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Response of Tomato (*Lycopersicon esculentum*): Growth and Yield, to Rates of Mineral and Poultry Manure Application in the Guinea Savanna Agro-ecological Zone in Nigeria

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Abstract

The study was designed to evaluate the impact of different levels of poultry manures (PM) on the growth and yield of tomato in comparison to mineral fertilizer (MF) and the combine treatment of PM + MF. The combined analysis revealed that application of poultry manure at 150 kg N/ha gave the tallest plant height, but not significantly different from application of manure at 300 kg N/ha. These were however, significantly different from the inorganic fertilizer treatment; an indication that tomato responded better to poultry manure than mineral fertilizer, in respect of plant height. Application of inorganic fertilizer at the rate of 300 kg N/ha gave significantly taller crop than 150 kg N/ha. The shortest plant heights were observed in the control treatment in both cropping seasons as well as in the combined result. Application of organic and inorganic fertilizers significantly ($p \leq 0.05$) influenced total number of harvested tomato and weight of harvest. Application of 150 kg PM/ha + 150 kg MF/ha gave the best yield, which was significantly different from other rates investigated, followed by 75 kg PM/ha + 75 kg MF/ha. While increasing poultry manure rate from 150 kg N/ha to 300 kg N/ha led to an increase in total number of harvested tomato and tomato yield / ha, increasing mineral fertilizer rate from 150 kg N/ha to 300 kg N/ha actually depressed tomato yield and number of tomato harvested per plot. Finally, application of inorganic nutrient at the rate of 150 kg N/ha yielded 88.15% return over the control, while applying 300 kg N/ha inorganic nutrient yielded only 74.68% return over the control. Application of organic nutrient at the rate of 150 and 300 kg N/ha yielded 81.93 and 85.98 percent returns, respectively over the control treatment. The highest return, however, was obtained with the application of 150 kg PM/ha + 150 kg MF/ha (90.17%) over the control, which was followed by application of 75 kg PM/ha + 75 kg MF/ha (89.42%) over the control. Based on the research outcome, it is recommended that if tomato is to be grown on inorganic fertilizer, application of N at the rate of 150 kg/ha is appropriate, while application of organic fertilizer at the rate of 300 kg N/ha is recommended. However, combine application of 150 kg PM/ha + 150 kg MF/ha is recommended for optimum tomato yield.

Keywords: Height, plant gilt, growth, development, yield and economics

1. Introduction

Organic fertilizers: farmyard manure (FYM), sheep manure (SM), poultry manure (PM), compost, among others have been used for crop production for centuries. The use of these forms of fertilizers certainly pre-date chemical (mineral) fertilizers, which is of more recent development in comparison with organic fertilizers. Organic fertilizers are more environmentally friendly, since they are of organic sources. Contrary, observations show that continuous use of mineral fertilizers create potential polluting effect on the environment (Oad *et al*., 2004), in addition to the fact that synthesis of this fertilizer form consumes large amount of energy with often huge financial implications. Although organic fertilizers exist in readily available forms; cheap and easy to assess, they need to be applied in large amounts to meet the nutrient requirements of crops (Prabu *et al*., 2003). Where large hectares are involved, this single fact play important role in the cost of organic fertilizer application; as it pushes up transportation cost. This salient factor thus introduces management component into an otherwise abundant nutrient source. Thus, a combination of organic and mineral nutrients have been advocated (Prabu *et al*., 2003). As the integration of organic sources and synthetic sources of nutrients not only supply essential nutrients but also have some positive interaction with chemical fertilizers to increase their efficiency and thereby reduce environmental hazards (Bocchi and Tano, 1994).

There is growing interest in the use of organic manures due to soil fertility depletion in most African soils coupled with the scarcity and cost of mineral fertilizers. In addition, economic premiums for certified organic grains in most developed countries: United States of America and Europe, have been driving many transition decisions related to organic farming (Delate and Camberdella, 2004). Generally, soil productivity maintenance is a major constraint to tropical agriculture. Without the use of fertilizers, crops are moved between fields to utilize only fertile soils for some years, which may not meet the yearning for global foods security. Thus, the efficient use of nutrients within crop production systems has been the focus of research for several decades.

An important question that needs addressing is, why the choice of poultry manure for this experiment? Poultry manure is an excellent organic fertilizer, as it contains high nitrogen, phosphorus, potassium and other essential nutrients (Oyewole and Oyewole, 2011). In contrast to chemical fertilizer, it adds organic matter to soil which improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration (Deksissa *et al*., 2008).

