Performance, Some Nutrient Elements and Heavy Metals Accumulation in Tomato under Soil Applied Poultry Manure, NPK and ZnSO4 Fertilizers

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Performance, Some Nutrient Elements and Heavy Metals Accumulation in Tomato under Soil Applied Poultry Manure, NPK and $ZnSO_4$ Fertilizers

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Summary

Two field experiments were carried out in 2015 and 2016 cropping seasons at the Teaching and Research Farm of Landmark University, Omu-Aran, Kwara state. The aim was to determine the effect of single and integrated application of poultry manure (PM), NPK and $ZnSO_4$ fertilizers on the agronomic performance, yield, some nutrient elements and heavy metal content of tomato (*Lycopersicon esculentum* Mill) in the derived savannah ecological zone of Nigeria. Treatments consisted of: 150 kg ha^{-1} NPK + 15 t ha^{-1} PM + 5 kgha^{-1} Zn (T_1); 150 kg ha^{-1} NPK + 15 t ha^{-1} PM (T_2); 15 t ha^{-1} PM + 5 kg ha^{-1} Zn (T_3); 30 t ha^{-1} PM (T_4); 150 kg ha^{-1} NPK + 5 kg ha^{-1} Zn (T_5); 10 kg ha^{-1} Zn (T_6); 300 kg ha^{-1} NPK (T_7) and control (T_8). The contribution of integrated application of PM and NPK at lower rates on growth and yield of tomato was high while application of zinc at higher rate (10 kg ha^{-1}) increased the availability of some nutrient elements and heavy metals of tomato fruits though not beyond the permissible limits as established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) to ensure food safety of the consumers. It can therefore be concluded that application of 150 kg ha^{-1} NPK + 15 t ha^{-1} PM + 10 Kg ha^{-1} Zn is beneficial for tomato production in the study area without any threat to human health.

Key words

Lycopersicon esculentum, $ZnSO_4$ fertilizer, poultry manure, NPK fertilizer, quality

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Introduction

Tomato (*Lycopersicon esculentum* Mill) is an important vegetable crop in the world which belongs to the family Solanaceae. It can be eaten fresh or in many other processed forms. Tomato is cultivated throughout tropical Africa, South America and southern Italy (Leister and Seck, 2002). Nigeria ranks as the second highest producer of tomatoes in Africa (FAO, 2011). Most tomatoes grown in West Africa are local cultivars whose resistance to diseases is usually good (Onwueme, 1989).

Tomato is grown in all types of soils on a small scale for family use and on a commercial scale as a cash crop by the vegetable growers. Tomato is a heavy yielder and hence, requires adequate fertilizer for growth and yield (Pandey and Chandra, 2013). Decreasing soil nutrient quality and rising cost of inputs, especially fertilizer, plague tomato production in Nigeria, resulting in the dwindling yields of tomato plants in the Country (Ogunwole et al., 2006).

NPK fertilizer application sustains soil fertility and crop production (Uyovbisere et al., 2000). Recent studies have shown that the use of commercial fertilizers in Nigeria for crop production is limited by their scarcity and high cost (Akanbi et al., 2001). In addition to being expensive and scarce, the use of inorganic fertilizer has not been helpful in intensive agriculture because it is often associated with reduced crop yield, soil acidity and nutrient imbalance (Agbede et al., 2008).

The need to use renewable forms of energy and reduce costs of fertilizing crops has revived the use of organic fertilizers worldwide (Ayoola and Adeniyan, 2006). Poultry manure is a source of organic manure from livestock that enriches the soil; it does not only increase the nutrient status of the soil but improves the structure (Odiete and Ogunmoye, 2005). Poultry manure should be managed for its nitrogen (N) value (Uyovbisere et al., 2000). Poultry manure may have higher values for phosphorous (P) and potassium (K) (Harty et al., 1992). About 70% of N in poultry manure can be available to the crop during the first year of application (Zublena et al., 1997).

Application of manure supplies the required nutrients, improves soil structure, water holding capacity, porosity, bulk density, moisture retention, increases microbial population and maintains crop quality (Adeleye et al., 2010). Despite the large quantities of plant nutrients contained in synthetic fertilizers, compared to organic nutrients, the presence of growth promoting agents in organic fertilizers make them important in enhancing soil fertility and productivity (Sanwal et al., 2007). High and sustained crop yield can be obtained with judicious and balanced NPK fertilization combined with organic matter amendment (Osundare, 2004).

