Journal of Agricultural Science and Practice
Volume 9(3), pages 57-65, June 2024
Article Number: 629F11103
ISSN: 2536-7072
https://doi.org/10.31248/JASP2024.462
https://integrityresjournals.org/journal/JASP

Full Length Research

Effects of organic fertilizers on agronomic performance of tomato (*Solanum esculentum* Mill) and nutrients availability in soils of Central Tanzania

Daines Sanga[1]*, Andekelile Mwamahonje[1], Athuman Mahinda[2], Akida Meya[3], Cornel Massawe[1] and Prosper Massawe[4]

[1]Tanzania Agricultural Research Institute, Makutupora Centre, P. O. Box 1676, Dodoma, Tanzania.
[2]University of Dar es salaam, College of Agriculture and Food Technology (CoAF), P. O. Box 35091, Dar es salaam, Tanzania.
[3]Nelson Mandela African Institution of Science and Technology, P. O. Box 447, Arusha, Tanzania.
[4]Tanzania Commission for Science and Technology (COSTECH), P.O. Box 4302, Dar es salaam, Tanzania.

*Corresponding author. Email: daines_sanga@yahoo.com; Tel: +255755074755.

Received 17th April 2024; Accepted 27th May 2024

ABSTRACT: Organic and mineral fertilizers are widely used to address low soil fertility in increasing yield of tomato. The study was conducted at Tanzania Agricultural Research Institute, Makutupora, Dodoma in Tanzania to evaluate the effect of two organic fertilizers and their combinations with mineral fertilizers on improving tomato production and its subsequent nutrients availability in the soil for two consecutive cropping seasons of 2019/2020 and 2020/2021. Experimental treatments consisted of: - Organic fertilizers with; i) Chicken manure with effective microorganism alone, ii) Combination of chicken manure with effective microorganism and mineral fertilizer, iii) Cattle manure alone, iv) Combination of cattle manure and mineral fertilizer) Mineral fertilizers; Nitrogen, Phosphorus and Potassium (17:17:17), Calcium Ammonium Nitrate (27% N, 8% Ca), and control. The treatments were replicated thrice to a test crop Rio-Grande tomato variety in a complete randomized block design. Data were analyzed using Genstat version 15 software. The results showed a significant difference in fertilizers ($p \leq 0.05$) on the growth and yield of tomatoes where chicken manure with effective microorganisms resulted in taller plants than cattle manure. Combinations of chicken manure with effective microorganisms and mineral fertilizer resulted in a higher number of branches, clusters and fruits than the sole cattle manure or in combination with mineral fertilizers. Based on the results, this study, recommends the use of chicken manure with effective microorganism combined with mineral fertilizers for improved tomato fruit yield while maintaining high soil fertility.

Keywords: Chicken manure, effective microorganisms, mineral fertilizers.

INTRODUCTION

Low soil fertility has been recognized for a long time as a major impediment to intensifying agriculture in sub-Saharan Africa (SSA) (Vanlauwe *et al.,* 2017). This is due to poor management practices which resulted into declining of soil nutrients that are essential in supporting physiological plant growth which led to a big challenge on the sustainability of crop production in Africa (Sileshi *et al.,* 2019; Kiboi *et al.,* 2019). Like in any other crop, in the production of vegetables, fertilizers either organic or inorganic or their combination are used to address low soil fertility. Worldwide, organic fertilizers that are commonly used include animal manures such as cattle manure, chicken manure and pig manure. Other manures are farmyard manure and green manure, slurry, compost and bio-solids while mineral fertilizer sources commonly used are Nitrogen-Phosphorus-Potassium (NPK), Urea, Diammonium Phosphate (DAP), Triple Supper Phosphate and Calcium Ammonium Nitrate (CAN) (FAO, 2019). Amongst organic fertilizers, chicken manure, pig manure, and compost have been reported to consistently supply nutrients to the soil through continual mineralization over a long period (Adeyeye *et al.,* 2018). Nonetheless, most farmers apply inadequate amounts of fertilizer resources that would meet crop nutrient demand, maintain soil fertility and increase soil productivity (Murimi *et al.,* 2020). Sub-optimal fertilization is coupled with several factors such as the high cost of mineral fertilizers, unavailability of the desired fertilizers, high solid content and inherently low nutrient content in organic fertilizers as well as the bulkiness and challenges for transportation of organic fertilizer (Joseph *et al.,* 2015; Babasola *et al.,* 2017). In addressing the nutrient supply challenges, findings have indicated that chicken manure with Effective Microorganisms (EM) has a vast potential to improve soil fertility and crop productivity due to its high capacity to increase soil organic matter that improves soil's physicochemical properties, and enhances microbial biomass (Roba, 2018). Effective Microorganisms (EM) alone are capable of increasing the rate of mineralization which increases the availability of soil nutrients to the crop, hence improving crop performance and final crop yield both in quantity and quality (Joshi *et al.,* 2019). Although the role of organic manure and Effective Microorganisms (EM) are separately known, it is not clear how their influence would be when the two are combined. This study, therefore, aimed to bridge the gap in knowledge and surface out the interactive influence of different sources of organic fertilizers with EM and mineral fertilizers on improving soil productivity and soil fertility using tomato as a test crop.