Poultry manure more readily supplies P to plants than other organic manure sources (Garg and Bahla, 2008). Although, poultry manure is an excellent nutrient source for plants, supplementing soil nutrients, require sound soil fertility management practices to prevent nutrient imbalances and associated animal health risks as well as surface - water and ground water contamination (Blay *et al*., 2002; Phan *et al*., 2002). In the absence of other constraints, nutrient uptake and yield are closely related (Hedge, 1997). Therefore, objective of this study is to determine the response of tomato to different levels of poultry manure, mineral NPK and the combined treatment in the study area and consequently recommend the most economical rate for optimum tomato yield.

2. Materials and Methods

2.1 Experimental area

The experiment was conducted in 2010 and 2011 cropping season at the Kogi State University Student Research and Demonstration Farm (latitude 7^0 30^1 and longitude 7^0 09^1E), Anyigba in the Southern Guinea savanna agro ecological zone of Nigeria to determine the effect of organic and inorganic fertilizers and their combination on the growth, development and yield of tomato.

The study area which is Kogi State, lies between latitude 5^0 15^1 to 7^0 45^1 N and longitude 5^0 45^1 and 8^0 45^1 East of the equator. The mean annual rainfall ranges from 1,560 mm at Kabba in the West to 1,808 mm at Anyigba in the East. The dry season generally extends from November to March. During this period, rainfall drops drastically to less than 12.0 mm in any of the months. Temperatures show some variations throughout the years, with average monthly temperature varying between 17 ^{0}C and 36.2 ^{0}C. The state has two main vegetations: the forest savanna mosaic zone and the southern guinea zone. It also has two main geological formations, they are: the Basement complex rocks to the west while the other half is on Cretaceous sediments, to the north of the confluence and east of River Niger (Amhakhian, *et al*., 2010). The soils like most soils in north central agricultural zone of Nigeria have high erodibility, structurally weak, coarse textured with low organic matter status (Amhakhian, *et al*., 2010).

2.2 Treatment and experimental design

The treatment consisted of two rates of poultry manure (PM) supplying 150 and 300 kg N/ha and two rates of mineral fertilizer (MF) (NPK 15: 15: 15) also supplying 150 and 300 kg N/ha, coupled with 75 kg PM/ha + 75 kg MF/ha, 150 kg PM/ha + 150 kg MF/ha, in addition to the control treatment. Treatment was assigned in a Randomized Complete Block Design (RCBD) (Gomez and Gomez, 1984) with three replications among plot of size: 1.5 x 2 m^2 separated by 1m leeway enforced with high ridges.

2.3 Soil analysis

Soil samples were randomly collected from five points at two depths: 0 – 15 cm and 15 – 30 cm, on the experimental plot thoroughly mixed together to form two composite samples. The samples collected were air dried, crushed with the aid of wooden roller and sieved through 2 mm sieve. The samples were then subjected to physical and chemical analysis as described by Chang and Jackson (1958) (Table 1).

2.4 Poultry manure analysis

To calculate the required amounts of poultry manure that would supply the needed experimental rates of 150 kg N/ha and 300 kg N/ha, sample of poultry manure to be used was analyzed for its total nitrogen, phosphorus and potassium content.

2.5 Seed bed preparation

The conventional tillage operations: plough, harrow and preparation of beds were carried out before seedling transplant. Main plot was be divided in sub plots of size 2 x 1.5 m separated by 1m leeway.

2.6 Nursery operations and seedling transplant

Seedlings were raised in the nursery, in boxes, for four weeks before being transplanted onto experimental plots. In the nursery, the seedlings were shaded against direct impact of solar radiation, while the boxes were kept weed free and watered every other day. Prior to seedling transplant into the field, the soil was heavily watered to enhance seedling removal. Vigorous seedlings were transplanted onto the experimental plot at 4 weeks old after a heavy rain fall.

2.7 Weed control

Hoe weeding was regularly carried out, complemented by regular hand pulling of weeds.

2.8 Nutrient management

Fertilizer and manure application were as in the treatment. For plots that received poultry manure, the nutrient was incorporated a week to seedling transplant, while for those plots treated with NPK fertilizer, this was applied immediately after seedling transplant. For those that received combined nutrient application ($^1/_2$PM + $^1/_2$NPK), the manure component was incorporated as in other sole manure treatments (a week prior to transplanting), while the NPK component came with seedling transplant.

2.9 Data collection and analysis

At two weekly, data on plant height and stem gilt were determined per plot as means of four randomly sampled plants from the net plot (1.5 m^2). Height was measured using a meter rule, while stem gilt was determined using the thread and meter rule method (Amhakhian, *et al*., 2010), where the thread was used to determine the circumference of the plant gilt, then measured over a meter rule. Yield was computed on fresh weight basis as sum of all harvests from net plot extrapolated to an hectare. The growth and yield parameters that were determined were then subjected to analysis of variance (ANOVA) using the SAS statistical package. Means found to be statistically significant ($p \leq 0.05$) were separated using Fisher's Least Significant Difference (FLSD).

