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Effect of different chemical fertilizers and application rate on tomato growth and yield

Masoso Freddy[1], Zingwari Obey A[2], Mutetwa Moses[3], Zendera Willard[4*]
[1] Chinhoyi University of Technology, Faculty of Agricultural Sciences and Technology, Zimbabwe
[2, 4] Bindura University of Science Education, Faculty of Science and Engineering, Zimbabwe
[3] DPhil Research Fellow, Midlands State University, Faculty of Natural Resource Management and Agriculture, Zimbabwe

Abstract
This present study was done to evaluate the effect of different basal chemical fertilizers singly and in combination at varying application rates on the growth and yield attributes of tomato (*Lycopersicon esculentum* Mill.). The field experiment was carried out in a randomized complete block design (RCBD) as a 3 x 3 factorial trial treatment with four replicates. Data was collected on number of: leaves, branches, fruits, flowers; plant height and fruit yield. All the collected data were subjected to statistical analysis. The results revealed that there were significant ($p< 0.05$) differences in number of: leaves, branches, fruits, flowers; plant height and fruit yield. In these parameters, the highest mean values were registered in treatment F3Compound D + Gypsum (combination of chemical fertilizers Compound D + Gypsum) than those in the chemical fertilizers applied alone or control treatment. The highest mean yield was significant from treatment A1300kgs with the highest application rate. The result determined that application of chemical fertilizers F3Compound D + Gypsum x A1300kgs can increase the growth and total yield in tomato cultivation over the standard control.

Keywords: tomato (*Lycopersicon esculentum* Mill.), chemical fertilizer, application rate, growth, yield

1. Introduction

Tomato (*Solanum lycopersicum*) is one of the most important high value vegetable crops grown around the world [1]. It is the second-most important vegetable in the world after potato [2], with an estimated world production of 182 million tons in 2017 [3]. Tomato, in terms of dollar value, is the second largest crop consumed in the world [4]. Tomato is an exceptional source of health-promoting compounds owing to the balanced mix of antioxidants as well as vitamins C and E, beta-carotene, lycopene, flavonoids and lutein [2], fatty acids, carbohydrates, proteins and amino acids [5]. Tomato is also rich in macronutrients, especially K [6], Ca, Mg and P [7] and has high quantities of trace elements such as Cu, Zn, Fe and Mn. Tomatoes, can play a vital role in preventing cancer, for instance lung and prostate cancer, breast, mouth, stomach, cervix, pancreas, esophagus and colo-rectum and cardiovascular diseases in humans [8, 9, 10, 11, 12]. Tomatoes are a source of raw materials to other food industries for the reason that they are used to make tomatoes sauces, soups and they are used in canning of food such as fish, beans and jams.

In Africa, soil nutrient balances are continuously negative due to low and unsuitable fertilizer utilizations, and soil nutrient depletion is the most important cause for diminishing agricultural output for most soils in the tropics [13, 14]. Low fertility status of vast areas of tropical lands that can be used once fertile has been exacerbated by continuous cultivation without adequate soil fertility enhancement measures [15, 16] and erosion which caused decreased cation exchange capacity (CEC), loss of soils organic matter (SOM) and physical disintegration and as well as increased Mn and Al toxicity [17]. The challenge of low fertility status of most tropical soils has demanded a growing exploration for many soil fertility improvement techniques, such as embracing sufficient and appropriate fertilizer packages, involving the use of combinations of inorganic fertilizers. The tomato crop is very much responsive to nitrogen (N) fertilizer application were N availability may be limited and time of application is critical [18]. Consequently, management of N fertilizer such as type of N fertilizer, rate and application time is very vital [19]. Nitrogen a major element for plant growth and development has an important role in plant nutrition and for that reason is a yield-limiting factor for plant growth especially in low organic soils. As reported in [20] that N fertilizer influence leaf number per plant, plant height, fruit number per plant, mean fruit weight and total yield per plant in tomato crops. Nutrients, when applied in adequate quantity, increase fruit quality, fruit size, colour, and fruit taste of tomato.

However, farmers in Zimbabwe still apply inefficient combinations and insufficient nutrient inputs. As a result, uneven soil nutrient compositions in due course lead to a decline in crop yield [21]. While mineral fertilizer application increase crop yield, the economic affordability by smallholder agrarians ought to also be considered. So, care of balanced plant nutrients source in an integrated manner is critical for crop nutrition improvement [22] and economic benefit. Integrated nutrient supply is the most practical and resourceful way to mobilize all the accessible, affordable and available plant nutrient sources in order to enhance the productivity and economic return to the farmer [23]. Therefore, the chief objective of this experimental study was to determine agronomically suitable combinations of mineral fertilizer on tomato under field conditions.