The soil acts as a long-term sink for heavy metals, which can have residence times ranging from hundreds to thousands of years depending on the element and the properties of the soil (Alloway, 1995). The major routes of heavy metal inputs to agricultural soils include atmospheric deposition, sewage sludge, animal manures, agrochemicals and inorganic fertilisers (Nicholson et al., 1998). Livestock manures contain a considerable amount of heavy metal; increasing interest in the recycling of manure as soil amendments has now raised concern about possible metal contamination from its use (Eneji et al., 2003).

Zinc (Zn) deficiency is wide spread all over the world and adversely affects human health due to its low intake in our diet. This can be overcome by using food having high content of Zn (Kutman et al., 2010). Zinc plays an important role as metal component of different enzymes (Marschner, 1995). It is essential trace element in various functions of the plant, increases the rate of chlorophyll, antioxidant, enzymes and it is essential component of many proteins (Sbartai et al., 2011). Zinc also helps in various metabolic processes; its deficiency inhibits growth and development of plants (Cakmak et al., 1999).

For the expansion and increased production of quality tomato in Nigeria, there is the need to increase the fertility status of the soil in order to meet up with the nutrient requirements of the soil and that of the plant. Therefore, integrated use of organic and inorganic fertilizer helps to provide and increase the needed nutrient in the soil for increased productivity and quality of tomato in the country without posing any threat to human health. The objective of the study was to determine the performance, nutrient elements and some heavy metals composition of tomato under soil applied sole and combined application of poultry manure, zinc and NPK fertilizers.

Materials and Methods

The experiments were conducted in 2015 and 2016 cropping seasons at the Teaching and Research farm of Landmark University Omu-Aran, Kwara state (Latitude 8° 8' N and Longitude 5° 6' E) located in the derived savannah ecological zone of Nigeria. It has an annual rainfall pattern which extends between the months of April and October with average annual rainfall of between 600 mm-1500 mm. The peak rainfall is in May-June and September - October while the dry season is between November and March.

Two levels of poultry manure (15 and 30 t ha^{-1}), two levels of Zn (5 and 10 kg ha^{-1}) and two levels of NPK fertilizer (150 and 300 kg ha^{-1}) that were combined and tested as follows: 150 kg ha^{-1} NPK + 15 t ha^{-1} PM + 5 kg ha^{-1} Zn (T_1); 150 kg ha^{-1} NPK + 15 t ha^{-1} PM (T_2); 15 t ha^{-1} PM + 5 kg ha^{-1} Zn (T_3); 30 t ha^{-1} PM (T_4); 150 kg ha^{-1} NPK + 5 kg ha^{-1} Zn (T_5); 10 kg ha^{-1} Zn (T_6); 300 kg ha^{-1} NPK (T_7) and control (T_8). The treatments were arranged in Randomized Complete Block Design (RCBD) and each treatment was replicated four times. Poultry manure for the two years study was collected from the poultry house of Landmark University, Omu-Aran while NPK and Zinc sulphate ($ZnSO_4$) fertilizers were purchased from the local market.

Poultry manure which is an organic amendment was applied two weeks before transplanting to give room for mineralization, while the inorganic fertilizers (NPK and $ZnSO_4$) were applied two weeks after transplanting based on the experimental layout.

Mechanical land preparation was adopted using tractor drawn disc plough and harrow. The land was ploughed once and harrowed twice to give a well pulverized soil after which 1.5 m x 2 m bed size with height of about 0.2 m was made to represent a plot.

The size of each plot in the experiment was 1.5 m x 2 m = 3 m^2 and there were eight plots per replicate (3 m^2 x 8 = 24 m^2) that were replicated four times. The size of the whole experimental plot was 24 m^2 x 4 = 96 m^2.

The tomato variety used for the experiment was the local variety commonly grown in Omu-Aran (study area) whose resistance to diseases is usually good. The seeds were pre-germinated in a covered and protected nursery using a germinating tray and sterilized soil as the germinating media for 21 days. Eight healthy seedlings were then transplanted in each bed at intra and inter-row spacing of 0.5 m x 1 m and they were watered once daily until they stabilize. At the nursery stage, seedlings were irrigated to field capacity on daily basis after germination while the remaining part of the experiments depends solely on rainfed. Weed control was done manually by using hand hoe. Ripe fruits of tomato were harvested at five days' intervals, counted and weighed based on treatments and the values were recorded.