2.10 Economics of nutrient application

To compute the economics of nutrient application, the following postulations were made: 50 kg NPK sold for ₦2, 500, while 50 kg poultry manure sold for ₦50 and a kilo of tomato fruits sold for ₦200; land preparation, seed, labour for nutrient application and other agronomic processes being held constant.

3. Results and Discussion

Result of laboratory analysis reveals varying levels of plant nutrients in sampled poultry manure, with N varying between 4.50 to 4.53 %, P_2O_5 between 2.56 and 2.71 % while K_2O varied between 0.97 and 1.40 % (Table 2). These components (N, P and K) are important plant nutrients require for plant growth, development and yield formation. It should therefore be expected that the fertility status of the soil would benefit from poultry manure application. Poultry manure production occurs as a result of the normal every day processes of the poultry industry; as a valuable by-product of the industry (Svotwa *et al*., 2007). Strictly, at the fate of the nutrient inputs, the major product of any animal feeding system is manure, not animal protein (Svotwa *et al*., 2007). If manure is considered a by-product of the industry, a possible use for it in a market economy can be found (Svotwa *et al*., 2007); that of soil enrichment.

3.1 Effect of plant nutrient on plant height

Analyzed data revealed that final plant heights in both cropping seasons and the combined result indicate significant ($p \leq 0.05$) influence of nutrient application on this parameter of growth (Table 3). The combined data showed that application of poultry manure at 150 kg N/ha gave the best response in respect of plant height, but not significantly ($p \leq 0.05$) different from application of manure at 300 kg N/ha. These were however, significantly different from the inorganic fertilizer treatment; an indication that tomato responded better to poultry manure than mineral fertilizer, in respect of plant height. Application of inorganic fertilizer at the rate of 300 kg N/ha gave significantly taller crop than 150 kg N/ha. The shortest plant heights were observed in the control treatment in both cropping seasons as well as in the combined result. The better crop performance; relative to plant height, obtained in the organic treatment as against the inorganic treatment could be the result of the presence of growth promoting factors like enzymes and hormones as previously reported (Egene, 2011; Ahmad, 1996). Nutrients contain in manures are reported to be released more slowly and stored for longer time in the soil ensuring longer residual effects, and improved root development (Sharma and Mittra, 1991; Abou El Magel *et al*., 2005), which must have been responsible for the consistent better height performance obtained with manure application over inorganic treatment. Simpson (1986) reported that the application of organic manure significantly increased crop growth parameters and yield, and attributed it to the high level of N supplied by the organic manure, an essential plant nutrient for growth. Generally, previous observations have shown beneficial effects of fertilizers (organic or inorganic) on soil nutrient composition, structural aggregates, infiltration rate, microbial and other biological activities of the soil (Omueti *et al*., 2000), which must have improve tomato growth over the control, cumulating in better plant performance with nutrient application.

3.2 Effect of plant nutrient on plant stem gilt

Stem diameter was significantly ($p \leq 0.05$) influenced by nutrient application (Table 4) in 2010 and 2011 cropping seasons. Application of 75 kg PM/ha + 75 kg MF/ha gave the highest response in respect of plant gilt, which was followed by application of 150 kg PM/ha + 150 kg MF/ha, 300 kg N/ha (PM), and 150 kg N/ha (PM), respectively, while the control treatment gave the least plant diameter in comparison with other treatments.

Generally, crop quality is improved by adequate use of fertilizer, provided they are applied in accordance with the latest concept and knowledge, observed Ayuso *et al*. (1996). Organic manures have been said to improve soil fertility by activating soil microbial biomass, which in turn leads to development in corps (Ayuso *et al*., 1996). The afore mentioned factors may have been responsible of the observed increase in stem diameter resulting from nutrient application. Manure, it has been reported, provide a source of all necessary macro-and micro-nutrients in available forms, thereby improving the physical and biological properties of the soil (Abou El - Maged *et al*., 2005);

consequently impacting on crop growth parameters such as plant diameter. Plant diameter would have positive implication on lodging, particularly during fruiting; the thicker the stem, the less likely the plant would lodge as a result of fruit carriage or other lodge inducing factors, such as wind.