MATERIALS AND METHODS

Description of the study area

The study was carried out at Tanzania Agriculture Research Institute (TARI)-Makutupora centre which is located about 23 kilometres north of Dodoma City along the Arusha road during two consecutive rainy seasons in 2019/2020 and 2020/2021. The area lies between latitudes 6° 0.2' 20'' South and between longitudes 35° 45' 23.5'' East at an altitude of 1140 meters above sea level. The area is characterized by erratic –rains, unimodal which start from December to April, and hardly reach 600 mm per annum. The dominant soil of the study site is classified as Haplic Luvisol–Aridic Profondic (Mahinda *et al.,* 2018).

Materials used in this study

The materials used in this study were: (i) Tomato Rio-Grand seeds variety, (ii) mineral fertilizers (NPK fertilizers with grade of 17:17:17, CAN with grade of 27% N, 8% Ca), (iii) insecticides with active ingredients of *Abamectine, Tetrametrin* and *Phenothrin,* (iv) fungicides containing *Metalaxyl, Mancozeb and Hexaconazole* as active ingredients, (v) cattle manure and (vi) chicken manure. Tomato seeds, mineral fertilizers and pesticides were purchased from the retail shop located in Dodoma city. On the other hand, cattle manure was collected from dairy cattle sheds around TARI-Makutupora centre, while chicken manure treated with EM was collected from Violet Nyongoto Organic Farm located at area 'C' Dodoma City.

Land preparation, experimental design and treatment allocation

Land preparation involved clearing, ploughing, harrowing and partitioning into 3 blocks with 6 plots in each block, giving a total of 18 treatment plots, with 8 m^2 each. The experiment was laid down in a randomized complete block design (RCBD) with three replications. Experimental treatments consisted of (i) chicken manure treated with EM (ii) chicken manure treated with EM + mineral fertilizer (CAN), (iii) cattle manure, (iv) cattle manure + mineral fertilizer (CAN), (v) mineral fertilizer alone (CAN + NPK) and (vi) absolute control (no fertilizer application).

Tomato seedlings were raised in a nursery by sowing seeds and covered with well-dried non-seed grass. The seedbed was watered twice a day to ensure sufficient moisture for seed germination. Immediately after seedling emergence, grasses were removed and shade was offered to allow proper seedling establishment.

Tomato seedlings were transplanted to the treatment plots, 21 days after sowing when the seedlings had three true leaves. One seedling per hole was transplanted at a spacing of 0.6 m x 0.6 m, making a total of 18 tomato plants in each treatment plot. One week before transplanting cattle manure at a rate of 10 t ha^{-1} and 8 t ha^{-1} were thoroughly incorporated and moistened in their respective treatment plots to allow mineralization. The treatment plot with 8 t ha^{-1} was added with mineral fertilizer (CAN) 21 days after seedling transplanting. The same applied to the chicken manure treated with Effective Microorganism (EM) 8 t ha^{-1} and 6 t ha^{-1} of it were incorporated and moistened in their respective treatment plots one week before transplanting. The 6 t ha^{-1} was combined with mineral fertilizer (CAN) 21 days after seedling transplanting. Mineral fertilizer (NPK 17:17:17) at a rate of 112 kg ha^{-1} was applied during transplanting while mineral fertilizer (CAN) at a rate of 112 kg ha^{-1} was applied 21 days after seedling transplanting. Other agronomic practices such as irrigation, weeding, pruning and pesticide application for pest and disease control were optimized.

Data collection and laboratory analysis

Soil samples were randomly collected at a depth of 0 – 30 cm from the experimental field before planting for initial soil fertility assessment. The composite soil samples of about 1 kg and a small sample of about 500 g from the two types of manure used in the study were taken for laboratory analyses at the Soil Science Laboratory of the Sokoine University of Agriculture, Morogoro Tanzania. Both soil and manure samples were analyzed for pH in water, exchangeable bases, total nitrogen, total phosphorus and organic carbon. Furthermore, the data collected from tomato plants were shoot length measured at early flowering, number of brunches, clusters and tomato fruits per plant. The yield of tomato fruits per plant and per plot was also measured. After plant harvest, a soil sample was collected from each plot to determine soil available nutrients.

Statistical data analysis and management

Data generated from the study were subjected to a one way analysis of variance (ANOVA) and means were separated using Duncan's Multiple Range Test (DMRT) at 5% confidence level. The statistical software used was GenStat Discovery 4th Edition.

