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Impact of Staking Methods and Poultry Manure Rates on the Performance of Tomato (*Solanum lycopersicum* L.) In Bauchi and Kashere, North - Eastern, Nigeria

Mshelia, J. S.[1]; Leddi, K. W.[2]; Auwalu Yakubu[3]; Anas, B. A.[4]; Jibrin, M.[5]; Bala, A.[6]; Dahiru AG. A.[7]

[1] Department of Crop Science, Federal University of Agriculture Mubi, PMB 2025, Mubi, Adamawa State.
[2]Department of Agronomy, Faculty of Agriculture, Federal University of Kashere, Gombe State.
[3, 6 &7]Department of Crop Production Technology, Bauchi State College of Agriculture, Bauchi State.
[4&5] Department of Horticultural Technology, Federal College of Horticulture Dakinkowa, Gombe State

Correspondent Author: Leddi, K. W.

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Abstract: Field trial were carried out at the Teaching and Research Farm of the Department of Agronomy, Faculty of Agriculture, Federal University of Kashere, Gombe State and Bauchi State College of Agriculture, Bauchi State in the 2024 dry season to investigate the impact of staking methods and different poultry manure rates on the performance of Tomato (Solanum lycopersicum L.). The study involved two staking methods (trellis and bench staking) and six different rates of poultry manure (0, 10, 15, 20, 25 and 30 tons per hectare) that were factorially combined and arranged in a Randomized Complete Block Design with three replications. Growth characteristics measured included plant height (cm), Number of leaves, number of branches, stem girth (cm), leaf area (cm^2) and leaf area index. Yield characteristics assessed were fruit diameter (cm), number of fruits, and fruit yield tons per hectare. The results indicated that tomato plants were significantly (P≤0.001) taller in plots treated with 30 tons per hectare of poultry manure. There was also a marked increase in canopy development, including the number of leaves, branches, stem girth, leaf area, and leaf area index, all significantly (P≤0.001) enhanced under the 30 tons per hectare, poultry manure application. Additionally, this treatment resulted in improved yield metrics such as fruit diameter, number of fruits, and overall fruit yield, which were also significantly (P≤0.001)higher in plots with 30 tons per hectare of poultry manure. The result of staking among characters showed that there is no significant (P≤0.001) difference between staking methods. Staking also positively impacted tomatoes performance, likely due to improved support and exposure to sunlight. Using both staking and poultry manure led to the best results in terms of fruit count and yield, which were 64.50 fruits and 35.44 tons per hectare, respectively. The study also showed that there is no significant interaction (P≤0.001) between the methods of using poultry manure and staking. These results indicate that applying 30 tons per hectare of poultry manure along with staking can enhance tomato production.

Keywords: *Staking; Poultry Manure; Rates; Performance; Trellis, Bench.*

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I. INTRODUCTION

The tomato is part of the Solananceae family and belongs to the Lycopersicon genus, which is a small group within a larger family that has about 90 genera (Olaniyi and Ajibola, 2018). This crop originally comes from Peru, Galapagos Island and Ecuador, but research indicates that Mexico was where it first became domesticated (Resende and Klee, 2020, Carillo, 2018). Tomato made their way to Africa in the 16th century and still today, it is the most widely grown vegetable crop (Dhaliwal *et al.*, 2011). The plant can reach a height of 1 to 3 meters and has weak stems that spread out on the ground. To get a good harvest, tomatoes need support or staking. They are usually grown outdoors in temperate climates as an annual crop, even though they are a perennial in their original habitat (Mohammed, 2017). In Nigeria, farmers grow tomatoes in both the wet and dry seasons, but they make more money during the dry season because demand is greater than supply.