The following vegetative parameters were collected from the five tagged plants per plot at flowering - plant height measured with the aid of meter rule, number of leaves and number of branches by physical counting. Number of fruits was also done by physical counting while weight of harvested ripe fruits was carried out with the aid of automated weighing balance of maximum capacity 2100 g, readable at 0.01 g and a model of OHAUS Corporation, USA.

Laboratory analysis of poultry manure

The nutrient composition of powdered poultry manure was determined after ashing in the muffle furnace. Total N was determined by Kjedahl method. For other nutrients, ground samples were subjected to wet digestion using 25 – 5-5 ml of HNO_3 – H_2SO_4 – $HClO_4$ acids (AOAC, 2003). The filtrate was used for nutrients determination as done in routine soil analysis. Total P was determined by colorimeter, K by flame photometer and Ca, Mg and micronutrients by atomic absorption spectrophotometer (AAS).

Pre-cropping soil samples were randomly collected at a depth of 0 – 0.15 m from each plot and bulked together to make a composite soil for determination of particle-size and chemical analysis. Particle-size analysis was done using the hydrometer method (Gee and Or, 2002). Sample pH was determined by using a soil–water medium at a ratio of 1:2 using Jenway digital electronic pH meter model 3520 (Ibitoye, 2006). The soil samples collected were air dried, ground, and sieved through a 2 mm sieve. The sieved soil samples were taken to the laboratory for chemical analysis as described by Carter (1993). Soil organic carbon (OC) was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). Organic matter was deduced by multiplying OC by 1.724. Total N was determined by the micro-Kjeldahl digestion method (Bremner, 1996). Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry. Exchangeable K, Ca, Na Zn and Mg were extracted using 1M ammonium acetate (Hendershot and Lalande, 1993). Thereafter, K level was determined on a flame photometer, and Ca and Mg were determined by EDTA titration method. Soil pH was determined using a soil-water medium at a ratio of 1:2 with a digital electronic pH meter.

Three representative fruit samples were taken per plot and per replicate to analyze for nutrient elements and some heavy metals at the Crop and Soil Laboratory of Landmark University, Omu-Aran, Kwara State. Ripe fresh fruits of tomato were collected, oven-dried for 24 h at 80°C and ground in a Willey mill. Mineral elements of tomato fruits were determined according to methods recommended by the Association of Official Analytical Chemists (AOAC, 2003). One gram of each sample was digested using 12 cm^{-3} of the mix of HNO_3, H_2SO_4 and $HClO_4$ (7:2:1 v/v/v). Contents of P, K, Ca and Mg were determined by atomic absorption spectrophotometer

Dry ashing of the fruit samples collected were carried out by the procedure as described by Chapman and Pratt (1961). One gram of the portion of each fruit sample was weighed into a 50 ml porcelain crucible and gently placed into the muffle furnace and temperature was gradually increased to 550°C for about five hours during which the muffle furnace was shut, after five hours the furnace was gently opened to allow for rapid cooling before carefully taking out the porcelain crucibles. The cooled ash was dissolved in 5 ml portion of 2 N hydrochloric acid (HCl) and mixed thoroughly with a plastic rod for 15 minutes. Then it was mixed with 50 ml of distilled water and allowed to stand for 30 minutes before using the supernatant (or filter through Whatman No. 42 filter paper) discarding the first portions of filtrates, the aliquots were used to analyze for the heavy metals (Cd, Pb, Cu and Zn) using the Atomic absorption spectrometry (AAS) as described in the methods of Association of Official Analytical Chemists (AOAC, 2003). Heavy metals (Cd, Pb, Cu and Zn) were calculated using:

$$Heavy\ metals\ (mg\ kg^{-1}) = \frac{Titre\ value\ from\ machine \times Molar\ mass}{Molar\ mass}$$

Data collected were subjected to statistical analysis of variance (ANOVA) using Statistical Analysis Software (S.A.S, Institute Inc. 2000). The significant treatment means were compared using least significant difference (LSD) at 0.05 level of probability.