RESULTS

Initial soil fertility characteristics

Data on the initial soil fertility characteristics of the study site taken at a furrow slice depth are presented in Table 1. The soil was sandy clay loam, slightly acidic with a pH range of 5.6 – 7.0, which is within the pH range (5.5 – 7.0) favourable for tomato production (Astija, 2020). Such a pH was expected to offer room for optimal availability of micro-nutrients (Fe, Mn, Zn and Cu), however, the case was not the same for Zn. The results showed that the soil contained smaller quantities of organic matter content (1.7%) due to its low organic carbon (0.09%). The observed smaller amounts (0.07%) of total N in the soil could be attributed to low OC contents and inadequate fertilizer applications. Soil available P (20.4 ppm), exchangeable K (0.12 $Cmolkg^{-1}$), Ca (5.41 $Cmolkg^{-1}$) and Mg (1.87 $Cmolkg^{-1}$) were medium, indicating the need for their replenishment to meet the recommended amount for optimal tomato plant growth and fruits yield (Fernandez and Brown, 2013; Reddy *et al.,* 2017; Hu *et al.,* 2023). The CEC of the soil was also noted to be low 11.8 $Cmolkg^{-1}$ as indicated in Table 1.

Chemical properties of manures used in the study

Data on the chemical properties of both manures used in the study are presented in Table 2. Chemical analyses revealed that both chicken and cattle manures had slightly alkaline pH of 8.14 and 7.4, available P of 0.34 and 0.19, Ca of 1.26 and 1.7, Na of 0.15 and 0.19, and Mg of 0.26 and 2.03, respectively (Table 2). The amount of total nitrogen was high in both chicken manure and cattle manure. However, the amount of available P, Ca and Na were low, while the level of K (0.95 and 0.7) was medium. The concentration of Mg was found to be medium in cattle manure but low in chicken manure treated with EM. According to the categorization of the nutrient levels by Sharma *et al.* (2022), total N and extractable micronutrients Zn and Cu both in cattle manure and chicken manure were above the critical level, implying that their additional could supply substantial amounts of nutrients to meet the crop's nutrients demand. The high organic carbon detected in both manures showed the potential of the two in improving and maintaining the physicochemical fertility characteristics of the soil that are collectively important in increasing nutrient availability, nutrient recycling, aeration, microbial biomass and water holding capacity.

Effects of fertilization treatments types on tomato plant height

The results from this study had no significant difference in tomato plant height from those in plots applied with combined chicken manure with EM and inorganic fertilizer (Table 3). The control treatment recorded the shortest plant height (35.27 cm), which was significantly short from those applied with sole cattle manure, inorganic fertilizer and the combination (Table 3).

Effect of fertilization treatments on the number of tomato plant branches

The results showed that plants fertilized with chicken manure treated with EM + inorganic fertilizer recorded the highest (7) tomato plant branches while the lowest (4) was recorded in the absolute control treatment (Table 3). The observed number of tomato branches in plants grown under chicken manure with EM in combination by inorganic fertilizer did not deviate statistically from those plants fertilized by cattle manure combined with inorganic fertilizer.

Effects of fertilization treatments on the number of tomato plant clusters

The results of the current study indicated that the highest number of tomato clusters (17) that was recorded in the plants fertilized with inorganic fertilizer, did not differ

Table 1. Initial soil characteristics of the experimental field prior the installation of the field treatments at TARI-Makutupora Centre, Tanzania.

Soil properties	Unit	Remarks
pH (H2O)	5.6	Slightly acidic
OC (%)	0.09	Low
Total N (%)	0.07	Low
Avail P (mg/Kg)	20.4	Medium
CEC (Cmol/kg)	11.8	Low
Ca (Cmol/kg)	5.41	Medium
Mg (Cmol/kg)	1.87	Medium
Na (Cmol/kg)	0.15	Medium
K (Cmol/kg)	0.12	Medium
Zn (mg/kg)	0.56	Low
Cu (mg/kg)	2.5	High
Fe (mg/kg)	2.8	High
Mn (mg/kg)	14	High
Texture Class		SCL

Oc = organic carbon, CEC=cation exchange capacity, N= nitrogen, P=phosphorus, K=pottasium, Ca=calcium, Mg=magnesium, Na=sodium, Zn=zinc, Mn=manganise, Cu=copper and Fe=iron.

Table 2. Chemical properties of manures used in the study.

Manure properties	Chicken manure + (EM)		Cattle manure	
	Unit	Remarks	Unit	Remarks
pH (H2O)	8.14	High	7.4	High
OC (%)	28.83	High	24.6	High
Total N (%)	2.14	High	1.9	High
Avail P (mg/l)	0.34	Low	0.19	Low
Zn (mg/kg)	4.27	High	4.08	High
Cu (mg/kg)	19.32	High	18.63	High
Fe (mg/kg)	1,989	High	1,003	High
Mn (mg/kg)	2,616	High	2,168	High
Ca (%)	1.26	Low	1.7	Low
Mg (%)	0.26	Low	2.03	Medium
Na (%)	0.15	Low	0.19	Low
Avail K (%)	0.95	Medium	0.7	Medium

Oc= Organic Carbon, CEC=Cation Exchange Capacity, N= Nitrogen, P=Phosphorus, K=Pottasium, Ca=Calcium, Mg=Magnesium, Na=Sodium, Zn=Zinc, Mn=Manganise, Cu=Copper and Fe=Iron.