Tomatoes play an important role in human diet because they are good source of minerals and vitamins a remedy for night blindness. Tomatoes contain a high level of lycopene; substances that is used in some of the more pricy facial cleansers that are available for purchase (Wang, 2020).Tomatoes also help to prevent several types of cancer. Studies indicate that high levels of lycopene in tomatoes reduce the chances of developing prostate, colorectal and stomach cancer. Lycopene is a natural antioxidant that works impactively to slow down the growth of cancerous cells (Bathla *et al.*, 2019, Labrie and Marcelis, 2020). Tomatoes contribute to bone health due to their high levels of calcium and Vitamin K, which are crucial for strengthening bones and facilitating minor repairs to bone tissue (Amon, 2018). Health professionals recommend boosting dietary intake of lycopene and Vitamin C by consuming fresh tomatoes and tomato based products (Wang, 2020).

Farmers use organic manures, which are natural products, to improve sustainable crop production (Robert, 2013) some examples of organic manure include farmyard manure, green manures, compost made from leftover crops and other farm waste, vermicompost, oil cakes, and biological waste like animal bones and slaughterhouses scraps. According to Li (2018), tomatoes are a high-yielding vegetable that needs many fertilizers for proper growth and yield. Tomato plants need many important nutrients, including macronutrients like nitrogen, potassium, phosphorous, calcium, as well as some micronutrients such as iron, manganese and zinc (Li, 2018). If there is not enough potassium and calcium, tomatoes can develop problems like blossom end-rot and would not be able to gather enough soluble sugar (White *et al.*, 2020). Using smaller amounts of other nutrients like nitrogen, magnesium, phosphorus, boron and copper together can significantly help with how the plants grows and set fruit (Pandey, 2018). These nutrients are specific in function and must be supplied to the plant at the right time and in the right quantity for proper growth and reproduction (Adekiya and Ojeniyi, 2022). However, there is renewed interest in proper and impactive use of organic manure to maintain soil fertility (Olatunji and Oboh, 2012). Aside from being source of plant nutrients, organic manure, for example poultry manure and ruminant dung has improved agricultural productivity in West African countries (Olatunji and Oboh, 2012). Organic manure helps to increase the population of soil microorganisms, which have some influence in protecting plant against pathogens like nematodes and soil born insects, and provides plant growth hormones like auxins (Sanchez and Miller, 2016; Agbede and Ojeniyi, 2019). Organic manure also helps to improve the physical condition of the soil and provides the required plant nutrients. It enhances cation exchange capacity and acts as a buffering agent against undesirable soil pH fluctuations (Ngeze, 1998; Giwa and Ojeniyi, 2014; Ojeniyi *et al.*, 2017; Akanni and Ojeniyi, 2018).

Staking represents a distinctive intercultural method for growing tomatoes and cherry tomatoes, potentially boosting the yield and improving the fruit quality. Cherry tomatoes on staked plants are larger and mature earlier than those on plants allowed to sprawl (Rashid *et al.*, 2020). Vertical staking or trellising could increase fruit production about 3 times than those of the plants without staking and improve the quality of the fruits (Rashid *et al.*, 2020). Good air circulation around the leaves and fruits of upright tomato plants lessens diseases problems and provide fruits that are free from dirt and slug bites. On the other hand, staking practice may also give the uniform sized fruit, easy harvesting of fruits and conveniences in intercultural operations without damage to the fruits and less infestation of insects and diseases as well as increase the yield of tomato (Santos *et al.*, 2018). Staking increases fruit yield, reduces the promotion of unmarketable fruits and facilitates chemical spraying and harvesting (Rashid, 2022). Staking produce high quality fruits and avoids fruit rot. It allows better aeration, reduces attacks of fungus diseases and ensures better exposure of the foliage to light for better photosynthesis (FAO, 2007).

II. MATERIALS AND METHODS

Field trial were carried out at the Teaching and Research Farm of the Department of Agronomy, Faculty of Agriculture, Federal University of Kashere (latitude $9^0$91'28"N and longitude $11^0$00'65"E) Gombe state and Bauchi State College of Agriculture Bauchi (latitude $10^0$16'56"N and longitude $9^0$48'14"E) in the 2024 dry season to investigate the impact of staking methods and different poultry manure rates on the performance of Tomato (*Solanum lycopersicum* L.). The climate of the area is characterized by high temperature and moderate rainfall. The mean daily temperature ranges between 30^0C and 33^0C.The treatments consisted of two staking methods (trellis and bench method) and six levels of poultry manure (0, 10, 15, 20, 25 and 30 tons per hectare) which were factorially combined and laid out in a Randomized Complete Block Design (RCBD) with three replications. two methods of