Results

Initial Soil Properties

The pre-planting soil analysis for 2015 and 2016 are as shown in Table 1. The pH of the soil was strongly acidic, the nitrogen content was very low, the available phosphorus was high, and the exchangeable K was moderate while the exchangeable Na, Ca, and Mg were all suitable. The organic matter content of the soil was also adequate. The soils are high in sand with relatively low values in both silt and clay; hence the textural class Sandy loam.

Table 1. Soil physical and chemical properties prior planting (0-15 cm) in 2015 and 2016 cropping seasons

Parameter	2015	2016
Sand %	76.12 ± 0.55	76.00 ± 1.15
Silt %	12.00 ± 0.42	12.08 ± 0.49
Clay %	11.88 ± 0.63	11.92 ± 0.78
Textural class	Sandy loam	Sandy loam
pH (H_2O)	5.25 ± 0.18	5.20 ± 0.20
Total nitrogen	0.16 ± 0.01	0.17 ± 0.01
Organic carbon	3.24 ± 0.17	3.36 ± 0.08
Exchangeable bases		
K (cmol/kg)	0.23 ± 0.02	0.23 ± 0.02
Na (cmol/kg)	0.66 ± 0.02	0.67 ± 0.02
Ca (cmol/kg)	3.97 ± 0.28	3.99 ± 0.25
Mg (cmol/kg)	1.32 ± 0.02	1.33 ± 0.05
Al+H (cmol/kg)	0.07 ± 0.01	0.07 ± 0.001
ECEC (cmol/kg)	6.25 ± 0.10	6.29 ± 0.06
Available phosphorus (mg/kg)	21.1 ± 0.46	21.2 ± 0.65
Zn (mg/kg)	0.45 ± 0.012	0.47 ± 0.05

Chemical composition of poultry manure

Laboratory analysis of poultry manure revealed that it contained adequate amount of nutrient elements suitable for plant growth and development (Table 2).

Mean effect of application of poultry manure, NPK and zinc fertilizers on plant height (cm), number of branches and number of leaves of tomato in 2015 and 2016 cropping seasons

Table 2. Chemical composition of poultry manure

Nutrient (%)	Values
Organic carbon	21.6 ± 0.66
Nitrogen	2.88 ± 0.19
C/N	7.50 ± 0.12
Phosphorus	1.30 ± 0.13
Potassium	1.67 ± 0.03
Calcium	0.83 ± 0.03
Magnesium	0.54 ± 0.02
Copper	0.29 ± 0.01
Manganese	0.21 ± 0.01
Zinc	0.23 ± 0.01

Table 3 shows the mean effect of sole and combined application of poultry manure, NPK and zinc fertilizers on the vegetative parameters of tomato in 2015 and 2016 cropping seasons. Application of 150 kg ha^{-1} NPK + 15 t ha^{-1} PM + 5 Kg ha^{-1} Zn (T_1) significantly increased plant height, though the effect was statistically similar with the applications of 150 kg ha^{-1} NPK + 15 t ha^{-1} PM (T_2), 150 kg ha^{-1} NPK + 5 kg ha^{-1} Zn (T_5), 15 t ha^{-1} PM + 5 kg ha^{-1} Zn (T_3) and 30 t ha^{-1} PM (T_4).

The effect of application of 15 t ha^{-1} PM + 5 kg ha^{-1} Zn (T_3) significantly increased number of branches and number of leaves of tomato the values of which were statistically similar when 30 t ha^{-1} PM (T_4), 150 kg ha^{-1} NPK + 15 t ha^{-1} PM (T_2) and 150 kg ha^{-1} NPK + 15 t ha^{-1} PM + 5 kg ha^{-1} Zn (T_1) were applied. The least value for all the vegetative parameters was observed with the control and the values were statistically similar to the values obtained when 10 kg ha^{-1} Zn and 300 kg ha^{-1} NPK were applied.

Mean effect of application of poultry manure, NPK and zinc fertilizers on yield parameters of tomato in 2015 and 2016 cropping seasons

The effects of sole and combined application of poultry manure, NPK and zinc fertilizers on the yield parameters of tomato in 2015 and 2016 cropping seasons is as shown in Table 4. Relative to the control and application of 10 kg/ha Zn which gave lower values for all the yield parameters, sole and combined application of organic and inorganic fertilizers significantly increased values for number of fruits per plot, fruit yield per plot and fruit yield (t ha^{-1}). Higher value was observed at application of 150 kg ha^{-1} NPK + 15 t ha^{-1} PM + 5 kg ha^{-1} Zn for all the yield parameters, though the values were statistically similar with the values obtained with the application of 150 kg ha^{-1} NPK + 15 t ha^{-1} PM, 15 t ha^{-1} PM + 5 kg ha^{-1} Zn and 30 t ha^{-1} PM. Values obtained for yield per plot and yield per ha when 300 kg ha^{-1} NPK and 30 t ha^{-1} PM were applied, were also statistically similar.