Table 3. Effects of fertilization treatments on plant growth and tomato's fruit yield.

Fertilization treatments	Plant height (cm)	No. of branches	No. of Clusters	No. of fruits plant^{-1}	No. of marketable fruits	No. of non-marketable fruits	Yields (kgs) plant^{-1}
Absolute control	35.27a	3.73a	7.47a	23.53a	15.60a	7.93a	2.24a
Cattle manure	53.4c	5.05b	13.48b	45.80b	33.00b	12.80b	3.16b
Cattle + inorganic fertilizer	48.06b	6.73c	15.06c	54.47c	40.27c	14.20b	3.84c
Inorganic fertilizer	55.19c	5.29b	17.17d	68.40d	54.13d	15.27b	4.80d
Chicken manure with (EM)	64.16d	5.17b	14.73c	53.87c	37.60c	16.27b	4.12c
Chicken manure with (EM) + inorganic fertilizer	60.17d	6.92c	16.84d	70.60d	50.60d	20.00c	5.46d

Table 4a. Soil characteristics of the field experiment after harvest as influenced by the tested fertilizer application techniques.

Fertilization treatments	Total N(%)	Extr. P (mg/kg)	OC (%)	Ca (Cmol/kg)	Mg (Cmol/kg)	Na (Cmol/kg)	K (Cmol/kg)
Abs control	0.07	20.4	0.09	5.41	1.87	0.15	0.12
Cattle manure	0.26	17.4	0.93	8.14	3.18	0.8	0.32
Cattle manure + inorganic fertilizer	0.19	29.49	0.93	8.5	3.26	0.8	0.44
Inorganic fertilizer	0.19	24.49	0.48	7.67	2.82	0.73	0.51
Chicken manure (EM)	0.19	19.51	0.99	9.74	3.77	0.76	0.27
Chicken manure (EM) + inorganic fertilizer	0.29	32.73	0.83	7.62	3.19	0.74	0.62

significantly from tomato plants fertilized with chicken manure with EM in combination with inorganic fertilizer (16) (Table 3). The lowest number of clusters (7) was recorded in the absolute control treatment (Table 3). The combination of cattle manure with inorganic fertilizer resulted in a similar number of tomato plant clusters as in the treatment with chicken manure with EM alone though, the addition of inorganic fertilizer in the treatment with chicken manure with EM resulted in a significant increase in the number of tomato's plant clusters than cattle manure alone or in combination with inorganic fertilizer.

Effect of fertilization treatments on the number of tomato fruits per plant

The highest number of tomato fruits on individual plants (71) was recorded in the plot fertilized with chicken manure with EM combined with inorganic fertilizer; however, it was statistically insignificant ($p \leq 0.05$) with plants grown in a plot fertilized with only inorganic fertilizer. The lowest number (24) of tomato fruits in tomato plants was recorded in the absolute control treatments (Table 3). The results showed further that there was no significant difference in tomato fruits per plant between treatment plots fertilized with cattle manure combined with inorganic fertilizer and that of chicken manure with EM alone. Although any addition of fertilizer resources resulted in a higher number of tomato fruits than the control treatment, combined use of inorganic fertilizer with cattle manure produced more tomato fruits per plant than cattle manure only.

Effects of fertilization treatments on tomato fruits weight per plant

The highest tomato fruit weight per plant (5.46 kg) was recorded in treatment plots that received the combined application of chicken manure with EM + inorganic fertilizer followed by the treatment plots that received inorganic fertilizer alone (Table 3). The lowest weight of tomato fruit per plant (2.24 kg) was recorded in treatment plots that received no fertilizer. Further, it was observed that tomato fruit weight per plant recorded in the treatment plots that received cattle manure + inorganic fertilizer was statistically similar to the treatment that received chicken manure with EM alone.

Soil characteristics of the field experiment after harvest as influenced by the tested fertilizer application techniques

The initial soil analysis in this study indicated soil with pH and CEC of 5.9 and 11.8 Cmol kg^{-1}, respectively which were increased by 20% at the end of the experiment. The percentage increase in pH and CEC of the soil was due to the application of fertilizer sources, however, a greater increase in pH values was observed in the treatment plots that received cattle manure alone. This is because of all environmental factors, soil pH is more important than nutrient content for providing a conducive environment for microorganism functioning and distribution (Reddy *et al.,* 2017; Wang *et al*., 2019). On the other hand, a greater increase in CEC was observed in the treatment plots that received inorganic fertilizer alone (Table 4). Similar results were reported by Brar *et al.* (2015) whereby the use of inorganic fertilizer and organic fertilizer resources (NPK and FYM) improved soil chemical properties such as CEC and pH resulting in higher crop yields.

