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Effect of Poultry Manure and Different Combinations of Inorganic Fertilizers on Growth and Yield of Four Tomato Varieties in Ghana

Agyeman, K.[1], I. Osei-Bonsu[1], J. N. Berchie[1*], M. K. Osei[1], M. B. Mochiah[1], J. N. Lamptey[1], Kingsley Osei[1], and G. Bolfrey-Arku[1]

[1]CSIR-Crops Research Institute, P.O. Box 3785, Kumasi, Ghana

*Correspondence: Dr. Joseph Nketiah Berchie, CSIR-Crops Research Institute. Tel: +233243709476; E-mail: jnberchie@yahoo.com

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Abstract

The agronomic response of four tomato (*Solanum lycopersicum L.*) varieties to fertilizer application was examined at the CSIR-Crops Research Institute, Kwadaso-Kumasi in the Forest agro-ecological zone of Ghana during the 2013 growing season. The four tomato varieties Shasta, Heinz, CRI POO and CRI 034 were evaluated on five different fertilizer types using a split plot arrangements in randomized complete block design with three replications. The Tomato varieties were the main plots, with the fertilizer treatments as the subplots. The CSIR-CRI breeding lines (CRI P00 and CRI P034) were able to yield higher than the exotic varieties. Using Winner fertilizer (6 g/plant at two weeks after transplanting (WAT)) and Sulfan (3 g/plant at 4 WAT) CRI P00 produced the highest yield (26.4 t/ha) followed by chicken manure (250 g/plant at 2 and 4 WAT) (23.1 t/ha). CRI P00 with Winner + Sulfan fertilizer application also produced significantly ($p \leq 0.05$) higher fruit yield (26.4 t/ha). Fertilizer application however did not have any significant effect on the days to flowering over the control.Fertilizer application however, increased the number of branching for the tomato plants with Unik15 + Urea having significantly more branches compared to the control. Results from this study showed that tomato yields in the Forest zones in Ghana can be increased using improved varieties and recommended fertilizer rates.

Keywords: tomato, *Solanum lycopersicum*, split plot, varieties, branching, fruit yield

1. Introduction

Tomato (*Solanum lycopersicum L.*) is a very important vegetable cultivated and consumed in most parts of the world, from home gardens and greenhouses to large commercial farms due to its wideradaptability to various agro-climatic conditions. Several different varieties of tomato are cultivated to serve various culinary and processing needs of consumers.

In Ghana, tomatoes are often used in large quantities as compared with other vegetables (Ellis, Olympio, Mensah, Adu-Amankwa, & Tetteh, 1998) and therefore it is imperative that local production be able to meet local consumption. However, this is not the case. This has resulted in high importation of tomato and tomato products to meet the deficit, which has a negative effect on the nation's economy.

There has been a gradual increase in the area of land cropped to tomato and this led to marginal increases in tomato production from 2009 to 2012 (FAOSTAT, 2013). Nevertheless, the yield (per hectare) of tomatoes in Ghana is among the lowest in the world. In 2012, the average yield of tomatoes in Ghana stood at 7.2 t/ha compared to a world average of 33.7 t/ha (FAOSTAT, 2013). According to Robinson and Kolavalli (2010) Ghana's tomato sector has failed to reach its potential in terms of attaining yields comparable to other countries among others.

Though agricultural productivity in general is constrained by several factors such as soil fertility, pests and diseases, Mbah (2006) asserts that soil fertility is a major overriding constraint that affects all aspects of crop production. As is the case in other regions in Africa, local farmers use inadequate nutrient inputs, inappropriate quality and inefficient combinations of fertilizers, which in the end prove to be very costly (Palm, Myers, & Nandwa, 1997). A consequence of this trend is a deeply unbalanced soil nutrient composition that ultimately leads to a reduction in crop yield potential (Tonfack *et al.*, 2009).

In order to increase the productivity of tomato in Ghana, there is a need to breed for high yielding and disease resistant varieties coupled with the use of appropriate fertilizers applied at the appropriate rate and timing. In this regard new varieties have been developed by the Council for Scientific and Industrial Research–Crops Research Institute (CSIR-CRI), in Ghana. New fertilizer formulations and combinations have also been developed by other companies. Poultry manure has a higher total solid content than most other types of manures from animal species such as swine, turkey and cattle and is considered a rich source of organic fertilizer for crop production (Nguyen, 2010).

When new fertilizer formulations are developed, they need to be tested on target crops under field conditions in order to determine their efficacy. The current study was therefore conducted to determine the effect of different fertilizer combinations, types and rates of applicationon the yield of four tomato varieties at the CSIR-Crops Research Institute, Kwadaso, Kumasi-Ghana.

