlings were protected against wind, exposure to the sun, and excess rainfall.

2. 3. 2. Land Preparation and Transplanting

The land was first ploughed and harrowed to a depth of 30 cm to provide good drainage and aeration to encourage strong rooting. Later, sunken beds were prepared using hoes to conserve moisture, and they were then demarcated by 0.5 m between plots and 1.0 m between replications to allow for easy movements. The soil was then disinfected by fumigating it chemically with fumigants and physically using solarization with polythene sheets when there was enough sunlight during the dry season. Four weeks after sowing, seedlings with 4-5 leaves, 15-20 cm tall, were transplanted with the ball of earth after irrigation. A plant population of 27,777 plants/ha was achieved by transplanting the seedlings at a spacing of 60 by 60 cm.

2. 3. 3. Fertilizer Application

In order to compare with the farmer's practices, the fertilizer was administered in accordance with the treatments. Farmer's techniques are the methods used by individual farmers in the past to manage sodic and saline soils so there was no standard.

2. 3. 4. Pest and Disease Control

Weeds were controlled effectively using manual hoeing, which was done as often as necessary to keep the field weed-free. Pests and diseases of tomatoes were controlled using the recommended dosage of chemicals. Cyperking (Cypermethrin 10% E.C.) was applied at a rate of 100 ml per 14-liter knapsack sprayer to control insect pests. Ampligo was also used at the rate of one sachet per 14-liter knapsack sprayer to protect against lepidopteran pests. The application was done early in the morning, before sunrise. Depending on the preferences of the market, the crop was harvested either at color break or at half red. After two months of transplanting, harvesting got underway. Handpicking was used for harvesting, and the produce was kept dry and cool.

2. 4. Data Collection

Data were collected on meteorological records of temperature (minimum and maximum), relative humidity, and sunshine hours during the period of the experiment, which were obtained and recorded from the trial locations. Data was equally collected on plant height, leaf area index, number of days to 50% flowering, number of days to first fruiting, number of days to maturity, and fruit yield using standard agronomic procedures. Similarly, the soil samples were randomly collected at a depth of 0-15 cm for routine soil analysis. Physical and chemical analysis of the salt-affected soil samples before and after the experiment was done according to standard procedure (Black, 1965). Electrical conductivity, pH, and ECEC Sodium Absorption Ratio were determined.

2. 5. Data Analysis

The data collected were subjected to analysis of variance (ANOVA) as described by Snedecor and Cochran (1967) using Genstat 17th edition (VSNI, 2015). Student Newman-Keuls test (SNK) was used to separate the significant treatment means at 5% probability level.

2. 6. Economic Analysis

Material input costs, non-material input costs, and miscellaneous costs were considered for the calculation of the total cost of production. Gross income was calculated based on the selling price of marketable fruit, and net return was calculated by deducting the total cost of production from the gross return for each treatment. The benefit-cost ratio (BCR) was calculated using the following formula by Reddy and Ram (1996):

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income}}{\text{Total cost of production}}$$

3. RESULTS

Table 1 presents the meteorological data of the experimental location during period of the trial. Result shows that march has the lowest minimum temperature (19.85 °C) and the highest maximum temperature (36.28 °C). Overall, the temperature and relative humidity tend to increase from March to May, and then decrease slightly in June. The wind speed is fairly consistent throughout the four months.

Table 1. Meteorological data covering the experimental period at Garun Mallam LGA Kano, 2020.

Month	Temperature (°C)		Relative humidity (%)	Wind speed (ms^{-1})
	Minimum	Maximum		
March	19.85	36.28	27.54	3.47
April	22.68	34.56	57.97	3.49
May	23.01	33.48	68.24	2.74
June	22.59	30.03	72.10	2.60

Source: Centre for Dryland Agriculture, BUK, GIS Laboratory.

The effect of organic manure, recommended fertilizer, and farmer practice on plant height and leaf area index of tomatoes at 4 and 7 WAT is presented in Table 2. The application of poultry manure significantly ($p<0.05$) increased plant height at both 4 and 7 WAT compared to other treatments; however, it was at par at 7 WAT. There were no significant ($p > 0.05$) differences in LAI among treatments at both 4 and 7 WAT. Although poultry manure and cow dung showed slightly higher LAI values, the differences were not statistically significant. Poultry manure appears to be the most effective treatment for enhancing tomato plant growth and development in terms of height. While LAI is an important indicator of plant growth, the results suggest that the treatments did not significantly affect leaf area expansion in this study.