2. Materials and Methods

2.1 Experimental Details

Tomatoes used in this research study were grown in Takavarasha, Chivi District in natural region four of Zimbabwe. The region receives rainfall of less than 400 mm per year and the average temperature ranges from 28ºC to 30ºC. Takavarasha lies at an altitude of 811m above sea level, longitude 30.5833º and latitude of 20.5º.

The experiment was laid out in a Randomized Complete Block Design involving four replications. Factors applied were as follows; three types of fertilizers,

F1 - [Compound D (7%N, 14%P_20_5, 8%K_20)],

F2 - [Gypsum ($CaSO_4$:$2H_20$, 23% Ca and 19% Sulphur)] and

F3 - [Compound D + Gypsum] combination of 1:1 ratio.

The second factor was rate of application of the fertilizer with three rates namely;

A1 - [50 kg ha^{-1}],

A2 - [100 kg ha^{-1}] and

A3 - [200 kg ha^{-1}].

Seedlings of a variety *Tengeru 97* were transplanted at 6 weeks old into plots which measured 3m by 2.5m. The different levels of fertilizer treatments were applied during the transplanting stage. Each plot had a total of 30 plants spaced at 30cm in-row and 80cm between rows. The plots were kept weed free throughout the experimental duration. Disease control measure employed the application of Copper Oxychloride 50% at ten-day intervals @ 2 kg ha^{-1} active ingredient up to the reproductive stage to prevent fungal diseases. Dimethoate was sprayed at two-week intervals to protect from sucking and leaf eating insect pests. Rate of application of dimethoate was 75ml into 100 litres of water per hectare. All other agronomic practices for general tomato practices remained the same. Irrigation was also done to supplement the rain and the plots were kept free from moisture stress.

2.2 Data Collection

Data collection was done on the following parameters at different intervals;

Plant height: Plant height was measured using string and a 5 m steel tape from the five plants randomly chosen plants in the middle row in each plot at 2, 4, 6, 8 and 10 WAT.

Number of leaves and branches: This was determined by counting the branches and matured leaves from five plants in the middle row of each treatment randomly and an average was calculated by dividing the total number of branches and leaves with the number of sampled plants.

Number of flowers and fruits: The number of flowers per cluster per plant and number of fruits per plant was determined from the five plants in the middle row of the plot randomly chosen and an average was calculated by dividing the total counts with the number of sampled plants.

Yield: The fruit weight was measured of all the harvested tomatoes in each plot and was measured using a 30 kg Atrontec digital scale (0.001) to determine the yield of tomatoes per plot. The yield per plot was converted to be expressed in kg/ha.

2.3 Data analysis

Data collected was statistically analyzed for Analysis of Variance (ANOVA) using GENSTAT Statistical package (version 14th) software. Differences between means were determined using the Least Significant Difference (LSD) test at 95% confidence level.

3. Results and Discussion

The results obtained from the present study as well as relevant discussion have been summarized under following headings:

3.1 Plant Height

The effect of fertilizer application on plant height was significant ($p<0.05$) over the Control as registered in Table 1. Fertilized plants had an overall height of 59.73 cm while plants from the Control treatment had height of 50.22 cm. Effect of type of fertilizers on plant height was significant ($p<0.05$) with treatment F3 recording the tallest (64.21 cm) plants while treatment F1 and F2 recorded plant height of 59.46 cm and 55.52 cm respectively.

The overall amount of fertilizer applied had significant ($p<0.05$) influence on plant height with treatment A3 registering the tallest (66.04 cm) plants.

3.2 Number of Branches

Comparison between the Control treatment with fertilized treatment shows that the effect of applying fertilizer was positively significant ($p<0.05$) on number of branches. Application of fertilizers produced 7.07 more branches than Control treatment. Fertilizer type differed significantly with treatment F1 and F3 producing the most branches, 34.40 and 36.73, respectively. On the other hand, effect of the amount of fertilizer applied was significant ($p<0.05$) on number of branches. Plants from treatment A3 (38.12) produced the most number of branches followed by treatment A2 (33.87) and treatment A1 (29.72) the least number of branches.

