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FULL LENGTH ARTICLE

Effect of methods and time of poultry manure application on soil and leaf nutrient concentrations, growth and fruit yield of tomato (*Lycopersicon esculentum* Mill)

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Abstract In order to obtain maximum economic value of plant nutrients in poultry manure and increase in tomato yield, field experiments were conducted at Owo, southwest Nigeria, during 2012 and 2013 early cropping seasons to study the effect of two methods (broadcasting on the soil surface and the incorporated) and four times (3 weeks before transplanting (3 WBTP), 0 week at transplanting (0 WATP), 3 weeks after transplanting (3 WATP), and 6 weeks after transplanting (6 WATP) of poultry manure (PM)) applications on soil chemical properties, leaf nutrient concentrations, growth and yield of tomato. The eight treatments were factorially arranged in a randomized block design with 3 replications. Results showed that PM incorporated into the soil produced higher soil organic matter and soil and leaf N, P, K, Ca, Mg, growth and yield (0.9 t ha^{-1}) of tomato compared with broadcast method. Also PM applied at 3 WBTP had higher leaf nutrient concentrations and better growth and yield of tomato compared with 0 WATP, 3 WATP and 6 WATP. The higher yield of 3 WBTP was adduced to better synchrony between crop demand and nutrient supply. Using the mean of the two years, 3 WBTP increased tomato fruit yield by 4.0, 2.8 and 1.5 t ha^{-1} compared with 6 WATP, 3 WATP and 0 WATP, respectively. This yield difference can be economical on large scale tomato production. Therefore application of PM at 3 WBTP with incorporated method is recommended for tomato cultivation in the forest-savanna transition zone of southwest Nigeria.

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1. Introduction

Tomato (*Lycopersicon esculentum* Mill) belongs to the family Solanaceae and is one of the most widely eaten vegetables in the world because they can be eaten fresh or in many other

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processed forms. As far as global vegetable production is concerned, tomato is the most popular and third most consumed vegetable in the world next to potato and sweet potato (FAO, 2002). It consists of minerals and antioxidants such as lycopene and vitamin C which are essential for human health (Kallo, 1993; Clinton, 1998; Kanr et al., 2002). Lycopene, the most important antioxidant has been linked with reduced risk of prostrate and various other forms of cancer as well as heart diseases (Barber and Barber, 2002). 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). Although chemical fertilizers have been claimed as the most important contributor to the increase in world agricultural productivity over the past decades (Smil, 2001), the negative effects of chemical fertilizer on the soil and environment limit its usage in sustainable agricultural system (Peyvast et al., 2003). Research comparing soils of organically and chemically managed farming systems has recognized that higher soil organic matter and total N with the use of organic agriculture (Alvarez et al., 1988; Drinkwater et al., 1995). Organic material such as poultry manure is identified as a suitable organic fertilizer. Poultry manure, if properly handled is the most valuable of all animal manures. The use of poultry manure for soil fertility maintenance, growth and yield of tomato had been reported (Adekiya and Agbede, 2009; Akanni and Ojeniyi, 2007; Ewulo et al., 2008). However, inappropriate use of poultry manure can greatly reduce manure efficiency and negatively affect productivity of the soil. Also to obtain maximum economic value of plant nutrients in poultry manure it should be applied to match nutrient need of crops (Ozores-Hampton, 2012). The demand of nutrients by growing crop generally varies through the growing season, with the highest uptake associated with the period of most rapid growth. Timing of nutrient application, therefore, ensures the availability of the nutrients when the crop needs them. This will also avoid nutrient losses which can be before and after periods of crop demand which in the long run result in wastage of resources (Ndukwe et al., 2011). This aspect of manure management has not been investigated for tomato. An important part of optimizing crop response to a fertilizer nutrient is placing the nutrient in such a way that it provides rapid uptake by crop and reduces potential losses (Steward, 2006). Manure application to the soil surface may not be as effective as incorporated manure because of potential N loss (Eghball and Power, 1999). Various experiments have shown that decomposed poultry manure is the best for tomato cultivation but the method of placement and time of application are yet to be investigated. Therefore the objective of this work was to determine the effects of method and time of poultry manure application on soil chemical properties, leaf nutrient concentrations, growth and yield of tomato.

