

Original Research Article

Yield and Yield Attributes of Tomato as Influenced by Organic Fertilizer

ABSTRACT

A field experiment was established at the Botswana College of Agriculture (BCA) to evaluate the effects of organic fertilizer on yield and yield attributes of tomato from October 2014 to March 2015. The experiment was laid out in a complete randomized block design (RCBD) with four treatments being varying levels of organic fertilizer; 0 kg m⁻², 5 kg m⁻², 7.5 kg m⁻² and 10 kg m⁻² each replicated three times. The growth attributes measured were plant height, stem thickness, canopy diameter, number of leaves, fruits and fruit weight. Organic fertilizer application rates of 7.5 and 10 kg m⁻² showed significantly ($P = .05$) taller plants from weeks 4 to 6 compared to other treatments. A highly significant difference in plant canopy was observed across the four application rates from weeks 1 to 5. Canopy spread was overall higher in the 10 kg m⁻² application rate across all the weeks. A highly significant treatment effect was observed on leaf number with plants in the 10 kg m⁻² application rate exhibiting the highest number of leaves. Stem thickness showed significance differences across treatments with the 10 kg m⁻² application rate having thicker stems. A highly significant treatment effect was observed on number of harvested fruits with the 7.5 kg m⁻² application rate showing higher yields between the first and fourth harvest and 10 kg m⁻² application rate from fifth to sixth harvest. Organic fertilizer had a significance effect on fruit weight from first to third harvest with the 10 kg m⁻² application rates having the heaviest tomato fruits. The 10 kg m⁻² application rate outperformed the lower treatments for most measured parameters. The organic fertilizer is recommended to small-scale vegetable growers because it is affordable and abundant.

Keywords: Organic fertilizer, tomato, yield and yield attributes

1. INTRODUCTION

Tomato (*Lycopersicon lycopersicum* L.) is an important and most popular versatile [1] and one of the 16 leading commercial vegetable crop in the world [2,3]. It is one of the most important members of nightshade family that are widely grown in many countries across the globe [2]. Tomato is a warm season fruit that is sensitive to cold [4] and can be grown both in the wet and dry seasons. In southern Africa the crop attracts higher profits during the dry season when the demand is higher than supply. Tomato has numerous health benefits which are attributed to its phytochemical constituents [5,6]. The red, edible fruit is an excellent source of nutrients and secondary metabolites (folate, potassium, vitamins C and E, flavonoids, chlorophyll, b-carotene and lycopene) that are important for human health [5]. The fruits contain lycopene, a carotenoid that helps in the prevention of cardiovascular disease and certain cancers [6]. According to Giovannucci [7] and Giovannucci *et al.* [8] the dietary lycopene reduces incidence of cardiovascular disease and some cancers, notably prostate cancer.

Soil fertility plays an important role in yield and quality of tomatoes [9]. Despite the importance of tomatoes to smallholder vegetable farmers, yields in Botswana are low due to low soil fertility. Continuous cropping without organic/inorganic inputs is very common with smallholder vegetable producers in Botswana and elsewhere in the developing world [10]. This practice together with nutrient losses through harvest, soil erosion and leaching, contribute to declining soil fertility [11,12]. Commercial farmers have resources to purchase inorganic fertilizers to improve soil fertility [10] compared to their smallholder counterparts. However, continuous use of chemical fertilizers may lead deterioration of soil characteristics

[13,14], reduction in nutrition values and the quality of edible fruits [15]. They reduce the dry matter content of tomato fruits [16,17,18,19] in addition to making fruits and vegetable more susceptible to disease and insect attacks [20].