Table 3 presents the effect of organic manure, recommended fertilizer, and farmer practice on the number of days to 50% flowering and the number of days to first fruiting of tomatoes during the 2020 and 2021 growing seasons. The results showed no significant ($p > 0.05$) effect on the treatments used on the above parameters across the two growing seasons. The effects of different treatments (organic manure, recommended fertilizer, and farmer practice) on the number of fruits per plant and fruit yield of tomato plants during the 2020 and 2021 wet and dry seasons are shown in Table 4. Results indicated that in 2020, poultry manure and cow dung resulted in a significantly ($p<0.05$) higher number of fruits per plant (80.83 and 82.08) compared to farmer practice and the recommended fertilizer rate.

Table 2. Effects of Organic manure, Recommended Fertilizer rate and Farmer practice on plant height and leaf area index of Tomato 4 and 7 WAT during 2021 dry season at KRIP.

Treatment	Plant height (cm)		Leaf area index (LAI)	
	Weeks after transplanting (WAT)			
	4	7	4	7
Farmer Practice	58.23c	83.02b	0.719	1.661
Recommended NPK (100:30:30)	63.70b	63.70b	0.551	1.333
Poultry Manure	86.14a	103.84a	0.604	1.611
Cow dung	58.23c	91.94ab	0.644	1.644
P of F	<0.001	<0.001	0.265	0.062
SE±	2.13	2.03	0.0593	0.0951

Means followed by the same letter(s) are not significantly different at 5% level of probability using SNK.

Table 3. Effects of Organic manure, Recommended fertilizer rate and Farmer practice on the Number of days to 50% flowering and Number of days to first fruiting of Tomato during 2020 and 2021 wet and dry seasons at KRIP.

Treatment	Number of days to 50% flowering (#)		Number of days to first fruiting (#)	
	2020	2021	2020	2021
Farmer Practice	25	25	40	38
Recommended Rate (100:30:30)	25	25	40	38
Poultry Manure	25	25	40	38
Cow dung	25	25	40	38
P of F	0.965	0.403	0.988	0.403
SE±	1.316	0.143	0.833	0.007

However, in 2021, all treatments showed a decrease in the number of fruits per plant compared to the 2020 season, with poultry manure again producing the highest number of fruits (26.9). Similarly, poultry manure and cow dung significantly ($p<0.05$) produced the highest fruit yield (14111 and 14470 kg ha^{-1}) during the 2020 season compared to other treatments, while during the 2021 season, the application of poultry manure consistently produced the highest fruit yield. Farmer practice resulted in the lowest fruit yield in 2020, while cow dung had the lowest yield in 2021. The findings suggest that incorporating organic matter, particularly poultry manure, into tomato cultivation can significantly improve yields. This could have implications for sustainable agriculture and small-scale farmers seeking to enhance their tomato production.

Table 4. Effects of Organic Manure, Recommended Fertilizer Rate and Farmer Practice on the Number of fruits per plant and Fruit weight of Tomato in 2020 and 2021 wet and dry seasons at KRIP.

Treatment	Number of fruits per plant (#)		Fruit yield (Kg ha^{-1})	
	2020	2021	2020	2021
Farmer Practice	58.58c	19.5	8793c	11063b
Recommended Rate (100:30:30)	66.92b	22.3	11846b	10825b
Poultry Manure	80.83a	26.9	14111a	14508a
Cow dung	82.08a	19.3	14470a	10501b
P of F	0.003	0.224	0.001	0.008
SE±	3.28	2.88	3.33	0.8

Means followed by the same letter are not significantly different at 5% level of probability using SNK.

Table 5 shows the effects of organic manure, recommended fertilizer rate, and farmer practices on soil properties (pH, EC, OC, N, P, Ca, and Mg). The results indicated that there was no significant difference among all treatments. However, there was a significant ($p<0.05$) difference due to years for N content and Mg, where there were significantly higher increases in percent N and Mg in 2021 than in the 2020 season.