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staking (Trellis and Bench staking) giving twelve (12) treatment combinations. Each plot size was 4m X 3m with 0.5m separating each plot and 1m between replicates. Each replication consisted of twelve (12) experimental units thus, having 36 experimental plots. The total experimental area was 630m^2. Growth characters assessed were plant height (cm), number of leaves per plant and number of branches per plant. Other growth indices assessed were leaf area (cm^2), leaf area index (LAI) and Stem girth (cm). Yield and yield characters studied were fruit diameter (cm), number of fruits per plant and fruit yield per hectare. The data collected underwent Analysis of Variance (ANOVA) with the aid of Statistical Analysis Software (SAS). To differentiate the means, the Duncan Multiple Range Test (DMRT) was employed.

III. RESULTS

A. *The Impact of Poultry Manure Rates and Staking Methods on Growth Characters*

- *Plant Height (cm)*

Table 1 showed the impact of poultry manure rates and staking methods on plant height of tomato at different locations. The impact of poultry manure consistently and significantly (P≤0.01) affected plant height at all sampling stages. The results revealed that the 30t/ha poultry manure produced taller plants (92.32cm), followed by 25t/ha (85.52cm), 20 t/ha (82.97cm), 15 t/ha (82.00cm) and 10 t/ha (73.83cm) respectively with control having the least plant height (64.42cm) throughout the period of the experiment.

Staking did not have significant impact on the height of tomato plants (P≤0.05) at either location. When comparing the different staking methods, trellis method led to taller plants (80.60 cm) than the bench method (79.75 cm), but this difference was not statistically significant.

The impact of location on plant height of tomato was significant (P≤0.01) at all sampling period except at 6 weeks after transplanting. Among the locations plants grown in Kashere were significantly (P≤0.01) taller (93.02cm) than those planted in Bauchi (67.34cm). There were no interactions between the treatments throughout the sampling season.

- *Number of Branches Per Plant*

The result of the impact of poultry manure rates and staking methods on number of branches is presented in Table 2. Branches were significantly (P≤0.01) affected by varying rates of poultry manure at all sampling stages. 30 t/ha of poultry manure rate significantly produce more number of branches (23.31) per plant followed by 15 t/ha (20.52), 25 t/ha (19.47), 20 t/ha (18.69) respectively, with least number of branches (12.00) obtained in control throughout the growing stages.

The impact of staking on number of branches per plant of tomato was not significant (P≤0.05) at all the sampling stages.

Location significantly (P≤0.01) affected number of branches in the period of the experiment except at 3 and 6 weeks after transplanting. Among the locations of the experimentation, plant grown in Kashere significantly produce higher number of branches (20.31) than those planted in Bauchi (15.62). However, the control plots consistently and significantly had fever leaves irrespective of the location under study. There were no interactions between the treatments.

B. *The Impact of Poultry Manure Rates and Staking Methods on Yield Characters*

- *Number of Fruit Per Plant*

The impact of poultry manure rates and staking methods on number of fruits per plant is showed in Table 3. The impact of poultry manure rates significantly (P≤0.001) and consistently affected number of fruits per plant at all sampling stages. Results revealed that 30t/ha poultry manure rate significantly (P≤0.001) produce more number of fruits per plant (64.50) followed by 25 t/ha of poultry manure producing 58.50 fruits of tomato, followed again by 20 t/ha of poultry manure producing 55.88 fruits of tomato. Least number of fruits observed were in control producing 29.45 fruits of tomato throughout the period of the experimentation.

Staking methods had no significant impact on number of fruits per plant at both locations.

Location variation revealed significant (P≤0.001) impact on number of fruits per plant. The result significantly revealed that more number of fruits were obtained on plants grown in Kashere producing 67.09 fruits of tomato with least number of fruits obtained in Bauchi producing 36.63 fruits throughout the period of the experiment.