Increasing costs associated with inorganic fertilizers is driving smallholder farmers in Botswana and elsewhere to look for alternative sources such as organic manures that are sustainable to improve soil fertility. Organic fertilizers such as farmyard manure, sewage sludge, crop residues, industrial waste and compost improve soil fertility [21,22,23]. Their application to the soil is an effective way of increasing soil organic matter content [24,25] and consequently improve the physical, chemical and biological properties of soil [26,27]. The performance of organic fertilizer is similar to that of their inorganic counterpart [28,29,30,31,32,33,34] except that nutrient are released slowly [35] but can stay in the soil for a long period of time. Organic fertilizers provide essential nutrients that improve crop growth and increase yield [36,37,38]. Organic fertilizers do not pollute the environment [37] which is beneficial to subsequent crops [36]. They suppress plant pest populations [22], control some crop diseases [39,40], prevent soil degradation and reduces the risk of water pollution [41]. In addition, they increase the soil microbial biomass C, N, and P [42] by increasing the proportion of bacterium and decreasing the proportion of fungi [38]. There is very little information on the effect of organic fertilizers in the production of vegetables in Botswana. The present study was therefore carried out to evaluate the effect of different application rates of organic fertilizer on yield and yield attributes of tomato.

2. MATERIAL AND METHODS

2.1 Description of Study Site

The field experiment was conducted from October 2014 to March 2015 at Botswana College of Agriculture (BCA), Sebele. Sebele lies about 10 km from the centre of Gaborone City on latitude 24° 34'S and longitude 25° 57'E elevated at 994 m above sea level. The climate of Sebele is semi-arid [43] and the soils are predominantly sandy loams with low water holding capacity and pH of 6.3 [44, 45].

2.2 Experimental Design, Treatments and Crop Establishment

The experiment followed a randomized complete block design (RCBD) with four treatments, each replicated three times. The four treatments were three different application rates of organic fertilizer being 0, 5.0, 7.5 and 10.0 kg m⁻² designated T₁, T₂, T₃ and T₄, respectively. The Organic Fertilizer [46] instruction manual used recommends a general combined basal and top dressing application rate of 5 kg m⁻² across the vegetables and plants. The organic fertilizer is made from a mixture of animal droppings, food waste, bark, wood flour, maize husk and grass. Soil improving agent (microbes) mixed with water for about 20 minutes is sprayed on the prepared raw material. The pile is turned once every two weeks and for 5 months to activate the bacteria. The temperature and moisture content is maintained at 40-75°C and 50-60% respectively throughout the process. After 5 months, the product is treated at high temperature to kill all the bacteria and weeds.

The site was cleared mechanically, ploughed and disked before plots were marked and demarcated. Twelve plots each measuring 1.5 × 2.7 m and separated by a buffer of 0.5 m were used. Plots were leveled using hand tools to provide a medium fine tilth for the growth of the tomato crop after which the organic fertilizer was applied and mixed with soil per treatment requirement. Tomato seeds were sown on seedling trays on the 26 October 2014 and kept in net shade for three weeks. On the 16 November 2014 vigorous seedlings were selected transplanted into their well-prepared plots. The inter row spacing of 50 cm and intra row spacing of 30 cm was used [47].

2.3 Crop Management

Plots were regularly watered to keep the soil at field capacity and weeds were manually removed by hand when necessary.

2.5 Plant Growth, Development and Yield Parameters

Ten seedlings per plot were randomly picked and tagged from each plot for data collection throughout the study. Plant height and plant canopy diameter were measured weekly from week 1 to 6 after transplanting using a meter ruler whereas number of leaves per plant was qualitatively measured for the same period by counting. The number of fruits harvested per plant was qualitatively measured from week 7 to 12 by counting. Ten tomatoes were randomly harvested from each plot to measure fruit weight from week 7 to 9 using a bench top electronic balance model PGW 4502e. Stem thickness was measured approximately 2 cm above the soil at the end of study using a calibrated vernier caliper (150 mm).

2.6 Statistical Analysis

Collected data was subjected to analysis of variance (ANOVA) using the STATISTIX-8 program. Where a significant F-test was observed and means comparison tests were carried out using Least Significant Difference (LSD) at $P = .05$ to separate treatment means.