2. Materials and Methods

The experiment was conducted on the experimental fields of the Kwadaso Station of CSIR-CRI, Kumasi, Ghana during the latter part of the major rainfall season of 2013 with supplemental irrigation. The design of the experiment was split plot with three replications. The four tomato varieties used namely; CRI P00, CRI P034, Heinz and Shasta served as the main plot with fertilizer combinations as the sub-plot treatments. The first two varieties are being developed by CSIR-CRI whereas the last two were exotic varieties from USA. The five fertilizer combinations used were:

1. Unik 15 + Urea: YaraMila Unik 15 (6 g/plant) at 2 WAT and Urea (3 g/plant) at 4 WAT
2. Winner + Winner: YaraMila Winner (6 g/plant) at 2 WAT and YaraMila Winner (3g/plant) at 4 WAT
3. Winner + SULFAN: YaraMila Winner (6 g/plant) at 2 weeks after transplanting (WAT) and YaraBelaSULFAN (3 g/plant) at 4 WAT
4. Manure: Chicken manure @ 250g per plant at 2 WAT and 4 WAT
5. Control: No fertilizer application

The nutrient composition of the fertilizer types are as follows:

- **Unik 15:** 15:15:15 (N:P:K)
- **Sulphan:** 24 % N, 6% S (12NO_3, 12 NH_4)
- **Winner:** 15:9:20 + 1.8 MgO + 3S + 0.02 Z + 0.15 B + 0.02Mn

Four weeks old tomato seedlings were transplanted unto ridged beds at a plant spacing of 60cm x 40 cm between and within rows. The plot dimensions for the sub-plots were 1.2 m x 4.8 m with a 1.5 m and 2 m alley between sub-plots and main plots respectively.

Insecticides (Golan: 20 mL /15 L, Karate 25mL /15 L) and fungicides (Karate: 50 mL/15 L) were applied at the vegetative, flowering and fruiting stages. Staking was also done to prevent the plants from falling under the weight of the fruits. However, no pruning was carried out on the plants. Irrigation was done as and when necessary.

The following data were taken: plant height (from the base to the apex) at 2 WAT and at flowering, number of branches per plant at flowering, days to 50% flowering and 50% fruit set, days to maturity, fruit number per plant, fruit weight per plant (kg), and fresh fruit yield (t/ha). All the data were taken from the middle row. Three plants within the middle row were randomly selected, tagged and used to determine the growth parameters as well as the yield (fruit number and weight) per plant. Harvesting of mature fruits at the orange to red stage was done twice weekly from 49 DAT to 79 DAT.

Soil samples were randomly collected from four different cores at 0-15cm and 15-30 cm for determination of soil physical and chemical properties beforetransplanting. Data was analyzed using GENSTAT software Discovery Edition 4.

3. Results and Discussion

3.1 Soil Analysis

Table 1 gives the results of soil analysis. Soil PH within the top 30 cm was acidic (5.3-5.4). Soil texture was sandy loam which enhances drainage. Sandy loam with well drained clay sub soil with PH of 6.0-7.0 has been considered favourable for tomato cultivation (My Agriculture Information Bank, 2014)

Table 1. Results of soil analysis

					Bray's Available		Exchangeable Cations m.e. 100^{-1}g			
Depth	PH	O.C	O.M	N	ppmK	ppmP	Ca	Mg	K	Na
0 – 15 cm	5.33	1.87	3.2	0.16	100.44	106.27	3.49	0.8	0.11	0.03
15 – 30 cm	5.42	1.56	2.7	0.14	55.8	3.75	2.94	0.8	0.05	0.03

Depth	TEB	Ex. Acidity	ECEC	% B.S	% Sand	% Silt	% Clay	Texture
0-15 cm	4.42	0.45	4.87	90.76	65.62	28.38	6	Sandy loam
15-30 cm	3.82	0.4	4.22	90.52	63.7	28.3	8	Sandy loam

3.2 Days to Flowering

There was significant difference ($p<0.05$) between the varieties with respect to the number of days to flowering (Table 2). Variety CRI P034 was the earliest to flower (25.7 DAT), closely followed by CRI P00 (27.9 DAT) with Heinz flowering last (33.5 DAT).

On the contrary, fertilizer application did not have any significant effect on the days to flowering over the control (Table 2). This implies that fertilizer application did not provide any advantage with respect to days to flowering.