- *Fruits Yield Per Hectare (t/ha)*

The various rates of poultry manure and staking methods affected significantly and consistently fruits yield per hectare of tomato at both locations as shown in Table 4. The used of 30t/ha of poultry manure rates significantly produced a lot of fruits yield of 35.44 t/ha throughout the period of the experimentation followed by 20t/ha, 15 t/ha, 25 t/ha and 10 t/ha respectively with the least fruits yield per hectare obtained in control treatment producing 9.79 t/ha.

The impact of staking methods on fruits yield tons per hectare of tomato was not significant. Trellis staking induced the highest fruits yield per hectare (22.17 t/ha) although statistically the same with bench staking (22.07 t/ha).

The impact of different locations on fruit yield in tons per hectare was shown to be important. Plants cultivated in Kashere produced a lot more fruits per hectare (33.59 t/ha) compared to those grown in Bauchi (10.65). Additionally, there is a relationship between the different amounts of poultry manure used and the staking methods applied.

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IV. DISCUSSION

➢ *Growth Character*

The growth of tomato plant was greatly affected by the amounts of poultry manure used and the staking method. The height of the tomato plants changed noticeably based on the different rates of poultry manure. The varying responses seen during the trial might be because of the moderate nutrient levels in the poultry manure and the initial fertility conditions of the experimental sites.The response of plant height was highly influenced by staking, although the findings revealed that there was no significant difference between the staking methods throughout the period of the experiment. These results concur with the finding of Hanson *et al*., (2020) who reported that staking increases plant height, number of branches and stem diameter. This point of view agreed with (Lemma, 2022) who reported that tomato growth and performance is influenced by different environmental conditions.

Plant height were significantly taller in 30 tons per hectare poultry manure rate and decreased as the poultry manure rates decreases. This pattern of response in plant height to applied poultry manure could be due to NPK and Mg and other essential nutrients contained in the manure, resulting in increase in cell size, cell elongation and enhancement of cell division, which ultimately increased plant growth. This result corroborates the finding of Singh and Gupta (2015), who reported that application of 30 tons per hectare significantly increased plant height with their genetic materials under their conditions. This also agreed with findings of Li, (2013), who reported that tomato is a high yielding vegetable that requires many fertilizers for its proper establishment, growth and yield. White *et al.* (2020) reported that tomato is a heavy feeder of macronutrients elements such as N, P, K, Ca and some other micronutrients like iron, magnesium and zinc. This also agreed with the findings of Ayeni *et al.* (2010), who reported that application of poultry manure leads to significant increase in plant height, number of leaves and number of branches.

Number of branches responded to applied poultry manure due to the nutrients contained in the poultry manure which included N,P, K, Ca and Mg. This result is envisaged as Nitrogen enhances shoot growth increases photo – assimilates and hence, the development of branches. This result is in line with the finding of Vaezzadeh and Naderidarbaghshahi (2012), who reported that poultry manure increases number of shoot per plant and are indices of growth and adaptability of plant to the soil and climatic conditions. It also corroborates the finding of Zamil *et al*. (2020), who stated that poultry manure encourages more number of branches to applied poultry manure indicating it contains P and N, which are always required by plants for good growth and productivity as they complement each other in their physiological activities. This further confirms the findings of Zelalem *et al.* (2019). Hanson *et al.* (2021), reported that staking provides better growth of tomato, branches, increased fruit bearing and improved quality of fruits.

The application of 30 t/ha poultry manure had the highest number of leaves and branches this may be attributed to the sufficient release of nutrient particularly N, P and K contained in poultry manure applied, as these nutrients improves growth and yield of crops. This result revealed that number of leaves and branches of tomato significantly increased with increase in the concentration of poultry droppings.