The residual soil OC and total N contents were also increased by 91% and 63%, respectively, at the end of the experiment in the treatment plots that received chicken manure with EM alone. Undoubtedly, this result was due to the direct effect of chicken manure composition and the direct impact on increased crop growth and its residue in response to the additional nutrient supply to the plant. These results are in accordance with the findings of Kuśmierz *et al.* (2023) that Soil OC content was significantly increased by (2.34%) when at least 150 kg N ha^{-1} in manure was applied. However, the highest percentage increase of total N, P and K values was observed in the combined application of chicken manure with EM and inorganic fertilizer (76%, 38% and 81%)

Table 4b. Soil characteristics of the field experiment after harvest as influenced by fertilizer application techniques.

Treat / Properties	pH (H_2O)	CEC (Cmol/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Textural class
Abs control	5.9	11.8	2.8	0.56	2.5	14.0	SCL
Cattle manure	8.01	10	1.39	1.75	155.8	17.59	SCL
Cattle manure + inorganic fertilizer	7.99	13.6	1.58	2.06	24.2	14.24	SCL
Inorganic fertilizer	7.57	17	1.57	1.79	21.3	17.85	SCL
Chicken manure (EM)	7.54	16.4	1.52	2.03	12.6	19.29	SCL
Chicken manure (EM) + inorganic fertilizer	7.34	13.2	1.52	1.82	10	19.67	SCL

(Table 4a). A similar result was reported by Walia *et al.* (2010), Redda and Kebede (2017), and Mahmood *et al.,* (2017) whereby the integrated nutrient management system resulted in increased OC content, available N, and K from 0.39% to 0.54%, 171.7 to 219.3 kg ha^{-1} and 20.5 to 43.3kg ha^{-1} respectively. Also, it was reported that higher organic matter content, N mineralization potential, and microbial biomass were observed in organically farmed plots than in those receiving commercial fertilizers (Assefa and Tadesse, 2019). Furthermore, the amount of Ca, Mg and Na increased by 29%, 41% and 79% respectively after the application of chicken manure with treated EM and inorganic fertilizer in combination. This result is in agreement with the findings of Awosika *et al.* (2014) who revealed that application of organic fertilizer (pig manure) and NPK fertilizer alone or in combination significantly increased soil N, P, K, Ca and Mg relative to the control.

DISCUSSION

Effect of fertilization treatments on growth performance of tomato plants

Plant height

Plant height is an important factor that shows the growth process which is determined by shoot and root growth parameters (Kang *et al.,* 2016). In the current study, the highest (64.16 cm) plant height was recorded in tomato plants grown under chicken manure with EM and the shortest plant height (35.27 cm) was recorded in the absolute control treatment (Table 3). This indicates that chicken manure with EM has a cross-cutting effect on promoting physiological functioning related to the primary growth of the plant. Similar findings on the influence of chicken manure in plant growth but in other plants have been reported by Ismaeil *et al.* (2012), Kibrial *et al*. (20130, Habimana *et al.* (2014) and Pujiastuti *et al.* (2018).

Number of tomato's plant branches

Combined application of chicken manure treated with EM and inorganic fertilizer has a very significant effect on the number of tomato plant branches. The results observed in plants grown under chicken manure with EM in combination with inorganic fertilizer did not deviate statistically from those plants fertilized by cattle manure combined with inorganic fertilizer. Such an increase in plant branches, suggests the role of combined organic and inorganic fertilizers in enhancing secondary growth of tomato, specifically on the number of branches, which are important growth components of a plant. Although the general role of fertilizer on plant performance is well known (Agyeman *et al.,* 2014; Roba, 2018; Mahinda *et al.,* 2018), with patches of evidence on the role of combined organic and inorganic fertilizers on the branches of tomato plant (Nakano *et al.,* 2003; Kisetu *et al*., 2014; Ilupeju *et al.,* 2015; Mohit *et al.,* 2019; Sadiq and Modi, 2021), these results solidify such existence. Other research works e.g by Mahmud *et al.* (2016), Mahinda *et al.* (2018) and Kakar *et al.* (2020) have indicated the positive influence of combined organic and inorganic fertilizers, notwithstanding, most of them focus on cereal crops.

Number of tomato plant clusters

Plant cluster is an important agronomic characteristic because it determines the number of fruits and their weight. In this study, the highest number of tomato clusters (17) was recorded in the plants fertilized with inorganic fertilizer, which did not differ significantly from tomato plants fertilized with chicken manure with EM in combination with inorganic fertilizer (16) (Table 3). The findings of this study also revealed that the application of reduced chicken manure with EM and inorganic fertilizer, resulted in a higher number of tomato plant clusters than full application of chicken manure with EM alone. Such a performance could have been due to the availability of more nutrients from mineralization, influenced by EM after additional readily available nutrients from inorganic fertilizers. These findings are in line with Islam *et al.* (2017) that mixed fertilizer (organic + inorganic) created the highest amount of flower clusters (31), fruit clusters (25) and tomato fruit yield (15.3 t/ha) relative to the control treatment.