3.3 Number of Leaves

There was significant ($p<0.05$) number of leaves recorded with use of different fertilizer types and rate of application (Table 1). The application of treatment F3 recorded significantly higher number of leaves (120.7) than all other treatments. Treatment A3 at fertilizer application rate of 200 kg ha^{-1} produced the highest number (123.5) of leaves followed by treatment A2 (114.5) and then treatment A1 (102.3), respectively.

3.4 Number of Flowers

The pooled data pertains to number of flowers (Table 1) revealed that the number of flowers per plant differed significantly ($p<0.05$) with application of type of fertilizer and rate of application. Treatments with fertilizers versus the Control produced more number of flowers. Application of fertilizer at treatment level F3 registered the highest number (27.53) of flowers followed by F1 (25.29) and then F2 (21.01). Data pertaining to effect of rate of fertilizer application on production of leaves reveal that most flowers (29.90) were recorded from applying 200 kg ha^{-1} followed by 100 kg ha^{-1} and then 50 kg ha^{-1} with 23.29 and 20.65 flowers, respectively.

3.5 Number of Fruits

Data in Table 1 shows that there was significant difference ($p<0.05$) in the number of fruits with respect to fertilizer type and fertilizer application rate. The pooled data reveal that significant higher fruits were recorded from treatment level F3 (34.1) while treatment F1 and F2 recorded an average number of fruits of 22.70 and 16.80, respectively. On the other hand, the pooled data pertaining to the effect of rate of fertilizer application was also significant ($p<0.05$). The fertilizer application rate was highest in the order of 200kg ha^{-1} > 100 kg ha^{-1} > 50 kg ha^{-1}; that is, 35.8, 25.5 and 12.3 fruits respectively.

3.6 Fruit Yield
The data related to final fruit weight (Table 1) differed significantly ($p<0.05$) between type of fertilizer and also between fertilizer application rate. The effect of type of fertilizers recorded significantly highest test weight in F3 (29 675 kg) in comparison to F1 (25 982 kg) and F2 (21 679 kg), respectively. The effect of fertilizer application rate recorded significantly highest test weight in A3 (36 726 kg) in comparison to A2 (22 810 kg) and A1 (17 799 kg), respectively.

Table 1

Treatments	Parameter					
	Height	***Branches***	***Leaves***	***Flowers***	***Fruits***	***Yield***
Effects of Fertilizer						
Fertilized	59.73^y	33.90^y	113.4^y	24.61^y	24.6^y	25778.0^y
Control	50.22^z	26.83^z	98.8^z	20.25^z	7.5^z	15071.4^z
Significance	<0.001	<0.001	0.002	0.002	<0.001	0.002
$LSD_{0.05}$	4.460	3.239	8.91	2.560	8.31	6308.74
Effects of type of Fertilizer (F)						
$F1_{Compound\ D}$	59.46^y	34.40^y	114.8^x	25.29^y	22.7^z	25982.1^{zy}
$F2_{Gypsum}$	55.52^z	30.57^z	104.7^z	21.01^z	16.8^z	21678.9^z
$F3_{Compound\ D\ +\ Gypsum}$	64.21^x	36.73^y	120.7^x	27.53^x	34.1^y	29675.0^y
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	0.009
$LSD_{0.05}$	3.455	2.509	6.90	1.983	6.44	4886.73
Effects of the amount of fertilizer (A)						
$A1_{50\ kgs}$	52.87^z	29.72^z	102.3^z	20.65^z	12.3^z	17798.8^z
$A2_{100\ kgs}$	60.28^y	33.87^y	114.5^y	23.29^y	25.5^y	22809.5^y
$A3_{200\ kgs}$	66.04^x	38.12^x	123.5^x	29.90^x	35.8^x	36725.6^x
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{0.05}$	3.455	2.509	6.90	1.983	6.44	488.673
F*A						
Significance	0.020	0.032	0.023	<0.001	0.002	0.161
$LSD_{0.05}$	5.983	4.346	11.92	3.435	11.15	8464.07
Control	50.22	26.83	98.8	20.25	7.5	15071.49
Significance	<0.001	<0.001	0.002	<0.001	<0.001	0.002
$LSD_{0.05}$	4.885	3.549	9.76	2.805	9.10	6910.88