➢ *Yield Characters*

Poultry manure and staking positively influenced fruit diameter, number of fruits per plant and fruit yield. All yield components were highest at 30 tons per hectare, poultry manure rate and decreased with decrease in poultry manure rate. The lowest yield components were obtained in control treatment. Adesodun *et al*. (2020) reported that application of poultry increased soil organic matter, N and P and aggregates stability. Plant sown on plots treated with 30 tons per hectare poultry manure had the highest number of fruits per plant and fruit yield with the values (64.50) and (35.44 t/ha) respectively. This may be attributed to the sufficient release of nutrients particularly N, P, K contained in the poultry manure applied, as these nutrients improves the growth and yields of crops. In comparison with the control, poultry manure treated plots had significantly higher than the control. Fruits and fruit quality is improved because of application of poultry manure. The variation in climatic conditions may have also accounted for this. These results coincide with the results recorded by Olajeda *et al*. (2018), that tomato response to poultry manure is greatly influenced by prevailing environmental conditions as well as cultural practices. Increase in yield component especially in Kashere could be attributed to the availability, uptake, improved nitrogen, and other macro and micronutrient absorption as well as enhanced the production and translocation of dry matter content from source to sink as earlier reported by Akinrinde (2016).

Fruit quality is promoted by staking as it avoids fruit contact with the soil, good staking practices ensure that tomato receive ample sunlight and air circulation and prevent disease by keeping the fruit off the ground. This agreed with the findings of (Kader and Norman, 2022), who reported that staking increases fruit yield and size, reduces the proportion of unmarketable fruits and facilitates chemical spraying and harvesting. Lemma (2022) further confirmed that staking of tomato plant for fresh fruit market increased yield and quality.

V. CONCLUSION

This study found that different amounts of poultry manure and staking techniques greatly affect the growth and yield of tomatoes. When 30 tons of poultry manure per hectare was used, the plants grew taller and had more branches. The yield and other important factors were also at their highest with these same treatments. The highest growth character

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recorded at 30 tons per hectare poultry manure and staking respectively translated into higher yields especially in Kashere. Based on the results of this finding, the following are hereby suggested for recommendation to farmers and researchers in the study area for the production of Tomato.

- To improve tomato production in Bauchi and Kashere, located in the Northern Guinea Savannah Agro-Ecological Zone of Nigeria, it is recommended to use trellis and a poultry manure rate of 30 tons per hectare
- More research should be done with higher rates of poultry manure to find the best amount needed for growing tomatoes.

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Table 1: Impact of Staking and Different Rates of Poultry Manures on Plant Height (cm) of Tomato at 3, 6, 9 and 12 Weeks After Transplanting (WAT) in the 2024 Dry Season in Bauchi and Kashere, North - Eastern Nigeria.

Treatment	**Plant Height (cm)**			
	3	**6**	**9**	**12 (WAT)**
PM (t/ha)				
0	13.446^{b}	34.88^{c}	50.05^{c}	64.42^{c}
10	17.753^{a}	48.84^{b}	68.02^{b}	73.83^{bc}
15	19.035^{a}	53.90^{ab}	76.46^{ab}	82.00^{ab}
20	18.892^{a}	54.17^{ab}	73.93^{ab}	82.97^{ab}
25	17.868^{a}	52.49^{ab}	80.60^{a}	85.52^{ab}
30	20.473^{a}	58.08^{a}	80.65^{a}	92.32^{a}
LS	***	***	***	***
SE±	0.77	1.5	2.69	3.35
SM				
BS	17.888	49.592	71.17	79.75
TS	17.935	51.196	72.07	80.60
LS	NS	NS	NS	NS
SE±	0.40	0.87	1.55	1.93
Location				
Bauchi	16.718^{b}	50.162	61.96^{b}	67.34^{b}
Kashere	19.105^{a}	50.626	81.27^{a}	93.02^{a}
LS	***	NS	***	***
SE±	0.44	0.87	1.55	1.93
Interaction				
PM×QM	NS	NS	NS	NS

The letters $^{a, b, c, d}$ indicate that values with different superscript in the same row are significantly different at probability levels of P≤ 0.01 and P≤ 0.001, as determine by Duncan's Multiple Range Test. LS = Level of Significance, SE± = Standard Error WEEKS AFTER TRANSPLANTING (WAT) = Weeks After Transplanting, NS = Not-Significant, Poultry Manure, SM = Staking Method.