Effects of fertilization treatments on tomato's fruits yield per plant

Number of tomato fruits per plant

The general trend performance in number of tomato fruits across the experimental treatments followed the order: Chicken manure with EM + inorganic fertilizer ≥ inorganic fertilizer > cattle manure + inorganic fertilizer ≥ chicken manure with EM > cattle manure only > control. Although any addition of fertilizer resources resulted in a higher number of tomato fruits than the control treatment, combined use of inorganic fertilizer with cattle manure produced more tomato fruits per plant than cattle manure only. Notwithstanding, the case was contrary when chicken manure was incorporated with inorganic fertilizer.

Holding inorganic fertilizer aside the results showed that the chicken manure with EM has a significant influence in increasing number of tomato fruits per plant compared to cattle manure whether applied alone or in combination with inorganic fertilizer. A similar trend was also observed in plant height and number of clusters, suggested that whenever there is chicken manure, and cattle manure, the use of chicken manure with addition of EM would without doubt enhance the general performance of the tomato plant. The results are in agreement with the work of Mehdizadeh *et al.* (2013) that among manures, chicken manure outweighs cattle manure and the trend should be arranged in this way: Municipal waste > Poultry manure > Cattle manure > Sheep manure > control. On the other hand, Islam *et al.* (2017) proved the results that a mixture of organic and inorganic fertilizers resulted in the highest number of flower clusters (31) and tomato fruit clusters (25) compared with the control. Several studies reported similar results e.g. Ogundare *et al.* (2015) reported that combined use of organic with inorganic fertilizers significantly ($p \leq 0.05$) increased the total number of tomato fruits.

Weight of tomato's fruits per plant

The highest weight of tomato fruits per plant recorded in the treatment plots that received cattle manure + inorganic fertilizer was statistically similar to the treatment that received chicken manure with EM alone. The findings of this study revealed a significant increase in the tomato fruit weight per plant when cattle manure or chicken manure with EM were applied in combination with inorganic fertilizer than when both materials were applied alone. The results are in accordance with the findings of Awosika *et al.* (2014) who reported that the combination of 187 kg/ha of NPK (15:15:15) with 6 t/ha of pig manure improved tomato fruit yield. Also, the work of Isitekhale *et al.* (2013) revealed that the application of mixed NPK fertilizer along with poultry manure is more effective for tomato production than the application of each material separately.

Conclusion

Combined application of the reduced amount of chicken manure treated with EM and reduced amount of inorganic fertilizer yielded better results compared to the application of sole cattle manure fertilizer or in combination with inorganic fertilizer. On the other hand, the full application of inorganic fertilizer alone produced similar results to the application of the reduced amount of chicken manure treated with EM in combination with the reduced amount of inorganic fertilizer. Additionally, the application of chicken manure treated with EM also found to improve soil characteristics. Therefore, based on the results of this study, the combined application of chicken manure treated with EM and inorganic fertilizer is the best for optimum production of tomatoes and sustainable soil fertility improvement in central Tanzania and areas with similar agro-ecologies.

CONFLICT OF INTEREST

The authors declared no conflict of interest

ACKNOWLEDGEMENTS

This research work was made possible through the financial support provided by Violet Nyongoto Organic Farm Company Ltd. Their support is highly appreciated. We are also very thankful to the anonymous reviewers and editors whose comments significantly helped to improve the quality of this manuscript.

REFERENCES

Adeyeye, A. S., Olalekan, K. K., Lmidi, W. A., Aji, P. O., Othman, H. J. and Ishaku, M. A. (2018). Comparative effect of organic and Inorganic fertilizer sources on the growth and fruit yield of tomato. *International Journal of Agricultural Policy Research*, 6(8), 122-126

Agyeman, K. I., Osei-Bonsu, J. N., Berchie, M. K., Osei, M. B., Mochiah, J. N., & Bolfrey-Arku, G. (2014). Effect of poultry manure and different combinations of inorganic fertilizers on growth and yield of four tomato varieties. In Ghana CSIR-Crops Research Institute, Science and Education Centre of North America. *Agricultural Science,* 4(2),71- 91.

Assefa, S., & Tadesse, S. (2019). The principal role of Organic fertilizer on soil properties and Agricultural Productivity: A review. *Journal of Agricultural Research and Technology*, 22(2), 61-92.

Astija (2020). Soil pH influences the development of tomato root organ (*Solanum lycopersicum L.*). *Asian Journal of Biosciences,* 14, 6903-6908.

Awosika, O. E., Awodun, M. A., & Ojeniyi, S. O. (2014). Comparative Effect of Pig Manure and NPKFertilizer on Agronomic Performance of Tomato (*Lycopersicon esculentum* Mill). *American Journal of Experimental Agriculture*, *4*(11), 1330-1338.

Babasola, O. J., Olaoye, I. J., Olalade, O. A., Matanmi, B. M., Olorunfemi, O. D. (2017). Factors affecting the use of Organic fertilizeramong vegetable farmers in Kware State, Nigeria. *Tanzania Journal of Agricultural Sciences, 16*(1), 46-53

Brar, S. B., Singh, J., Singh, G., Kaur, G. (2015). Effects of long term application of Inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. *Agronomy, 5*(2), 220-238.