2. Material and methods

2.1. Site description and treatments

Trials were carried out at Owo (Latitude 7°12′N and Longitude 5°32′E) in Ondo State, southwest Nigeria, during the early cropping seasons of 2012 and 2013 growing seasons. The soil at Owo is an Alfisol and is classified as Oxic Tropudalf (Soil Survey Staff, 2010) or Luvisol (FAO, 1998) derived from quartzite, gneiss and schist (Agbede, 2006). The average rainfall varied from 1000 to 1240 mm. Owo has a bimodal rainfall pattern with first season commencing from March to July with dry spell in August followed by the second season from September to November. The site in 2012 was cleared from a year fallow after 2 years of maize cropping. The soil adjacent to the site was used for 2013 experiment.

The experiment on each year consisted of 2 × 4 factorial combinations of two methods: broadcasting (the poultry manure was uniformly spread over the surface of the experimental plot) and the incorporated (the poultry manure was buried into the soil) and four times of application of poultry manure: 3 weeks before planting = poultry manure applied to the soil at 3 weeks before transplanting tomato (3 WBTP), 0 week at planting = poultry manure applied to tomato at transplanting (0 WATP), 3 weeks after planting = poultry manure applied to the soil at 3 weeks after transplanting tomato (3 WATP) and 6 weeks after planting = poultry manure applied to the soil at 6 weeks after transplanting tomato (6 WATP). The poultry manure was applied at the rate of 30 t ha^{-1} to appropriate plots. The eight treatments were factorially arranged in a randomized complete block design with 3 replications. Each block comprised of 8 plots, each of which was 3 × 4 m. Blocks were 1 m apart and plots were 0.5 m apart. Adjacent soil (soil beside the first experimental site) was used for the second trial in 2013 with same experimental layout.

2.2. Land preparation, planting of tomato and application of poultry manure

The experimental plot was ploughed and harrowed once with a tractor after which a uniform rate of 30 t ha^{-1} poultry manure was applied (Adekiya and Agbede, 2009). Three weeks old local variety of tomato seedlings was transplanted to the field at a spacing of 1 × 1 m in April for years 2012 and 2013. Poultry manure at 30 t ha^{-1} was applied accordingly, viz: broadcasting and incorporated at 3 WBTP, 0 WATP, 3 WATP, 6 WATP. Weeding was done manually with hoe 3 times throughout the experiment each year.

2.3. Determination of soil properties

Prior to the commencement of the experiment in 2012 and 2013, soil samples were taken from 0 to 15 cm depths from each site. The soil samples were also bulked, air-dried and sieved using a 2 mm sieve and analyzed for particle-size, soil organic matter, total N, available P, exchangeable K, Ca and Mg, and pH. At the end of the experiment in 2012 and 2013, soil samples were also taken for routine soil analysis on plot basis. Samples were analyzed as described by Pansu and Gautheyrou (2006). Particle-size analysis was done using hydrometer method (Gee and Or, 2002). The organic matter was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers, 1996). Total N was determined by micro-Kjeldahl digestion method (Bremner, 1996), and available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank et al., 1998). Exchangeable K, Ca and Mg were extracted using ammonium acetate, Thereafter, K level was analyzed with a flame photometer, and Ca and Mg were determined with an atomic absorption spectrophotometer (Okalebo et al., 2002).

2.4. Leaf analysis

In 2012 and 2013, at mid-flowering stage, leaf samples were collected randomly from each plot. Leaf samples were oven dried for 24 h at 70 °C and ground in a Willey-mill. Leaf N was determined by micro-Kjeldahl digestion method. Samples were dry ashed at 500 °C for 6 h in a furnace and extracted using nitric-perchloric-sulfuric acid mixture for determination of P, K, Ca, and Mg (Tel and Hagarty, 1984). Leaf P was determined using vanadomolybdate colorimetry method, K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method (Horwitz and Latimer, 2005).