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Table 2: Impact of Staking and Different Rates of Poultry Manures on Number of Branches of Tomato at 3, 6, 9 and 12 Weeks After Transplanting (WAT) in the 2024 dry season in Bauchi and Kashere, North - Eastern Nigeria.

Treatment	Number of Branches			
	3	6	9	12 (WAT)
PM (t/ha)				
0	2.017^{c}	6.200^{c}	9.31^{c}	12.00^{c}
10	3.383^{b}	10.133^{b}	15.14^{bc}	13.82^{bc}
15	3.958^{b}	11.917^{b}	19.70^{ab}	20.52^{ab}
20	3.558^{b}	11.150^{ab}	18.75^{ab}	18.69^{a}
25	4.083^{b}	12.000^{ab}	21.30^{ab}	19.47^{a}
30	5.492^{a}	14.117^{a}	23.01^{a}	23.31^{a}
LS	***	***	***	***
SE±	0.22	0.56	1.61	1.22
SM				
BS	3.59	10.63	17.87	17.42
TS	3.91	11.21	17.87	18.52
LS	NS	NS	NS	NS
SE±	0.13	0.32	0.93	0.71
Location				
Bauchi	3.58	10.59	14.93^{b}	15.62^{b}
Kashere	3.92	11.25	20.81^{a}	20.31^{a}
LS	NS	NS	***	***
SE±	0.13	0.32	0.93	0.71
Interaction				
PM×SM	NS	NS	NS	NS

The letters $^{a, b, c, d}$ indicate that values with different superscript in the same row are significantly different at probability levels of P≤ 0.01 and P≤ 0.001, as determine by Duncan's Multiple Range Test. LS = Level of Significance, SE± = Standard Error WEEKS AFTER TRANSPLANTING (WAT) = Weeks After Transplanting, NS = Not-Significant, Poultry Manure, SM = Staking Method.

Table 3: Impact of Staking and Different Rates of Poultry Manures on number of fruits of Tomato in the 2024 dry season in Bauchi and Kashere, North - Eastern Nigeria.

Treatment	Number of fruits
PM (t/ha)	
0	29.45^{c}
10	48.59^{b}
15	54.24^{ab}
20	55.88^{ab}
25	58.50^{ab}
30	64.50^{a}
LS	***
SE±	2.82
SM	
BS	52.06
TS	54.66
LS	NS
SE±	1.63
Location	
Bauchi	36.63^{b}
Kashere	67.09^{a}
LS	***

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SE±	1.63
Interaction	
PM×QM	NS

The letters [a, b, c, d] indicate that values with different superscript in the same row are significantly different at probability levels of P≤ 0.01 and P≤ 0.001, as determine by Duncan's Multiple Range Test. LS = Level of Significance, SE± = Standard Error WEEKS AFTER TRANSPLANTING (WAT) = Weeks After Transplanting, NS = Not-Significant, Poultry Manure, SM = Staking Method.

Table 4: Impact of Staking and Different Rates of Poultry Manures on Yield (t/ha) of Tomato in the 2024 dry season in Bauchi and Kashere, North - Eastern Nigeria.

Treatment	Yield (t/ha)
PM (t/ha)	
0	9.79[c]
10	16.64[bc]
15	23.61[b]
20	26.72[ab]
25	20.53[bc]
30	35.44[a]
LS	***
SE±	2.78
SM	
BS	20.07
TS	22.17
LS	NS
SE±	1.60
Location	
Bauchi	10.65[b]
Kashere	33.59[a]
LS	***
SE±	1.60
Interaction	
PM×QM	NS

The letters [a, b, c, d] indicate that values with different superscript in the same row are significantly different at probability levels of P≤ 0.01 and P≤ 0.001, as determine by Duncan's Multiple Range Test. LS = Level of Significance, SE± = Standard Error WEEKS AFTER TRANSPLANTING (WAT) = Weeks After Transplanting, NS = Not-Significant, Poultry Manure, SM = Staking Method.

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