The 2020 season recorded a decrease of (-28.81%), while 2021 recorded an increase of (8.98%) in N content. A similar trend was also noticed with Mg in the same year. The year 2021 (9.32%) led to an increase, while 2020 (-15.93%) brought about a decrease in Mg content. No significant difference was recorded among the treatments.

The effects of organic manure, recommended fertilizer rate, and farmer practices on soil properties (K, ECEC, Zn, Cu, Mn, Fe, and SAR) are shown in Table 6. Results showed that there was no significant difference ($p > 0.05$) recorded among all treatments except for the K content, where the recommended fertilizer rate recorded the highest (46.74%) increase in K content and was significantly higher than farmer practice but at par with the other treatments. There was also no significant difference among the years, except for Cu and SAR. Cu content in the soil in 2021 increased by 10.60%, while that in 2020 decreased by 52.39%. Whereas the SAR in 2020 increased by 27.96%, in 2021 it increased by 4.266%.

Table 5. Effects of Organic Manure, Recommended Fertilizer Rate and Farmer Practice on the percentage change in soil properties

	pH (1:1)	EC (Us/cm)	OC (%)	N (%)	P (mg/Kg)	Ca (cmol(+) /Kg)	Mg (cmol(+) /Kg)
Initial	6.14	114.06	0.61	0.04	4.54	2.41	0.70
Treatments (T)							
Cow dung	1.49	3.53	-15.15	-4.11	-13.33	11.17	4.61
Farmers Practice	0.81	5.05	-15.35	-13.77	10.02	1.30	-3.80
Recommended Fertilizer	-0.34	-0.51	4.00	-11.55	27.18	-0.58	5.54
Poultry manure	2.25	-4.44	-9.66	-10.23	4.20	18.22	8.49
P-value	0.4579	0.5536	0.7920	0.7920	0.4367	0.1816	0.3007
SE ±	1.85	7.67	13.84	9.00	19.99	10.87	6.51
Year (Y)							
2020	0.90	4.64	-15.41	-28.81b	10.43	14.89	-15.93b
2021	1.20	-2.83	-2.67	8.98a	3.61	0.17	9.32a
P-value	0.8433	0.2491	0.3507	0.0001	0.7458	0.0916	0.0002
SE ±	1.70	6.46	11.75	7.72	15.99	10.01	5.61
Interaction							
T * Y	0.3930	0.4499	0.5256	0.7890	0.7633	0.6602	0.6808

Means followed by the same letter are not significantly different at 5% level of probability

Table 7 shows the interaction between organic manure, recommended fertilizer rate, and farmer practice with the year for an increase in K content. The application of the recommended fertilizer rate in the 2020 season recorded the highest (78.02%) increase in the K content and was significantly different from all the other treatments except poultry manure. However, in 2021, there was a significant difference among the fertilizer practices. Looking at the years under fertilizer practices, the difference between the years was not significant.

Table 8 presents the economic analysis of the fertilizer treatments. The highest benefit cost ratio was recorded from cow dung (2.30), which was closely followed by poultry manure (2.29), while the recommended fertilizer rate (2.12), recorded a lower benefit cost ratio. From an economic point of view, it was apparent from the above details that the treatment of organic manure, which includes poultry manure and cow dung, was more profitable compared to other treatments for tomato production in the study area.

Table 6. Effects of Organic Manure, Recommended Fertilizer Rate and Farmer Practice on the percentage change of soil properties

Initial	K (cmol(+) /Kg)	ECEC (cmol(+) /Kg)	Zn (mg/Kg)	Cu (mg/Kg)	Mn (mg/Kg)	Fe (mg/Kg)	SAR
	0.17	3.48	14.90	2.62	27.61	189.14	0.20
Treatments (T)							
Cow dung	15.69ab	-1.93	-21.27	-19.75	1.54	13.60	16.13
Farmers Practice	8.83b	-0.99	0.29	-28.96	6.60	14.98	21.94
Recommended Fertilizer	46.84a	-1.51	4.57	-16.15	4.21	2.86	9.71
Poultry manure	13.45ab	9.77	-0.27	-18.70	3.40	5.10	16.67
P-value	0.0193	0.3938	0.75	0.7799	0.9897	0.4818	0.4365
SE ±	12.94	8.65	26.06	14.36	15.82	9.41	7.07
Year (Y)							
2020	19.11	1.75	-23.76	-52.38b	-9.07	7.66	27.96a
2021	23.29	0.91	15.42	10.60a	16.94	10.48	4.26b
P-value	0.7161	0.9054	0.0948	0.0001	0.0583	0.7396	0.0006
SE ±	11.54	7.90	23.25	13.11	14.30	8.35	6.21
Interaction							
T x Y	0.0003	0.3271	0.9957	0.7104	0.4188	0.5392	0.3547