Mean effect of application of poultry manure, NPK and zinc fertilizers on some mineral composition (Calcium, Magnesium, Potassium and Phosphorus) of tomato fruits in 2015 and 2016 cropping seasons

Data presented in Table 5 showed that application of 10 kg ha^{-1} Zn increased Ca and Mg content of tomato fruit. However, the difference was not significant regarding Mg content when 5 kg ha^{-1} Zn was applied in combination with varying levels of poultry manure and NPK fertilizers. Significantly lower values for Ca and Mg were observed on the control.

Table 3. Mean effect of application of poultry manure, NPK and zinc fertilizers on plant height (cm), number of branches and number of leaves of tomato in 2015 and 2016 cropping seasons

Treatment	Vegetative growth		
	Plant height (cm)	Number of branches	Number of leaves
150 kg NPK + 15 t PM + 5 Kg Zn (T_1)	100.87	16.35	41.50
150 kg NPK + 15 t PM (T_2)	88.37	18.80	43.18
15 t PM + 5 kg Zn (T_3)	90.80	20.63	60.56
30 t PM (T_4)	85.10	16.33	47.66
150 kg NPK + 5 kg Zn (T_5)	92.20	15.30	37.80
10 kg Zn (T_6)	56.50	7.42	21.00
300 kg NPK (T_7)	66.43	8.33	25.00
Control (T_8)	53.67	5.60	16.00
$LSD_{(0.05)}$	12.55	1.83	18.68

Table 4. Mean effect of application of poultry manure, NPK and zinc fertilizers on number of fruits/plot, fruit yield (kg plot^{-1}) and fruits yield (t ha^{-1}) in 2015 and 2016 cropping seasons

Treatments	Yield parameters		
	Number of fruits/plot	Fruit yield (kg plot^{-1})	Fruit yield (t ha^{-1})
150 kg NPK + 15 t PM + 5 Kg Zn (T_1)	56.67	5.11	12.77
150 kg NPK + 15 t PM (T_2)	52.00	4.80	12.25
15 t PM + 5 kg Zn (T_3)	54.00	4.97	12.43
30 t PM (T_4)	41.67	4.25	11.61
150 kg NPK + 5 kg Zn (T_5)	45.65	4.69	11.72
10 kg Zn (T_6)	13.33	1.80	4.35
300 kg NPK (T_7)	30.33	4.21	11.33
Control (T_8)	10.40	1.51	3.87
$LSD_{(0.05)}$	4.60	0.42	0.52

Table 5. Mean effects of application of poultry manure, NPK and zinc fertilizers on some mineral composition of tomato fruits in 2015 and 2016 cropping seasons

Treatments	Mineral elements (mg kg^{-1})			
	Calcium	Magnesium	Potassium	Phosphorus
150 kg NPK+ 15 t PM + 5 Kg Zn (T_1)	1.30	2.82	2.85	1.64
150 kg NPK+ 15 t PM (T_2)	0.87	2.12	2.65	1.84
15 t PM + 5 kg Zn (T_3)	1.41	2.80	2.37	1.58
30 t PM (T_4)	0.80	2.00	2.35	1.95
150 kg NPK + 5 kg Zn (T_5)	1.23	2.76	2.35	1.60
10 kg Zn (T_6)	1.61	2.88	1.60	0.58
300 kg NPK (T_7)	0.85	1.21	2.58	1.90
Control (T_8)	0.34	1.10	1.20	0.45
$LSD_{(0.05)}$	0.20	0.12	0.45	0.36

Table 6. Effects of application of poultry manure, NPK and Zinc fertilizers on some heavy metals accumulation in tomato fruits in 2015 and 2016 cropping seasons