3. RESULTS AND DISCUSSION

3.1 Plant height

There was no significant difference in plant height across treatments from week 1 to 3 (Table 1). This observation is not surprising because organic fertilizers release nutrients slowly [35, 48] since they require microbes to convert them into inorganic forms available to plants [49]. There were significant differences ($P = .05$) in plant height across treatments from week 4 to 6. In week 4, T_4 had the tallest plants (28.92 cm) that were not significantly different from T_3 (27.01 cm) and the same trend was observed in week 5 and 6 (Table 1). Results in Table 1 show that T_3 and T_4 had significantly taller plants than T_1 and T_2 between weeks 5 and 6. This result is similar to those observed in other plants elsewhere, where plant height was found to increase with increasing organic fertilizer [50,51,52,53,54,55,56,57]. According to Ng'etich *et al.* [57] farm yard manure application rates of 11.5 and 15 t ha⁻¹ significantly increased plant height in *Solanum scabrum* Mill. Agbo *et al.* [54] found that 30 t ha⁻¹ of manure increased plant height than 0 and 10 t ha⁻¹ in *Solanum melongena* L. The organic fertilizer used in the present study increased plant height probably by improving the physio-chemical properties of the soil [24,58,59].

Table 1. The effect of organic fertilizer on plant height (cm).

Treatments	Plant height (weeks after transplanting)					
	1	2	3	4	5	6
T_1	5.27	7.27	10.11	16.47 ^c	31.81 ^b	64.32 ^b
T_2	7.37	9.34	12.70	20.31 ^{bc}	38.52 ^b	68.84 ^b
T_3	9.53	11.96	15.71	27.01 ^{ab}	55.89 ^a	111.79 ^a
T_4	11.52	14.26	17.60	28.92 ^a	59.26 ^a	119.63 ^a
Significance	ns	ns	ns	*	*	*
LSD 0.05	ns	ns	ns	8.36	16.36	37.17
CV (%)	30.66	26.56	22.01	18.04	17.66	20.41

Significant at $P = .05$, ^{ns} non-significant at $P > .05$. Means separated by Least Significance Difference (LSD) Test at $P = .05$. Means within columns followed by the same letters are not significantly different. Where T_1 , T_2 , T_3 and T_4 are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m⁻² respectively and week 1 to week 6 are dates from 15-12-14 to 19-01-15 respectively.

3.2 Stem Thickness

Plant stem thickness was significantly ($P < .001$) influenced by different application rates of organic fertilizer. Organic fertilizer application rates (5, 7.5 and 10 kg m⁻²) produced plants with significantly thicker stems than the control (Fig. 1.). However, plants treated with the higher rate of organic fertilizer (T_4) produced plants with slightly thicker stems than T_2 and T_3 . Stem thickness increased as the organic

fertilizer amendment dose was increased. This is in agreement with Hou *et al.* [56] who observed that different application rates of organic fertilizer increased tomato plant stem thickness compared to the control. In a study conducted by Agbo *et al.* [54] farmyard manure applied at a rate of 30 t ha⁻¹ produced *Solanum melongena* plants with thicker stems than the control and application rates of 10 t ha⁻¹. Improvements in stem thickness observed in plants treated with organic fertilizer in the present study could probably be attributed to increased nitrogen, phosphorus and potassium [60] associated with organic fertilizers [61].

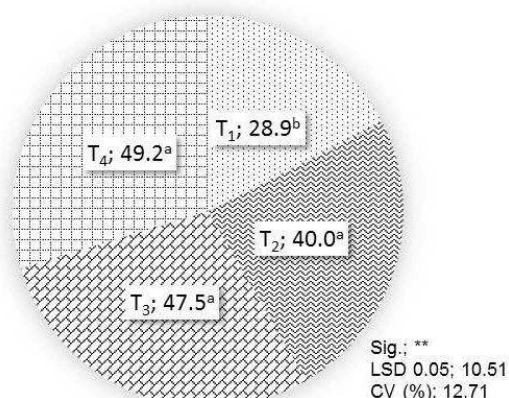


Fig. 1. The effect of organic fertilizer on tomato stem thickness (mm).

Highly significant at $P < .001$, Means separated by Least Significance Difference (LSD) Test at $P = .05$. Means within columns followed by the same letters are not significantly different. Where T₁, T₂, T₃ and T₄ are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m⁻² respectively.