2.5. Growth and yield parameters

Ten plants per plot were selected for biweekly determination of plant height as from three weeks after transplanting. Leaf area was determined at the mid-flowering stage of the tomato plant in each plot. The number and weight of the fruits were evaluated between 72 and 90 days after transplanting (Adekiya and Ojeniyi, 2002).

2.6. Statistical analysis

Data collected from each experiment were subjected to analysis of variance (ANOVA), using SAS and Microsoft Office Excel 2007 packages, and treatment means were compared using the Duncan's multiple range test (DMRT) at $p = 0.05$ probability level.

3. Results

The physicochemical properties of soils at the sites of experiment are presented in Table 1. The data indicated that the soils were slightly acidic, sandy loam in texture. The soils were low in organic matter (OM), total N, and exchangeable Ca, but adequate in exchangeable K and Mg. The available P was deficient in 2012 site, but adequate in 2013 site.

Table 1 Initial soil physical and chemical properties of the sites before experimentation.

Soil property	Site 2012	Site 2013
Sand (%)	68	68
Silt (%)	14	14
Clay (%)	18	18
Textural class	Sandy loam	Sandy loam
pH (water)	6.0	6.1
Organic matter (%)	1.27	1.65
Total N (%)	0.10	0.12
Available P (mg kg^{-1})	8.9	12.3
Exchangeable K (cmol kg^{-1})	0.52	0.56
Exchangeable Ca (cmol kg^{-1})	0.38	0.62
Exchangeable Mg (cmol kg^{-1})	0.66	0.71

The effect of methods and time of poultry manure application on soil chemical properties at the end of the experiments in 2012 and 2013 are shown in Table 2. In both years, methods of poultry manure application significantly influenced ($p = 0.05$) soil chemical properties with incorporation of poultry manure having the highest values of soil organic matter, N, P, K, Ca and Mg compared with broadcasting method. Time of application of poultry manure also influenced soil chemical properties significantly. Application of poultry manure at 6 WATP has the highest values and at 3 WBTP has the least values in both years. The order of soil chemical properties among the time of application of poultry manure was 6 WATP > 3 WATP > 0 WATP > 3 WBTP.

Table 3 shows the results of the effect of methods and time of poultry manure application on leaf nutrient concentrations of tomato in 2012 and 2013 cropping seasons. Methods of application of poultry manure influenced leaf N, P, K, Ca and Mg of tomato significantly ($p = 0.05$) with the incorporated method having the highest values. Among times of application of poultry manure, 3 WBTP have the highest values of leaf N, P, K, Ca and Mg while 6 WATP gave the least values. The order was 3 WBTP > 0 WATP > 3 WATP > 6 WATP.

Table 4 shows the results of the effect of methods and time of poultry manure application on the growth and yield of tomato. Methods of application of poultry manure had significant effect on the growth and yield of tomato. Incorporated method has the highest values of tomato plant height, leaf area, number of fruits per plant and fruit weight of tomato. Using the mean of the two years, incorporated method increased yield of tomato by 0.9 t ha^{-1} compared with broadcast method of application of poultry manure. Time of poultry manure application also has significant effect on tomato growth and yield. 3 WBTP gave the highest and 6 WATP produced the least values. Also using the mean values of the two years, 3 WBTP increased tomato fruit yield by 4.0, 2.8 and 1.5 t ha^{-1} compared with 6 WATP, 3 WATP and 0 WATP, respectively. The interactive effect of methods of poultry manure application (M) × time of manure application (T) showed that M × T were significant for plant height, leaf area, number of fruits per plant and fruit weight in both years except for number of fruits per plant that was not significant in 2013.

