#7517 TOMATO YIELD AND ECONOMIC PERFORMANCE UNDER ORGANIC AND MINERAL FERTILIZER APPLICATIONS IN COASTAL TOGO

Jean M. Sogbedji and Mouhamadou Lare
Ecole Supérieure d'Agronomie, Université de Lomé. 01 BP 1515 Lomé 01 Togo,
mianikpo@yahoo.com

ABSTRACT

Research efforts towards enhancing vegetables production are still needed in Togo. We assessed tomato (*Solanum lycopersicum*) yield and associated economic returns under three soil fertility management strategies in a 3-yr period study. Three tomato varieties were used including: MONGAL-F1 (V1), SUMO-F1 (V2) and COBRA 26-F1 (V3). The fertilization regimes were: no fertilizer application as the control (F1), application of 200 kg of $N_{15}P_{15}K_{15}$ + 100 kg of urea (46% N) corresponding to $N_{76}P_{30}K_{30}$ ha^{-1} (F2) and application of farm yard manure (FYM) at the rate of 6 Mg ha^{-1} (F3). The 3-yr period was segmented into two different cropping periods with three tomato crops for each period. The first period runs from October to January and the second runs from the subsequent period of February to May. Tomato fresh fruit yields were collected and were used to determine the net cash return through a partial budget analysis under each variety – fertilization regime combination. Across tomato varieties, three-crop mean yields were 93 to131% and 109 to 144% higher for fertilization regimes F2 and F3, respectively, as compared to yield under the control (F1), and mean yields with F3 were 7.5% on average superior to those for F2. Irrespective of fertilization regime, the MONGAL-F1 mean yields were 6 to 24 and 16 to 31% superior to yields under SUMO-F1 and COBRA 26-F1, respectively, and SUMO-F1 based yields were 6 to 10% higher than those for COBRA 26-F1. Higher economic returns (typically ranging from 9500 to 27000 USD ha^{-1}) were recorded when fertilizers were applied, and lower returns (typically in the range of -131 to 4700 USD ha^{-1}) were obtained with no fertilization, with the highest economic return under the V1F3 combination during the February to May cropping period. Tomato cropping without external mineral and/or organic nutrient input may not be advised for the study area.

Keywords: tomato variety, cropping period, ferralsols, fertilization regime, yield and net cash return

INTRODUCTION

Vegetables production continuously gains importance because of the high nutritional value of its products. These non-traditional crops could revitalize rural economies and contribute to food and nutrition security towards achieving the United Nations Sustainable Development Goals (SDGs). Historically, research and extension in Africa has concentrated on staples (cereals) because of food security. However, to achieve food, nutrition and financial security, vegetables production should be promoted in sub-Saharan Africa (SSA) because of their importance. A recent study conducted in several West African countries by IFDC using the IFAD grant No 1174 (IFDC, 2014) established that vegetable cropping highly contributes to provision of revenues to address key needs including food security, children education, inputs provision for annual crops, and several other social needs for smallholder farmers. Moreover, the value of vegetables (over 3000$ per hectare per year) in Benin, Burkina Faso, Ghana, Niger and Togo is 6 to 10 times that of cereals (150-250$ per hectare per year).

Tomato is one of the most produced vegetables in the world, ranking second after potato (Kalbani et al., 2016). As it is a relatively short duration crop and gives a high yield, it is economically attractive and the area under cultivation is increasing daily (Naika et al., 2005). Moreover, tomatoes contribute to a healthy, well balanced diet and having rich in minerals, vitamins, essential amino acids, sugars and dietary fibers (Kalbani et al., 2016). Although tomato may be produced throughout the year in coastal western Africa, it tends to be abundantly available only part of the year, which leads to very low demands with associated non-economic sale prices along with important postharvest losses.