3.3 Plant Canopy Diameter

Results in Table 2 indicate that treatment effect was highly significant. There were no significant differences in plant canopy spread between T₁ and T₂ throughout the 6 weeks. Similarly, plants grown in T₂ and T₃ were not significantly different from week 1 to 3. However, from week 4 to 6, T₃ plants had significantly wider canopy than their counterparts in T₂. No significant differences were observed in plant canopy diameter between plants in T₃ and T₄ throughout the 6 weeks (Table 2). The canopy diameter of T₄ plants was consistently wider than those grown in T₁ and T₂. Overall, these results demonstrate that the higher organic fertilizer application rate encouraged the uppermost lateral growth of the tomato plant. The observed plant canopy spread in T₃ and T₄ in this study was probably enhanced by improved plant nutrients in the soil [62,63,64,65] that stimulated photosynthesis. The higher organic fertilizer application rate can be used by smallholder vegetable producers to restore soil fertility [67,68] to increase productivity because they are rich in nitrogen (N), phosphorous (P) and potassium (K) [61].

Table 2. Mean tomato canopy diameter (cm) of as influenced by organic fertilizer.

Treatments	Canopy diameter (weeks after transplanting)					
	1	2	3	4	5	6
T ₁	7.48 ^c	10.50 ^c	14.89 ^c	21.07 ^u	33.84 ^u	48.43 ^u
T ₂	8.84 ^{uc}	12.96 ^{uc}	20.12 ^{uc}	26.54 ^u	43.74 ^u	63.53 ^u
T ₃	10.31 ^{au}	15.90 ^{au}	25.77 ^{au}	36.62 ^a	63.37 ^a	92.64 ^a
T ₄	10.77 ^a	16.83 ^a	27.62 ^a	39.92 ^a	69.84 ^a	100.70 ^a
Significance	**	**	**	**	**	**
LSD 0.05	1.73	3.19	6.02	9.19	17.54	15.54
CV (%)	9.27	11.35	14.06	14.82	16.66	26.24

Highly significant at $P < .001$, Means separated by Least Significance Difference (LSD) Test at $P = .05$. Means within columns followed by the same letters are not significantly different. Where T₁, T₂, T₃ and T₄ are application

rates of 0 (control), 5.0, 7.5 and 10.0 kg m⁻² respectively and week 1 to week 6 are dates from 15-12-14 to 19-01-15 respectively.

3.4 Leaf Number

There were significant differences statistical in leaf number across treatments from week 1 to 6 (Table 3). The number of plant leaves in T₁ was significantly lower than the other treatments throughout the study. There were no significant differences statistical between T₂ and T₃ from week 1 to 3. Plants grown in T₄ produced significantly more leaves than T₁ and T₂ throughout the study, however no significant difference was observed between T₃ and T₄ (Table 3). These results show that overall, the number of tomato plant leaves increased with increasing application rate of organic fertilizer. This is in agreement with [68, 69] who reported that plant leaves increased with increasing organic manure application rate. According to Mohapatha and Das [70] and Dinesh *et al.* [71] organic manure enhances plant vegetative growth and biomass production in crops and stimulate photosynthesis because it increases carbon, nitrogen, pH, cation exchange capacity and exchangeable Ca, Mg and K [72].

Table 3. The effect of organic fertilizer on tomato leaf number.

Treatments	Leaf number (weeks after transplanting)					
	1	2	3	4	5	6
T ₁	3.13 ^c	5.50 ^c	13.63 ^c	15.77 ^c	31.47 ^c	62.93 ^c
T ₂	4.53 ^u	8.57 ^u	16.93 ^u	21.63 ^u	42.83 ^u	85.67 ^u
T ₃	5.00 ^{du}	9.90 ^{du}	19.67 ^{du}	28.20 ^a	56.07 ^a	112.13 ^a
T ₄	6.10 ^a	11.77 ^a	23.10 ^a	31.67 ^a	62.47 ^a	124.93 ^a
Significance	**	**	*	**	**	**
LSD 0.05	1.28	2.43	5.96	5.57	10.64	21.28
CV (%)	13.68	13.60	16.26	11.47	11.04	11.04

Highly significant at $P < .001$, significant at $P = .05$. Means within columns followed by the same letter are not significantly different. Where T₁, T₂, T₃ and T₄ are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m⁻² respectively and week 1 to week 6 are dates from 15-12-14 to 19-01-15 respectively.