4. Discussion

The increase in the values of soil organic matter, N, P, K, Ca and Mg concentrations of the soils in incorporated plots compared with broadcast plots can be adduced to rainfall water which might have carried or washed away part of the manure/nutrients on the surface of the soil in broadcast plots thereby reducing the amount of nutrient released (Gana, 2011). Another reason for reduced values of soil nutrients especially N in the broadcast plots is due to volatilization. When exposed, NH_4^+ in manures is highly susceptible to volatilization (Havlin et al., 2005). Jokela and Meisinger (2008) reported that incorporation of manure can reduce losses of NH_3 volatilization by 50 to over 90% compared to surface application. The higher values of soil nutrients in 6 WATP compared to other time of application were due to the fact that plots where poultry manure was applied earlier at 3 WBTP had started and concluded decomposition and mineralization and

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Table 2 Effect of methods and time of poultry manure application on soil chemical properties.

Treatment	Organic matter (%)		N (%)		P (mg kg^{-1})		K (cmol kg^{-1})		Ca (cmol kg^{-1})		Mg (cmol kg^{-1})	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Methods of application												
Incorporated	1.94a	2.37a	0.25a	0.26a	19.5a	26.1a	0.89a	0.95a	0.97a	1.09a	1.21a	1.26a
Broadcast	1.71b	2.13b	0.22b	0.23b	17.1b	22.9b	0.80b	0.82b	0.82b	0.96b	1.06b	1.08b
Time of application												
3 WBTP	1.42d	1.85d	0.15d	0.16d	10.4d	15.3d	0.59d	0.65d	0.47d	0.73d	0.87d	0.89d
0 WATP	1.76c	2.11c	0.20c	0.21c	16.1c	20.1c	0.81c	0.80c	0.94c	1.02c	1.11c	1.13c
3 WATP	2.10b	2.55b	0.26b	0.30b	21.3b	30.2b	0.99b	1.07b	1.14b	1.19b	1.31b	1.37b
6 WATP	2.46a	2.98a	0.34a	0.36a	30.1a	38.7a	1.15a	1.26a	1.33a	1.41a	1.56a	1.64a

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT); 3 WBTP = 3 weeks before transplanting; 0 WATP = 0 week at transplanting (at planting); 3 WATP = 3 weeks after transplanting; 6 WATP = 6 weeks after transplanting.

Table 3 Effect of methods and time of poultry manure application on leaf nutrient concentrations of tomato.

Treatment	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Methods of application										
Incorporated	0.96a	1.14a	0.22a	0.25a	1.79a	1.90a	0.21a	0.35a	0.26a	0.29a
Broadcast	0.80b	1.01b	0.18b	0.19b	1.39b	1.70b	0.18b	0.33b	0.22b	0.25b
Time of application										
3 WBTP	1.29a	1.39a	0.37a	0.41a	2.42a	2.66a	0.35a	0.49a	0.38a	0.41a
0 WATP	1.09b	1.24b	0.25b	0.29b	2.04b	2.10b	0.23b	0.41b	0.29b	0.30b
3 WATP	0.84c	1.08c	0.14c	0.17c	1.61c	1.70c	0.17c	0.34c	0.20c	0.23c
6 WATP	0.62d	0.86d	0.10d	0.13d	1.09d	1.12d	0.12d	0.25d	0.15d	0.20d

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT); 3 WBTP = 3 weeks before transplanting; 0 WATP = 0 week at transplanting (at planting); 3 WATP = 3 weeks after transplanting; 6 WATP = 6 weeks after transplanting.

Table 4 Effect of methods and time of poultry manure application on the growth and yield of tomato.

Treatment	Plant height (m)			Leaf area (m^2)			Number of fruits/plant			Fruit weight (t/ha)		
	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean	2012	2013	Mean
Methods of application												
Incorporated	0.48a	0.61a	0.55	0.46a	0.53a	0.50	16a	16a	16	7.9a	8.3a	8.1
Broadcast	0.37b	0.50b	0.44	0.41b	0.48b	0.45	12b	16a	14	7.1b	7.3b	7.2
Time of application												
3 WBTP	0.81a	0.86a	0.84	0.56a	0.62a	0.49	19a	21a	20	9.6a	10.8a	10.2
0 WATP	0.56b	0.66b	0.61	0.50b	0.54b	0.52	17b	18b	18	8.4b	9.0b	8.7
3 WATP	0.34c	0.51c	0.43	0.40c	0.48c	0.44	15c	15c	15	7.3c	7.4c	7.4
6 WATP	0.28d	0.39d	0.34	0.36d	0.40d	0.38	12d	10d	11	6.2d	6.1d	6.2
M × T	*	*		*	*		*	ns		*	*	