Some constraints to vegetable production are water deficiency/quality, poor soils, labor, inadequate information on production and processing, low yielding varieties that are susceptible to insect pests and diseases, cost of inputs, and poor infrastructure for processing, storage and transport that contribute to high postharvest losses. In coastal Togo, tomato yields are between 5 and 6 Mg ha^{-1} (ITRA, 2011), which is drastically below the world average yield of 34 Mg ha^{-1} as reported by Debela et al. 2016. To secure and sustain the social and economic potential role of tomato cropping in the region, research is needed towards improving its yields and net cash returns.

The objective of this work was to assess the response of three tomato varieties to three fertilization schemes and the effect of cropping timing on both the productivity and economic profitability of the crop on costal West African ferralsols. The aim was to identify management practices that enhance and secure tomato cropping contribution to social welfare in this agro ecosystem.

MATERIAL AND METHODS

Experimental Site

The study was conducted at the University of Lomé Agricultural Research Station in Lomé, Togo (6°22’N, 1°13’E; altitude = 50 m). The soil type was a rhodic ferralsol locally called “Terres de Barre” that originated from a continental deposit, and covers part of the arable lands in Togo, Bénin, Ghana, and Nigeria in coastal Western Africa. Annual rainfall typically ranges from 800 to 1100 mm and allows for two cropping seasons: a first season from April to July, the main season with a 25-yr average rainfall of 470 mm, and a second season from September to December with a 25-yr average rainfall of 200 mm. At the onset of this experiment, the site has been under continuous mineral (NPK) fertilized maize cropping.

Soil and Crop Management

A 3-yr period (2016-2019) split-plot experiment was settled with three replicates. Three tomato varieties were the main plot effects and three fertilizer schemes were at the subplot level. The site was manually plowed and 9 main plots (4 m x 3 m) were laid out in a randomized complete block design. The three tomato varieties were: (i) MONGAL-F1, V1, (ii) SUMO-F1, V2 and (iii) COBRA 26-F1, V3. Three fertilizer treatments were applied: (i) no fertilizer application as the control (F1), (ii) application of 200 kg of $N_{15}P_{15}K_{15}$ + 100 kg of urea (46% N) corresponding to $N_{76}P_{30}K_{30}$ ha^{-1} (F2) and (iii) application of FYM at the rate of 6 Mg ha^{-1} (F3). Fertilizer treatment F2 is a recommendation by the national agricultural extension services in Togo, and F3 is a recommended FYM-based organic amendment by IFDC (2014).

Six tomato crops were performed during the three years of experimentation in two periods typically embedded in the two cropping seasons. The first period runs from October to January and the second from the subsequent period of February to May, with three crops for each period. During each crop period, tomato was transplanted after three weeks of nursing at a density of 37,000 plants ha^{-1} and weeded as needed. Fertilizer $N_{15}P_{15}K_{15}$ and FYM rates were applied two weeks after transplanting (just after the first weeding) while urea was applied four weeks after transplanting as recommended by the national agricultural research and extension services in the region. In each cropping period of each of the three years, all fertilizers were manually point-placed at approximately 8 cm depth. Plants were chemically treated against diseases and insects and received additional water (apart from rainfall) as needed that was brought through hand watering.

Data Collection and Analysis

Tomato fresh fruit yield was determined under each treatment by harvesting all the plants from each plant bed. The GENSTAT statistical software package was used to run the analysis of variance (ANOVA) on the yield data sets and the Duncan test at 5% was used to discriminate among mean tomato yields. Mean tomato fruit yield data were used to establish a partial financial budget which represents the net profitability of the production under each variety – fertilization combination.

Economic Analysis

The profitability of tomato fresh fruit production in each cropping period was estimated through a partial budget (output value minus inputs cost value) analysis. Output consisted of the amount of cash corresponding to the mean fresh fruit yield under each tomato variety – fertilization scheme combination, which was determined to be sold at 600 CFA (US$1.2) kg^{-1} and at 800 F CFA (US$1.6) kg^{-1}, the average sale price for the first and the second crop periods, respectively. The inputs consisted of the production costs under each combination, including those for soil preparation, seed, crop nursing and transplanting and related tasks, fertilizer purchase and application, crop weeding and crop harvesting and associated tasks. Labor costs were determined to be 2 000 F CFA (US$4.0) per person-day based on labor records from the experiment, and fertilizer costs were based on ongoing prices which were 220 F CFA kg^{-1} (US$0.44) for both $N_{15}P_{15}K_{15}$ and urea. Farmyard manure cost was determined to be 20 000 F CFA Mg^{-1} (US$40.0).