3.3 Effect of plant nutrient on tomato yield

Application of organic and inorganic fertilizers significantly ($p \leq 0.05$) influenced total number of harvested tomato and weight of harvest (Tables 5 and 6). Application of 150 kg PM/ha + 150 kg MF/ha gave the best yield, which was significantly different from other rates investigated, followed by 75 kg PM/ha + 75 kg MF/ha and lastly the control. While increasing poultry manure

rate from 150 kg N/ha to 300 kg N/ha led to an increase in total number of harvested tomato and tomato yield / ha, increasing mineral fertilizer rate from 150 kg N/ha to 300 kg N/ha actually depressed tomato yield and number of tomato harvested per plot, probably indicating that maximum nutrient uptake has been reached with application of 150 kg N/ha to the tomato crop.

For all treatments, combining PM with FM gave better yield responses, compared with individual nutrient application. Application of organic nutrients gave better yield performances compared with counterpart mineral fertilizer application. That manures and inorganic fertilizers provide source of all necessary macro-and micro-nutrients in available forms, thereby improving the physical and biological properties of the soil (Abou El - Maged *et al*., 2005) must have accounted for the better yield performance obtained in nutrient treated plots as against the control. Uyovbisere and Elemo (2000), while working on okra, observed that the number of fruits per plant, fruit length, fruit girth and fresh fruit weight per plant were significantly ($p \leq 0.05$) increased when 150 NPK kg / ha was applied to the crop. Akanbi *et al* (2005) also observed great increase in crop yield with fertilizer treatment. However, the best response to fertilizer use is obtained if the soil has a high inherent fertility level (Adeniyan and Ojaniyi 2005).

3.4 Economics of nutrient application

Application of inorganic nutrient at the rate of 150 kg N/ha yielded 88.15% return over the control (Table 7), while applying 300 kg N/ha inorganic nutrient yielded only 74.68% return over the control. Application of organic nutrient at the rate of 150 and 300 kg N/ha yielded 81.93 and 85.98 percent returns, respectively over the control treatment. The highest return, however, was obtained with the application of 150 kg PM/ha + 150 kg MF/ha (90.17%) over the control, which was followed by application of 75 kg PM/ha + 75 kg MF/ha (89.42%) over the control.

4. Conclusion

The main reasons for applying PM include the organic amendment of the soil and the provision of nutrients to crops. Keeping in view the above facts, the present study was therefore, designed to evaluate the impact of different levels of poultry manures (PM) on the growth and yield of tomato in comparison to mineral fertilizer (MF) and the combine treatment of PM + MF and the most economic rate. The combined analysis revealed that application of poultry manure at 150 kg N/ha gave the tallest plant height, but not significantly different from application of manure at 300 kg N/ha. These were however, significantly different from the inorganic fertilizer treatment; an indication that tomato responded better to poultry manure than mineral fertilizer, in respect of plant height. Application of inorganic fertilizer at the rate of 300 kg N/ha gave significantly taller crop than 150 kg N/ha. The shortest plant heights were observed in the control treatment in both cropping seasons as well as in the combined result.

Application of organic and inorganic fertilizers significantly ($p \leq 0.05$) influenced total number of harvested tomato and weight of harvest. Application of 150 kg PM/ha + 150 kg MF/ha gave the best yield, which was significantly different from other rates investigated, followed by 75 kg PM/ha + 75 kg MF/ha and lastly the control. While increasing poultry manure rate from 150 kg N/ha to 300 kg N/ha led to an increase in total number of harvested tomato and tomato yield / ha, increasing mineral fertilizer rate from 150 kg N/ha to 300 kg N/ha actually depressed tomato yield and number of tomato harvested per plot.

Finally, application of inorganic nutrient at the rate of 150 kg N/ha yielded 88.15% return over the control, while applying 300 kg N/ha inorganic nutrient yielded only 74.68% return over the control. Application of organic nutrient at the rate of 150 and 300 kg N/ha yielded 81.93 and 85.98 percent returns, respectively over the control treatment. The highest return, however, was obtained with the application of 150 kg PM/ha + 150 kg MF/ha (90.17%) over the control, which was followed by application of 75 kg PM/ha + 75 kg MF/ha (89.42%) over the control. Based on research outcome, it is recommended that if tomato is to be grown on inorganic fertilizer, application of N at the rate of 150 kg/ha is appropriate, while application of organic fertilizer at the rate of 300 kg N/ha is recommended. However, combine application of 150 kg PM/ha + 150 kg MF/ha is recommended for optimum tomato yield in the study area.