Means followed by the same letter(s) are not significantly different at 5% level of probability.

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manure, which includes poultry manure and cow dung, was more profitable compared to other treatments for tomato production in the study area.

Table 7. Interaction between Organic Manure, Recommended Fertilizer Rate and Farmer Practice with year for percentage change in K content.

	2020	2021
Cow dung	2.75b	28.63ab
Farmers Practice	-18.34b	36.00ab
Recommended Fertilizer	78.02a	15.66ab
Poultry manure	14.04ab	12.86b
SE ±	15.64	

Means followed by the same letter(s) are not significantly different at 5% level of probability

Table 8. Cost and return of Tomato Production from application of different treatments.

Farmer Practice	Total Cost of Production (₦)	Gross Return (₦)	Net Return (₦)	Benefit Cost Ratio
Recommended Rate (100:30:30)	257733	545876	288143	2.12
Poultry Manure	233111	534106	310995	2.29
Cow dung	310617	715872	405255	2.30
Farmer Practice	243607	518121	274514	2.13

4. DISCUSSION

4. 1. Effects of Fertilizer Treatments on the Growth and Yield of Tomato

Plant height, fruit yields, and production were shown to be greatly increased by the application of organic manure, whereas the application of cow dung and poultry manure significantly increased tomato plant growth and productivity. Organic manure, rich in nitrogen and nutrients, boosts crop growth, yield, and development, while poultry manure improves nutrient absorption and growth conditions, resulting in taller plants. The application of poultry manure resulted in the tallest plant due to improved nutrient absorption and favorable growth conditions. This corroborates with the findings of Adekiya and Agbede (2017) and Olajide *et al.* (2023) who reported independently the effect of bioactive compounds (poultry manure) in enhancing the productivity of tomato and *Saba senegalensis*, respectively. Organic manure addition improves soil microbial activity, conserves irrigation water, and boosts fertility and productivity in tomato and pomegranate crops, as reported by Mehdizadeh et al. (2013) and Choudhary et al. (2022). Poultry manure contains macro and micronutrients including N, P, K, S, Ca, Mg, Cu, Mn, Zn, Bo, and Fe, according to Adeyemo *et al*. (2019). In addition, Fahad *et al*. (2018) and Rasool *et al*. (2023) discovered that intact litters and composting chicken manure produced irrigated maize with greater growth and yield than NPK fertilizer alone.

Additionally, Doklega and Abd El-Hady (2017) found that applying organic manure significantly improved the mineral composition, chemical composition, plant growth and head yield of broccoli. Badu Brempong and Addo-Danso (2022) claim that applying organic manure increases the soil's water-holding capacity, structure, and ability to support biological transformations such the mineralization of N in the soil, all of which benefit crop development and growth. Rehman *et al*. (2023) opined that the application of vermicompost significantly enhances plant growth and helps combat biotic and abiotic stress. According to Dróżdż *et al*. (2023), compost and biochar made from chicken manure have a good impact on the characteristics of the soil and the growth of plant biomass.

4. 2. Effects of Fertilizer Treatments on Soil Physico-chemical Properties

Soil pH and electrical conductivity (EC)

An essential factor in the growth and development of plants is the pH of the soil. Starting at 6.14, the pH was slightly acidic. There was no discernible variation in the percentage rise across the four treatments, while the pH rose in the greatest amounts when poultry manure and cow dung manure were added. The pH of the soil may have increased due to the original condition of the soil. According to Babalola *et al*. (2018), adding organic fertilizer raises the soil's pH to almost neutral or alkaline. Furthermore, Cavalli *et al*. (2016) and Köninger *et al*. (2021) reported that the addition of fresh cattle dung caused an instantaneous rise in pH in two acid soils. They deduced that the impact of manure on soil pH would vary depending on the source of the manure and the properties of the soil.