4. Discussion
Results indicate that it is only when the fertilizer application rate is increased to 200 kg ha^{-1} that the distinct advantages to plant growth of applying a combination of compound D plus gypsum becomes evident. Compound D contains nitrogen, phosphorus and potassium; its supplementation with gypsum containing calcium and sulphur increased the spectrum of essential mineral nutrients to the tomato plant, boosting plant growth as shown by the significantly higher plant height, number of branches and leaves in this treatment compared to when gypsum was applied and the untreated control. As noted by [24] that the improvement in vegetative growth was due to increased N availability in the soil nutrient pool and its uptake. Increase in N supply leads to utilization of carbohydrates to form protoplasm and more cells, the improved growth is quite in consonance with increase in N application. Nitrogen is crucial for formation of chlorophyll which gives plants the green colour and permits plants to turn solar energy to sugars used for growth [25]. Potassium on the other hand plays an essential role in many critical processes such as synthesis of proteins, cell extension, photosynthesis and phloem transport [26,27]. The results are correlated to findings by [28, 29, 30] that plant growth rate were improved due to foliar application of potassium and calcium compound under stress conditions.

The interaction between potassium and calcium produced the tallest plants [28]. Calcium application increases plant height by activating enzyme for cell mitosis, division and elongation [31, 32] observed that Calcium, Mg and their interaction significantly increased plant height.

Results pertaining to number of branches for tomato plants conform to a study by [33] in which he found an increase in the number of branches with fertilizer application increase. Significantly higher number of primary, secondary, and tertiary branches per plant with the application of 250:75:75 kg NPK ha^{-1} in chilli were also observed by [34]. The numbers of branches per plant increased with an increase in application of nitrogen [35].

The lowest numbers of branches per plant between the type of fertilizer was found in gypsum, but the numbers of branches per plant were higher than the control because it does not contains other essential nutrients like N, P and K. As observed by [36] that Ca in combination with other mineral nutrients were more effective than individual application in increasing the number of branches per plant.

Flower formation is improved as soil N concentration increased as a result of N fertilizer [37]. Nitrogen helps in flowering and fruit set, a similar function found by [38] while P affects flowers and seed production [39, 40]. Phosphorus nutrition promotes flowering and fruit set but excess of it postpones fruit maturity and diminishes fruit size [41]. As stated by [42] potassium helps in vigorous growth and also stimulates in early flowering and setting of fruits, thereby booming the numbers of fruits per plants.

The results of the study show that the number of fruits per plants which were applied gypsum was higher than the control and the reason may be that calcium promotes the germination and growth of the pollen tube. Similar results were noted by [36] the number of fruits per plant improved with NPK fertilizers but these were further improved significantly with addition of Calcium carbide. Calcium increase yield of tomato by flower drop reduction but also better fruit retention [43, 44]. As reported by [45] reported that the number of fruits per plant was amplified by application of Ca^{+2} and N in strawberry and is comparable to results of this present study.

The yield results obtained agreed with [46] who stated that application of micronutrient with NPK fertilizer demonstrated higher weights of tomato pulp and fruit over NPK fertilizer alone. As reported by [47, 48, 49], they credited the better yield to the thickness of the improved pericarp and dry matter contents of fruit as a result of increased application of micronutrients, in this case from the gypsum. As cited by [50] stated that application of macro- and micro-nutrients increase the fruit weight and fruit yield. Similarly, [51, 52, 53, 54, 55, 56] also reported an improved tomato yield when mineral fertilizer was applied in mixture with other mineral fertilizer sources. In the present study, soil application of fertilizers comprising micronutrient improved pulp and fruit weights of tomato than in the control.

5. Conclusion

Several fertilizer combination alternatives, though agronomically superior, may fail to be adopted by farmers for the reason of commercial feasibility. Given the dissimilar response to different types of fertilizer, we can recommend a particular amount of a specific type of fertilizer for combination with Compound D (7:14:7) chemical fertilizer. Conferring to the results, where the criterion for fertilizer selection and its application rate is established on the overall plant growth and total yield, then the following fertilizer regime can be recommended: combination of Compound D (7:14:7) + Gypsum at an application rate of 300 kgs ha^{-1} for a maximum yield.

For commercial cropping, facets supplementary to crop yield come keen on play, and in the present study several other crop and fruit attributes, besides gross yield, were stated (Tables 1). Other reflections such as the availability of the gypsum fertilizers, the security of supply, and the different supply costs of fertilizers, as well as the altered costs of the application and management of the various fertilizers, will be further significant contemplations for commercial cropping and are worthy of further research.

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Conflict of Interests

The authors declare that there is no conflict of interest, financial or otherwise regarding the publication of this paper.

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