FAO (2019). International Code of Conduct for the Sustainable Use and Management of Fertilizers. Submission by the Food and Agriculture Organization of the United Nation to the development of the post. Global Biodiversity Framework. Retrieved from https://www.sieusoil.eu/wp-content/uploads/2019/10/12.-FAO-The-international-Code-of-Conduct-2019.pdf.

Fernandez, V., & Brown, P. H. (2013). From plant surface to plant metabolism: the uncertain fate of foliar applied nutrients. *Journal of Plant Sciences, 4*(3), 289-389.

Habimana, S., Ngezahimana, J. B., Nyabyenda, E., & Umulisa, C. (2014). Growth and yield of Watermelon as affected by different spacing and mulching types under Rubona conditions in Rwanda. *Plants, Soil and Environment Journal,* 4(10), 517-520.

Hu, Y., Bellaloui, N., & Kuang, Y. (2023). Editorial: Factors affecting the efficacy of foliar ferilizers and the uptake of atmospheric aerosols. *Frontiers in Plant Science*, 14, 85-89.

Ilupeji, E. A. O., Akanbi, W. B., Olaniyi, J. O., Lawal, B. A., Ojo, M. A., & Akintokun, P. O. (2015). Impact of organic and Inorganic fertilizers on growth, fruit yield, nutritional and lycopene contents of three varieties of tomato (*Lycopersicon esculentum* (L) Mill). *African Journal of Biotechnology*, 14(31), 2424-2433.

Isitekhale, H. H., Osemwota, I. O., & Amhakhian, S. O. (2013). Poultry manure and NPK fertilizer application and their residual effect on yield and yield components of tomato (*Lycopersicon esculentum mill L)* in two District Ecological Zones of Central Southern Nigeria. *Journal of Agriculture and Veterinary Science, 3*, 40-47.

Islam, M. A., Islam, S., Ayasha, A., MdHabibur, R., & Dilip, N. (2017). Effect of organic and inorganic fertiliers on soil properties and the growth, yield and quality of tomato in Mymensingh. *Bangladesh Journal of Agriculture*, *7*(3), 18.

Ismaeil, F. M., Abusuwar, A. O., & El Naim, A. M. (2012). Influence of chicken manure on growth and yield of forage sorghum *(Sorghum bicolor L.). International Journal of Agriculture and Forestry, 2*(2), 56-60.

Joseph, A., Ademiluyi, B. O., Aluko, P. A., & Alabeni, J. M. (2015). Effect of poultry manure treated and untreated with effective microorganisms on growth performance and insect pet infestation on *Amaranthus hybridus*. *African Journal of Plant Science*, *10*(1), 10-15

Joshi, H., Somduttand, C. P., & Mundra, S. L. (2019). Role of effective microorganisms (EM) in sustainable agriculture. *International Journal of Current Microbiology and Applied Sciences*, *8*(3), 172-181.

Kakar, K., Tran, D. X., Zubain, N., Shafiqullah, A., & Gulbuddin, G. (2020). Effect of organic and inorganic fertilizer application on growth, yield and grain quality of rice (*Oryza stiva* L.). *Journal of Agriculture*, *10*(11), 544.

Kang, M., Hua, J., Reffye, P., & Jaeger, M. (2016). Parameter Identification of plant growth models with stochastic development: *2016 IEEE International Conference on Functional-Structural Plant Growth Modeling, Simulation, Visualization and Applications*. Pp. 98-105.

Kiboi, M. N., Ngetich, K. F., Fliessbach, A., Munuki, A., & Mugendi, D. N. (2019). Soil fertility inputs and tillage influence on maize crop performance and soil water contents in the Central Highlands of Kenya. *Journal of Agriculture and Water Management*, *217*, 316-331.

Kibria, M. G., Hossain, N., Ahammad, M. J., & Osman, K. T. (2013). Effects of poultry manure, kitchen waste compost and NPK fertilizer on growth and yield of ladies' finger. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *2*(6), 55-60.

Kisetu, E., & Heri, P. (2014). Effect of poultry manure and NPK (23:10:5) fertilizer on Tomato variety Tanya grown on selected soils of Morogoro, Tanzania. *Asian Journal of Crop Science*, *6*(2), 165-175.

Kuśmierz, S., Skowrońska, M., Tkaczyk, P., Lipiński, W., & Mielniczuk, J. (2023). Soil organic carbon and mineral nitrogen contents in soils as affected by their pH, texture and fertilization. *Agronomy*, *13*(1), 267.

Mahinda, A., Funakawa, S., Shinjo, H., & Kilasara, M. (2018). Interactive effects of in situ rainwater harvesting techniques and fertilizer sources on mitigation of soil moisture stress for sorghum (*Sorghum bicolor* (L.) Moench) in dryland areas of Tanzania. *Soil Science and Plant Nutrition*, *64*(6), 710-718.