3.3 Growth Parameters

CRI P034 and CRI P00 had significantly ($p<0.05$) higher number of branches (7.5 and 6.3) than Shasta and Heinz (5 and 4.5) (Table 2). Since tomato fruits are borne on the branches, having more branches may result in more fruit number. Shasta recorded the greatest plant height (73.1 cm) among the varieties whereas CRI P00 produced the shortest plants (61.8 cm). Duman (2006) found that in lettuce, tall plants were able to compete better with weeds in terms of sunlight interception and this had a positive effect on yield and total dry matter.

Fertilizer application increased the number of branching for the tomato plants with Unik15 + Urea having significantly more branches compared to the control (Table 2). Significant differences ($p<0.05$) were also observed among treatments with respect to plant height. Plants that received Unik 15 + Urea fertilizers again recorded the highest plant height (70.2cm).Tall tomato plants that produce more vegetative growth have reduced incidence of sunburned fruits (Eivazi, Rastergarni, Habibzadeh, Mogaddam, & Khlilzadeh, 2013). The control, which had no additional nutrients, had relatively shorter plants (62.0 cm) and this was significantly different from the plants that received chicken manure, Winner + Winner and Winner + Sulfan (Table 2). This observation is in agreement with results of Oyewole, Opaluwa, and Omale (2012) who reported that chicken manure applied at a rate of 150 kg/ha and 300 kg/ha produced taller plants compared to the control.

3.4 Yield of Tomatoes

The tomato varieties differed significantly ($p<0.05$) in total fruit yield (Table 2). The CSIR-CRI breeding lines (CRI P034 and CRI P00) had significantly ($p<0.05$) higher fruit yields (20.9 t/ha and 17.8 t/ha respectively) compared to the introduced varieties Shasta and Heinz (13.2 and 8.2 respectively) (Table 2). CRIPO34 one of the materials being developed by the CSIR-Crops Research Institute yielded over 250% times the yield of Heinz one of the exotic types. The higher yield observed in the CSIR-CRI breeding lines over the exotic varieties could be due to inherent genetic differences that enabled better utilization of nutrients leading to production of more branches and higher weight of fruits per plant as well as a better adaptation to the local environment.

Similarly, the analysis of variance for the fertilizers showed significant differences ($p<0.05$) among treatments with respect to fruit yield (Table 2). The application of the chicken manure produced the highest fruit yield (17.2 t/ha). The lowest fruit yield (11.5 t/ha) was obtained with the control (No fertilizer) treatment. Chicken manure treatment yielded about 50% higher than the yield of the control. Results obtained showed the positive effect of poultry manure on tomato yield which compares well (in this case even slightly higher) with the yield obtained by mineral fertilizers such as Winner + Winner and Winner + Sulfan. This benefit of poultry manure has been reported by other researchers (Mehdizadeh, Darbandi, Naseri-Rad, & Tobeh, 2013; Oyewole *et al*., 2012; Adekiya & Agbede, 2009; Olaniyi & Ajibola, 2008). This may be possibly explained by the fact that the poultry manure improved the soil physical and biological properties and provided the macro and micro nutrient requirements of the plants (Abou El-Magd, Hoda, & Fawzy, 2005; Stephenson, McCaskey, & Ruffin, 1990), thereby increasing yield. Among the fertilizer treatments, it is possible that the low yield observed with the Unik 15 + Urea treatment may have been caused by a higher allocation of resources to vegetative growth to the detriment of reproductive growth since Unik 15 + Urea treatment produced the tallest plants with more branches (Table 2). Yeboah, Berchie, Asumadu, Agyeman, and Acheampong (2013) using the 'Petomech' cultivar of tomato also obtained similar low yields with the Unik 15 + Urea application in different locations (Fumesua and Ejura) in Ghana.

Table 2. Effect of different fertilizer combinations and types on growth parameters and yield of four tomato varieties

Factor	Days to 50% flowering (DAT)	No. of branches/plant	Plant height at harvest (cm)	Fruit yield (t/ha)
Main plot: Varieties				
CRI P00	27.9	6.3	61.8	17.8
CRI P034	25.7	7.5	67.3	20.9
SHASTA	32.3	5.0	73.1	13.2
HEINZ	33.5	4.5	64.8	8.2
SED	1.0	0.6	4.3	3.4
CV (%)	8.1	21.3	10.6	36.9
Sub-plot: Fertilizer				
Unik 15 + Urea	29.6	6.9	70.2	13.9
Winner + winner	29.4	6.4	67.1	16.5
Winner + Sulfan	29.1	5.8	68.2	16.0
Chicken manure	30.4	5.0	66.3	17.2
Control	30.3	5.1	62.0	11.5
SED	0.9	0.5	2.8	2.3
CV (%)	8.1	21.3	10.6	36.9