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Table 1: Selected physical and chemical properties of experimental soil

Soil property	**0 – 15 cm depth**
Texture	Sandy
Sand g/kg	90.10
Silt g/kg	6.50
Clay g/kg	3.40
pH (H_2O)	5.88
ECEC cmol/kg	7.63
Ca	4.08
Mg	2.00
Na	0.84
K	0.35
H^+	0.20
Al	0.20
Organic matter (g/kg)	17.20
Bray P-1 (mg/kg)	9.59
Total N (g/kg)	6.20

Table 2: Result of poultry manure analysis

Nutrient elements	2010 cropping season	2011 cropping season
% N	4.50	4.53
% P_2O_5	2.71	2.56
% K_2O	1.40	0.97

Table 3: Mean effect of plant nutrient application on tomato height

Plant nutrient application	Height (cm)		
	2010	**2011**	**Mean height**
Control	9.47	10.43	9.95
Inorganic Nutrient			
150 kg N/ha	10.24	11.43	10.84
300 kg N/ha	11.62	14.20	12.91
Organic Nutrient			
150 kg N/ha	19.21	21.20	20.21
300 kg N/ha	19.76	20.20	19.98
Organic Nutrient +Inorganic Nutrient			
75 kg PM/ha + 75 kg MF/ha	14.83	16.32	15.58
150 kg PM/ha + 150 kg MF/ha	15.72	17.20	16.46
LSD $_{0.05}$	0.614*	0.312*	0.346*

* Statistically significant ($p \leq 0.05$)

Table 4: Mean effect of plant nutrient on tomato stem gilt

Plant nutrient application	Mean stem gilt (cm)		
	2010	2011	Mean stem gilt
Control	1.56	1.70	1.63
Inorganic Nutrient			
150 kg N/ha	1.54	1.83	1.69
300 kg N/ha	1.67	1.96	1.82
Organic Nutrient			
150 kg N/ha	1.73	2.03	1.88
300 kg N/ha	1.79	2.43	2.11
Organic Nutrient +Inorganic Nutrient			
75 kg PM/ha + 75 kg MF/ha	2.73	2.76	2.75
150 kg PM/ha + 150 kg MF/ha	2.63	2.78	2.71
$LSD_{0.05}$	0.091*	0.487*	0.826*

* Statistically significant ($p \leq 0.05$)

Table 5: Effect of plant nutrient on fruit number per hectare

Plant nutrient application	Fruit number per ha		
	2010	2011	Mean
Control	94,176	125,567	109,871
Inorganic Nutrient			
150 kg N/ha	383,325	511,100	447,213
300 kg N/ha	409,439	419,359	414,399
Organic Nutrient			
150 kg N/ha	429,100	573,333	501,666
300 kg N/ha	575,825	767,767	671,796
Organic Nutrient +Inorganic Nutrient			
75 kg PM/ha + 75 kg MF/ha	711,420	759,450	735,435
150 kg PM/ha + 150 kg MF/ha	709,175	945,567	827,371
$LSD_{0.05}$	1006.76*	1612.68*	1311.65*

* Statistically significant ($p \leq 0.05$)

Table 6: Effect of plat nutrient on fruit weight per hectare

Plant nutrient application	Mean fruit weight (kg/ha)		
	2010	2011	Mean
Control	1.4	1.5	1.5
Inorganic Nutrient			
150 kg N/ha	11.8	13.6	12.7
300 kg N/ha	5.9	6.0	6.0
Organic Nutrient			
150 kg N/ha	7.9	8.7	8.3
300 kg N/ha	10.3	11.0	10.7
Organic Nutrient +Inorganic Nutrient			
75 kg PM/ha + 75 kg MF/ha	13.6	14.8	14.2
150 kg PM/ha + 150 kg MF/ha	14.9	15.6	15.3
$LSD_{0.05}$	0.71*	0.88*	0.80*

* Statistically significant ($p \leq 0.05$)

Table 7: Economics of Nutrient application

Plant nutrient application	Mean fruit weight (kg/ha)				
	Mean of two years	Total return on enterprise	Input cost (₦)	Net return on enterprise (₦)	Per cent returns (%)
Control	1.5	300,000	-	300,000	-
Inorganic Nutrient					
150 kg N/ha	12.7	2,540,000	7,500	2,532,500	88.15
300 kg N/ha	6.0	1,200,000	15,000	1,185,000	74.68
Organic Nutrient					
150 kg N/ha	8.3	1,660,000	150	1,659,850	81.93
300 kg N/ha	10.7	2,140,000	300	2,139,700	85.98
Organic Nutrient +Inorganic Nutrient					
75 kg PM/ha + 75 kg MF/ha	14.2	2,840,000	3825	2,836,175	89.42
150 kg PM/ha + 150 kg MF/ha	15.3	3,060,000	7650	3,052,350	90.17