2.5 Fruit Number

Table 4 shows that fruit harvesting started seven weeks after transplanting. The results show that the effect of organic fertilizer application rates on tomato fruit number was highly significant across the treatments from week 7 to 12. These results show that more fruits per plant were harvested from T₃ in week 7 which was not significantly different from T₄, but significantly higher than T₁ and T₂. A similar trend was observed in week 8 and 9. The number of fruits harvested per plant in T₁ was significant lower compared to other treatments throughout the harvesting period. No significant difference was observed in the number of fruits harvested per plant across the organic fertilizer amended treatments in week 10. Furthermore, results reveal that T₄ produced a highly significantly number of fruits than other treatments in week 11 and 12 (Table 4). The organic fertilizer produced more fruits per plant than the control which could be attributed to improvement in the soil physical, biological properties and nutrient availability [73,74,75]. The findings are supported by studies conducted elsewhere [22,28,29,31,32,33,69,76,77,78,79,80,81,82,83,84,85,86,87,88] which reported increased crop yield in soils amended with organic fertilizers.

Table 4. Mean tomato fruit number as influenced by organic fertilizer.

Treatments	Fruit number (weeks after transplanting)					
	7	8	9	10	11	12
T ₁	0.33 ^c	3.67 ^c	16.33 ^c	17.00 ^u	12.67 ^c	15.67 ^c
T ₂	9.00 ^u	27.67 ^u	45.33 ^u	53.67 ^a	47.67 ^u	54.00 ^u
T ₃	18.33 ^a	54.67 ^a	66.67 ^a	69.00 ^a	60.67 ^u	75.00 ^u
T ₄	13.67 ^{du}	23.33 ^u	58.00 ^{du}	68.00 ^a	95.67 ^a	116.67 ^a
Significance	**	**	**	**	**	**
LSD 0.05	7.17	15.26	17.05	18.06	27.58	39.19

CV (%) 34.74 27.94 18.32 17.42 25.49 30.02

Highly significant at $P < .001$. Means within columns followed by the same letter are not significantly different. OF is organic fertilizer. Where T_1 , T_2 , T_3 and T_4 are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m⁻² respectively and week 7 to week 12 are dates from 26-01-15 to 02-03-15 respectively.

3.6 Fruit Weight

The fruit weight recorded for three consecutive harvests is shown in Table 5. Fruit weight of the first harvest was highly significant across the treatments. Fruits harvested from T_4 were significantly heavier than the rest of the treatments. The weight of fruits harvested from T_2 and T_3 was significantly different but significantly heavier than T_1 . The control (T_1) produced fruits with weight significantly lower than other treatments. Prior studies have shown that organic fertilizers improved soil fertility, productivity and thus enhance crop quality and yield [51,71,89,70,90,91]. The findings are in agreement with the present study.

Table 5. The effect of organic fertilizer on tomato fruit weight (g).

Treatments	Fruit weight (weeks after transplanting)		
	Week 7	Week 8	Week 9
T_1	31.56 ^c	40.68 ^c	47.74 ^c
T_2	44.93 ^u	54.65 ^{au}	57.51 ^{uc}
T_3	44.80 ^u	51.23 ^{au}	65.44 ^{au}
T_4	62.46 ^a	66.47 ^a	71.09 ^a
Significance	**	*	*
LSD 0.05	11.89	16.44	13.28
CV (%)	12.96	15.45	11.00

Highly significant at $P < .001$, significant at $P = .05$. Means within columns followed by the same letter are not significantly different. Where T_1 , T_2 , T_3 and T_4 are application rates of 0 (control), 5.0, 7.5 and 10.0 kg m⁻² respectively and week 7 to week 9 are dates from 26-01-15 to 09-02-15 respectively.

4. CONCLUSION

Measured productive parameters performances increased with increase in application rate of organic fertilizer with the highest application rate 10 kg m⁻² outperforming the rest. The use of organic fertilizer is therefore recommended to smallholder farmers because its components are readily available to most farmers in Botswana.

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