Values followed by similar letters under the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT); 3 WBTP = 3 weeks before transplanting; 0 WATP = 0 week at transplanting (at planting); 3 WATP = 3 weeks after transplanting; 6 WATP = 6 weeks after transplanting; M = Methods of application; T = Time of application; ns = Not significant.
* Significant.

even used up by tomato crop compared with plots where poultry manure was applied at 6 WATP.

The higher values of tomato leaf N, P, K, Ca and Mg concentrations in incorporated plots compared with broadcast plots are consistent with higher presence of N, P, K, Ca, Mg and soil organic matter in their soils. The higher values of leaf nutrient concentrations of tomato due to application of poultry manure at 3 WBTP are adduced to the fact that the nutrients in the poultry manure mineralized first compared with others and nutrients were released to the tomato plants at the right time the plant needs it for its growth and development. To obtain maximum economic values of plant nutrients in animal manure, it should be applied to match nutrient need of a crop (Ozores-Hampton, 2012). As tomato is a short duration crop, about 90 days, poultry manure applied at 6 WATP may not be useful to the plant. It implies that the time of release of the nutrients from the manure, the phenological stage for the need of the nutrients had passed.

The incorporated manure plots compared with broadcast plots have higher plant height, leaf area, number of fruits per plant and fruit weight of tomato. This result is consistent with the soil and leaf nutrient concentrations for this treatment. It suggests that incorporation enhanced earlier mineralization and release of nutrients from the poultry manure, hence their availability for absorption for plant growth. It also showed that poultry manure application method determines tomato growth and fruit yield by influencing nutrient availability and release for plant uptake and growth. Eghball and Power (1999) had earlier reported that manure application to the soil surface may not be as effective as incorporated for crop production, because of potential N loss. In the study by Zake et al. (2000) to compare the effect of four methods of applying coffee husks on soil fertility, root system and yield of banana, it was found that half-incorporated and half on the surface were most effective.

At 3 WBTP the highest values of growth and yield are obtained and at 6 WATP the least values in both years 2012 and 2013 are produced. This is also consistent with the leaf nutrient concentrations for these treatments. This was attributed to the synchrony in the time of availability of sufficient amount of nutrients from poultry manure in the soil proportional with the demand of the plant for uptake. Thus applying poultry manure at 6 WATP is perhaps wastage as the tomato does not have the capacity to use the nutrients in any significant amount at this stage of its growth. This result is corroborated by that of Cassman et al. (2002) who reported that synchrony between crop demand and nutrient supply is necessary to improve nutrient use efficiency and better growth of plants. In this experiment, there was scarce synchrony between soil nutrients and crop demand at 6 WATP treatment. Kolawole (2014) also in an experiment carried out at Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria, reported that poultry manure applied two weeks before planting improved maize grain yield and nutrient uptake compared with poultry manure applied at 2 weeks after planting and at planting.

5. Conclusions

Results showed that poultry manure incorporated into the soil produced higher soil organic matter and soil and leaf N, P, K, Ca, Mg, growth and yield of tomato compared with broadcast method. Also poultry manure applied at 3 weeks before transplanting (3 WBTP) had higher leaf nutrient concentrations and better growth and yield of tomato compared with 0 week at transplanting (0 WATP), 3 weeks after transplanting (3 WATP) and 6 weeks after transplanting (6 WATP). The higher yield at 3 weeks before transplanting (3 WBTP) compared with other time of applications was adduced to better synchrony between crop demand and nutrient supply. Therefore application of poultry manure at 3 weeks before transplanting (3 WBTP) with incorporation is recommended for cultivation of tomato in the forest-savanna transition zone of southwest Nigeria.

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