Mahmood, F., Khan, I., Ashraf, U., Shahzad, T., Hussain, S., Shahid, M., Abid, M., & Ullah, S. (2017). Effect of Organic and Inorganic manures on maize and their residual impact on soil physico-chemical properties. *Journal of Soil Science and Plant Nutrition*, *17*, 22-32.

Mahmud, A. J., Shamsuddoha, A. T. M., & Haque, N. (2016). Effect of organic and inorganic fertilizer on the growth and yield of rice (*Oryza sativa* L.). *Journal of Nature and Science, 14*, 45-54.

Mehdizadeh, M., Darbandi, E. I., Naseri-Rad, H., & Tobeh, H. (2013). Growth and yield of Tomato (Lycopersicon esculentum mill.) as influenced by different organic fertilizers. *International Journal of Agronomy and Plant Production*, *4*, 734-738.

Mohit, M. K., Manoj, K. S., Singh, S. P. and Naresh, R. K. (2019). Effect of integrated use of organic and inorganic sources of nutrients on growth, yield quality and profitability of tomato *(Lycopersicon esculentum (L) Mill). International Journal of Agricultural and Statistical Sciences, 15*(1), 57-66.

Murimi, D. N., Mucheru-Muna, M. W., Mugi-Ngenga, E., Zingore, S., & Mutegi, J. K. (2020). Nutrients management options for enhancing productivity and profitability of conservation agriculture under conditions in Central Highlands of Kenya. *Journal of Agriculture and Food*, 5(4), 666-680.

Nakano, A., Uehara, Y., & Yamauchi, A. (2003). Effect of organic and inorganic fertigation on yields of tomato (*Lycopersicon esculentum* Mill. Cv. Saturn). Roots: The Dynamic Interface between Plants and the Earth: The 6th Symposium of the International Society of Root Research, 11–15 November 2001, Nagoya, Japan Springer Netherlands. Pp. 343-349.

Ogundare, S. K., Kabalola, T. S., Hinmikaiye, A. S., & Oloniruha, J. A. (2015). Growth and fruit yield of tomato as influenced by combined use of organic and inorganic fertilizer in Kabba, Nigeria. *European Journal of Agriculture and Forestry Research*, *3*(3), 48-56.

Pujiastuti, E. S., Tarigan, J. R., Sianturi, E., & Ginting, B. B. (2018). The effect of Chicken manure and beneficial microorganisms of EM-4 on growth and yield of kale (*Brassica oleraceaeacephala*) grown on Andisol soil. Vol 205: International conference on Agribusiness, food and Agro-Technology in Earth and Environmental Science. Conference Series: pp. 1315-1755.

Redda, A., & Kebede, F. (2017). Effects of integrated use of organic and inorganic fertilizers on soil properties performance, using rice (*Oryza sativa* L.) as an indicator crop in Tselemti district of north-western Tigray, Ethiopia. *International Research Journal of Agricultural Science and Technology*, *1*(1), 6-14.

Reddy, T. P., Lakshmi, D. V., Kamalakar, J., & Rao, C. S. (2017). Critical levels of micro and secondary Nutrients in soils and crops for optimum plant nutrition. *International Journal of Scientific Research,* 6(5), 594-595.

Roba, T. (2018). Review on the effect of mixing organic and Inorganic fertilizer on productivity and soil fertility. *Open Access Library Journal,* 5, e4618.

Sadiq, S., & Modi, S. (2021). Effects of organic manures and inorganic fertilizers on growth, yield and shelf life of tomato (*Lycopersicon esculentum* Mill*.)*. *International Journal on Environmental Sciences*, 12(1), 9-11.

Sharma, R., Kandel, S., Khadka, S., & Chaudhary, S. (2022). Nutrient contents of different sources of organic manures of different farms in Bhaktapur district of Nepal. *Journal of Agriculture and Natural Resources*, *5*(1), 150-156.

Sileshi, M., Kadigi, R., Mutabazi, K., Sieber, S. (2019). Determination for adoption of physical soil and water conservation measures by small holder farmers in Ethiopia. *International Soil Water Conservation Research,* 7(4), 354-361.

Vanlauwe, B., Abdelgadil, A. H., Adewopo, J., Adjei-Nsiah, S., Ampadu-Boakye, T., Asare, B., & Mutsaers, H. J. W. (2017). Looking back and moving forward: 50 years of soil fertility management research in Sub-saharan Africa. *International Journal of Agricultural Sustainability,15*(6), 613-631.

Walia, M. K., Walia, S. S., & Dhaliwal, S. S. (2010). Long-term effect of integrated nutrient management of properties of Typic Ustochrept after 23 cycles of an irrigated rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) system. *Journal of Sustainable Agriculture*, *34*(7), 724-743.

Wang, C., Zhou, X., Guo, D., Zhao, J., Yan, L., & Zhao, L. (2019). Soil pH is the primary factor deriving the distribution and function of microorganisms in farmland soils in Northeastern China. *Journal of Microbiology, 69*(13), 1-13.