For crop productivity and fertilizer management, soil electrical conductivity, or EC, is essential. Compared to inorganic fertilizer, the use of poultry manure lowers EC, but other treatments raise EC of the soil. This could be because of the presence of materials with a high capacity for adsorption, such as poultry dung, which can absorb more sodium. Mahmoud and Ibrahim (2012) found that adding vermicompost reduced the soil EC by 46%. Similar findings were noted by Bharadwaj et al. (2011), who discovered that adding two distinct kinds of soil amendments at varying doses caused the EC values of the soil to drop. These outcomes were further supported by Khan et al. (2010) and Ashraf et al. (2017), who discovered that adding farmyard manure (FYM) significantly decreased soil EC and that doing so decreased the damaging impacts of salinity while also improving soil properties such as pH, SAR, and EC.

Nitrogen (N), phosphorus (P) and potassium (K)

The study discovered that all treatments reduced the overall nitrogen content of the soil, with cow dung and poultry manure exhibiting the least amount of decline in comparison to inorganic fertilizer and farmers' practices. When comparing the application of poultry manure to inorganic fertilizer, the latter showed the greatest increase in P and K in the soil following harvest. This may be the consequence of the P and K content being increased by the poultry manure, which also serves to improve plant uptake of P and K by assisting in the conversion of soil P and K into forms that plants can absorb. Phosphorous (P) is a macronutrient that crops can absorb less readily under dry soil conditions and that is less available in salty soils, as noted by Diacono and Montemurro (2015). On the other hand, because of their high total acidity, hardly soluble rock minerals can be better released from soil phosphates by releasing humic compounds during the mineralization process (Mabagala and Mng'ong'o, 2022). Furthermore, in salty soils, an increase in CEC associated with an increase in organic matter content might raise the accessible proportion of potassium (K). To be more specific, adding compost and chicken dung to the soil can raise the CEC and the soluble and exchangeable K+, which is a competitor of Na+ in situations of sodicity and can prevent Na+ from entering the exchange complex (Walker and Bernal, 2008; Alsudays *et al.*, 2024).

Effective cation exchange capacity (ECEC)

Farmers practices, cow dung, and recommended fertilizers resulted in a reduction of the ECEC, with only poultry manure increasing the ECEC in the soil, although changes in exchangeable cations (except for K^+) were not significant. The increase in ECEC may be a result of the increase in some of the cations (Ca, Mg, and K) due to the application of poultry manure. Walker and Bernal (2008) found that the application of poultry manure at rates of 20 and 30 g kg^{-1} increased the soil ECEC, ranging from 3 to 5 units (cmol/kg) after 84 days. They also reported that the increment in ECEC resulted in more occupation of exchangeable sites by Ca^{2+}, Mg^{2+}, and K^+ relative to Na^+.

The results obtained for the ECEC were similar to the findings of Dikinya and Mufwanzala (2010), who observed that with the addition of chicken manure, the amount of ECEC increased with an increasing application rate of poultry manure. The increase in ECEC after the application of biological amendments has also been reported in previous research (Walker and Bernal, 2004; Seenivasan *et al.*, 2015; Nisha *et al.*, 2018; Mao *et al.*, 2022). In a general sense, the use of organic matter in areas affected by salinity should be promoted. It allows for maintaining soil fertility while also improving the soil structure and availability of mineral elements.

5. CONCLUSION

The application of organic fertilizer to soils affected by salinity resulted in a better yield. From the findings of the present study, it may be concluded that the application of poultry manure can provide the best results for the growth and yield of tomatoes. Results revealed that organic fertilizers are suitable nutrients for improving soil fertility and tomato yield. It also increased the soil pH in an acid soil and increased the nutrient uptake by the plant. Based on the results of main effects cost – benefit analysis it could be seen that incorporating cow dung and poultry manure in to the saline – sodic soil significantly improved yield and cash return to the farmer. This could have implications for sustainable agriculture and small-scale farmers seeking to enhance their tomato production.

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