Treatment	Heavy metals (mg kg^{-1})			
	Copper	Lead	Cadmium	Zinc
150 kg NPK+ 15 t PM + 5 Kg Zn (T_1)	0.14	0.020	0.066	0.17
150 kg NPK+ 15 t PM (T_2)	0.16	0.060	0.037	0.12
15 t PM + 5 kg Zn (T_3)	0.17	0.090	0.070	0.17
30 t PM (T_4)	0.02	0.020	0.040	0.12
150 kg NPK + 5 kg Zn (T_5)	0.11	0.060	0.066	0.16
10 kg Zn (T_6)	0.11	0.060	0.073	0.20
300 kg NPK (T_7)	0.13	0.080	0.034	0.12
Control (T_8)	0.03	0.012	0.040	0.13
$LSD_{(0.05)}$	0.01	0.03	Ns	0.02
FAO/WHO Limit	40.00	0.30	0.20	99.4

Relative to the control and application of 10 kg ha^{-1} Zn, which gave statistically lower but similar values for K in the fruit, application of poultry manure and NPK fertilizer either as sole or in combination with each other significantly increased values for K present in the fruit. though the values were not statistically different when varying levels of zinc fertilizer were applied.

In a similar vein, P content of tomato fruits increased with application of poultry manure and NPK fertilizer, however, the difference was not significant with the application of other treatments where zinc fertilizer was applied except at the control and 10 kg ha^{-1} Zn where the values were significantly lower.

Mean effect of application of poultry manure, NPK and zinc fertilizers on some heavy metals (Copper, Lead, Cadmium and Zinc) accumulation in tomato fruits in 2015 and 2016 cropping seasons

The effect of the treatments on the accumulation of some heavy metals in the fruits in 2015 and 2016 cropping seasons is as shown in Table 6. Application of all the treatments resulted in varying levels of heavy metals accumulation in tomato fruits. Increasing levels of zinc fertilizer significantly increased zinc content of tomato fruits.

Compared with the recommended limits established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) to ensure food safety of the consumers, values of all heavy metals detected in the tomato fruits as a result of application of poultry manure, NPK and zinc fertilizers were all below the recommended limits.

Discussion

Response of tomato to application of poultry manure, NPK and $ZnSO_4$ fertilizers in the present study could be attributed to the inherent physical and chemical properties of the experimental soil. The result of the analysis of the initial physical and chemical properties of the experimental soil indicated that the nutrient status of the soil was low except phosphorus which was high. The poor fertility status may be attributed to the nature and continuous cropping of the soil over the years.

Vegetative parameters increased with combined application of PM, NPK and Zn when compared with sole application of 10 kg ha^{-1} Zn, 300 kg ha^{-1} NPK and the control. Animal manures have been shown to supply required plant nutrients, improve soil structure and water holding capacity, increase microbial population, and promote plant growth (Dauda et al., 2008).

Positive response of tomato to application of PM in this study could be attributed to the better soil physical conditions by increasing soil organic matter and availability of both macro- and micro-nutrients in its composition. Organic matter can improve soil structure and aeration, reduce soil bulk density, enhance water infiltration and retention, and increase microbial populations (Atakora et al., 2014). Oladotun (2002) also reported that poultry manure contains macro- and micro-nutrients such as N, P, K, S, Ca, Mg, Cu, Mn, Zn, Bo and Fe.

Chemical fertilizers have been claimed as the most important contributor to the increase in world agricultural productivity over the past decades (Smil, 2001). Increase in vegetative parameters as a result of application of NPK fertilizer could be due to fact that they are made up of nutrient in their mineralized form that are readily available for plant absorption. A similar finding was by Ayoola and Adeniyan (2006) where they reported that nutrients from mineral fertilizers enhance the establishment of crops.

Zinc helps in various metabolic processes; its deficiency inhibits its growth and development of plants (Cakmak et al., 1999). The result of this study also revealed that combined application of Zn fertilizer with PM and NPK fertilizer resulted in non significant increase in the vegetative parameters of tomato. The increase in the vegetative parameters could be as a result of the role of Zn in photosynthesis by increasing the amount of chlorophyll in the leaves. The poor vegetative growth in the control plots and when sole 10 kg ha^{-1} Zn was applied could be attributed to low fertility status of soil before the commencement of the experiments.

Integrated soil fertility management (ISFM) advocates the combined use of organic and inorganic of sources; thereby, exploiting the potential of positive interactions between both inputs (Vanlauwe et al., 2002) but efficient use and often low and/or unstable producer prices, limits farmers interest in fertilizer use (IFDC, 2005).