3.5 Interactive Effect on Fruit Yield

During 2013 cropping season, significant fertilizer X variety effect was observed on fruit yield (Table 3). The results showed that CRI P00 with Winner + Sulfan fertilizer application produced significantly higher fruit yield (26.4 t/ha) as compared to the other treatments. This yield is higher than the average yield of tomatoes in Ghana (7.2 t/ha) and closer to the world average yield of 33.7 t/ha obtained in 2012 (FAOSTAT, 2013). On the hand, the lowest fruit yield (4.4 t/ha) was recorded with Heinz with no fertilizer application.

The significant difference in fruit yield between the four cultivars could be due to their distinct growth habit. All the four nutrient levels differed significantly from each other in influencing fruit yield with inorganic and chicken manure producing higher mean fruit yield (26.4 t/ha and 23.1 t/ha) over lowest fruit yield records of 4.4 t/ha from Heinz with no fertilizer application. For farmers who may not have the funds to purchase fertilizer, it is suggested that chicken manure where available can be applied or a combination of chicken manure and Winner + Winner or Winner +Sulfan at reduced rate may be considered.

Table 3. Interaction between fertilizer (combinations and types) and tomato varieties with respect to days to 50 % flowering, no. of branches per plant, height at harvest, no. of fruits per plant and fruit yield (t/ha)

Tomato variety	Fertilizer	50% Flowering	No. of branches per plant	Height at harvest (cm)	No. of fruits per plant	Yield (t/ha)
CRI P00	Unik 15 + Urea	29.0	8.0	64.8	29.0	18.3
	Winner + Winner	29.0	7.3	60.4	29.0	19.6
	Winner + Sulfan	28.3	5.7	63.2	28.3	**26.4**
	Chicken manure	26.3	5.7	61.7	26.3	**23.1**
	Control	27.0	5.0	59.0	27.0	17.2
CRI P034	Unik 15 + Urea	26.0	9.0	77.6	22.3	15.9
	Winner + Winner	24.7	7.3	70.0	19.3	**20.5**
	Winner + Sulfan	24.7	7.3	69.9	20.7	19.6
	Chicken manure	26.7	7.0	61.8	14.3	**20.3**
	Control	26.3	7.0	56.9	12.3	12.9
SHASTA	Unik 15 + Urea	31.6	6.0	72.9	12.3	11.2
	Winner + Winner	31.3	6.0	72.4	12.0	16.7
	Winner + Sulfan	31.3	5.3	76.5	15.6	10.5
	Chicken manure	34.0	4.0	73.6	18.3	15.8
	Control	33.0	3.7	69.8	11.0	11.4
HEINZ	Unik 15 + Urea	31.7	4.7	65.3	17.3	10.1
	Winner + Winner	32.7	5.0	65.4	15.3	9.5
	Winner + Sulfan	32.3	5.0	63.2	16.7	7.4
	Chicken manure	34.7	3.3	68.1	21.3	9.5
	Control	35	4.7	62.1	9.0	4.4
SED	Variety	1.0	0.56	4.3	3.4	3.4
	Fertilizer	0.9	0.51	2.8	2.6	2.3
	Variety X Fertilizer	2.0	1.06	6.7	5.7	5.3
CV (%)		8.1	21.3	10.6	38.2	36.9

4. Conclusion

In general, the CSIR-CRI breeding lines (CRI P00 and CRI P034) were able to yield higher than the exotic varieties. Using Winner fertilizer (6g/plant at 2 WAT) and Sulfan (3g/plant at 4 WAT) together with CRI P00 variety produced the highest yield (26.4 t/ha) followed by chicken manure

(250g/plant at 2 and 4 WAT) and CRI P00 (23.1 t/ha). CRI P034 together with the split application of Winner fertilizer (6 g/plant at 2 WAT and 3 g/plant at 4 WAT) and chicken manure also produced significantly higher yields (20.5 and 20.3 respectively) compared to the control (12.9 t/ha). The lowest yield obtained with the application of fertilizers (7.4 t/ha) was recorded with the Heinz variety under Winner fertilizer (6 g/plant at 2 WAT) + Sulfan (3 g/plant at 4 WAT). When no fertilizer was applied to Heinz (Control), it recorded the lowest yield (4.4 t/ha) in the present experiment. The choice of varieties and application of recommended fertilizers can help improve tomato yields.

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