Poultry manure becomes more efficient when combined with other mineral fertilizer (Murwira, 1995). The result of the experiments also revealed that there was relative increase in the yield of tomato under combined application of PM and NPK fertilizer. Higher yield response of tomato might be due to the complimentary roles of organic and inorganic fertilizers in improving crop yield. This result is in agreement with the findings of Woomer and Muchana (2006) that the enhanced performance of combined application when compared to poultry manure or NPK fertilizer alone could be attributed to release of plant nutrient elements and organic matter addition.

There was a reduction in the growth and yield of tomato when 30 t ha^{-1} PM and 300 kg ha^{-1} NPK were applied. The application of 30 t ha^{-1} PM and 300 kg ha^{-1} NPK might have impaired with the nutrient uptake ability leading to reduced growth and yield of tomato. It could also be attributed to soil acidity that reduces the pH of the soil. This observation is in agreement with that of Ewulo et al. (2008) where they found that excess N in the soil and soil acidity could cause nutrient imbalance in tomato crop and a reduction in the uptake of certain nutrients.

Combined application of poultry manure, NPK and Zn fertilizer significantly increase the vegetative parameters and yield of tomato. This could be attributed to the fact that uptake of some nutrients (NPK) are facilitated by the application of zinc fertilizer. Gurmani et al. (2012) found that application of Zn significantly increased the dry biomass, fruit yield, fruit fresh weight and numbers of fruits per plant in the tomato, the highest increase was found with 10 kg ha^{-1} Zn. Agrawal et al. (2010) found that Zn fertilizer increases the uptake of NPK, copper and iron when it is applied at the rate of 10 kg ha^{-1}.

Increase in yield and yield parameters of tomato could also be attributed to better vegetative growth, more photosynthesis as well as better utilization capacity of available nutrients by the tomato in soil applied Zn. It could also be due to influence of Zn in increasing metabolism, biosynthesis of auxins and better nutrient uptake (Cakmak, 1999).

Zinc deficiency is wide spread all over the world and adversely affects human health due to its low intake in our diet. It is the fifth major factor affecting human health in developing countries (Anthony et al., 2002). This can be overcome by using food having high content of Zn (Kutman et al., 2010). The result of this research work indicated that application of 10 kg ha^{-1} Zn increased Ca and Mg content of tomato fruits. This could be attributed to the effect of Zn in increasing the availability and uptake of some nutrients. Singh and Singh (2004) reported that Zn application increased chlorophyll content and raised the concentration of Zn, Ca, Mg, K and P in tissues. Increase in Ca and Mg content of tomato fruit could also be attributed to the effect of applied P present in both PM and NPK fertilizer which facilitated root formation and growth thereby enhancing nutrient uptake. This is similar to the findings of Borkert and Barber (1985) where they found that applied P increases root growth and may have contributed to enhanced Mg uptake.

Poultry litter contains notable amounts of heavy metals (As, Cd, Cu, Mn, Pb and Zn) which may vary depending on poultry production and management practices (Kunkle et al., 1981). Heavy metals are conventionally defined as elements with metallic properties and an atomic number >20. Some of these metals are micronutrients necessary for plant growth, such as Zn, Cu, Mn, Ni and Co, while others have unknown biological function, such as Cd, Pb and Hg (Gaur and Adholeya, 2004). The findings of this study also revealed that application of zinc, poultry manure and NPK fertilizer at all rates did not increase the accumulation of some heavy metals in the tomato fruits.

Conclusion

Results of this study showed that application of poultry manure, NPK and $ZnSO_4$ fertilizers applied singly proved less effective when compared to their combined application. Combined application of poultry manure and NPK fertilizer improved both the vegetative growth and fruit yield of tomato. Also application of 5 kg ha^{-1} Zn fertilizer increased yield and the availability of some nutrients and heavy metals in tomato fruits, however application 10 Kg ha^{-1} Zn had shown to be more effective in providing qualitative parameters to tomato fruits without increasing the levels of heavy metals beyond the recommended limits as established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA)to ensure food safety of the consumers, hence, for better productivity and good quality tomato in the study area, combined application of 150 kg ha^{-1} NPK + 15 t ha^{-1} PM + 10 kg ha^{-1} Zn is recommended for its large scale production as it is economical without any threat to human health.

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