RESULTS AND DISCUSSION

Tomato Fresh Fruit Yield

Tomato mean yields were typically between 8 and 30 Mg ha^{-1} (Table 1) with the lowest yield under the control fertilizer treatment. This reasonably agrees with mean yield range of 10 to 30 Mg ha^{-1} reported by Tesfay et al. 2018 and Rajya et al. 2015 using a control and various combinations of organic and inorganic fertilization schemes. The three varieties were clearly responsive, although differently, to fertilization schemes. Irrespective of tomato variety, three-crop mean yields were consistently highest under fertilization regime F3 and lowest for F1 in both cropping periods. During the first cropping period and for V1, mean yields increased by 95 and 119% under F2 and F3, respectively, as compared to yield under F1, and yield for F3 was 12% superior to that under F2. For V2, F2 and F3 resulted in mean yield increase by 115 and 139% under F2 and F3, respectively, as compared to yield under F1, with F3-based yield being 11% higher than that of F2. Mean yields for V3 increased by 93 and 109% under F2 and F3, respectively, as compared to yield under F1, and yield for F3 was 9% superior to that under F2. In the second cropping period and for V1, mean yields increased by 131 and 144% under F2 and F3, respectively, as compared to yield under F1, and yield for F3 was 5% superior to that under F2. For V2, F2 and F3 resulted in similar mean yield but 122% higher than yield for F1. Mean yields for V3 increased by 103 and 120% under F2 and F3, respectively, as compared to yield under F1, and yield for F3-based fertilization was 8% superior to that under F2. The results of this study demonstrate that enhancement of soil fertility is needed for tomato production in the area of study if high yields are to be achieved, which agrees with research results published by Gorobani et al. 2017 in the area. Organic (FYM) fertilizing regime proved superiority over mineral (NPK)-based fertilization by 7.5% on average. This trend in our yield data sets does not corroborate results by Kochakinezhad et al. 2012 who found that the difference between the two classes of fertilizers (organic and chemical) was not very high (yield under chemical fertilizer was 2.2% higher than that for organic fertilizer), and concluded that organic fertilizers are competitive and may be a suitable replacement for chemical fertilizer. In our area of study, Gorobani et al. 2017 found no-significant difference between tomato yield under FYM fertilizing regime and that under inorganic (NPK) based fertilization. The superiority of organic fertilization over the inorganic fertilization in our study may be explained by the continuous use (six consecutive crops) of organic fertilizer that might lead to more nutrient released for the crop use.

Table 1. Tomato yield (Mg ha^{-1}) and net cash profit (USD ha^{-1}).

Treatment	*Cropping period*									
	October to January					February to May				
	Crop 1	Crop 2	Crop 3	Mean yield	Net cash profit	Crop 1	Crop 2	Crop 3	Mean	Net cash profit
V1F1	10.64c¶	11.94b	10.81c	11.13c	1386	7.74b	13.03c	11.91b	10.90c	4768
V1F2	17.94b	23.10a	23.98b	21.67b	12464	21.97a	24.80b	28.88a	25.21b	25069
V1F3	22.79a	24.25a	26.02a	24.35a	15304	22.09a	27.49a	30.07a	26.55a	26944
Mean	**17.12**	**19.76**	**20.27**	**19.05**		**17.27**	**21.77**	**23.62**	**20.88**	
V2F1	10.65c	9.71c	8.83b	9.73c	-131	8.24c	11.17b	8.57b	9.33b	2502
V2F2	21.23b	19.74b	21.83a	20.93b	11659	15.29a	22.67a	24.06a	20.67a	18525
V2F3	23.58a	23.63a	22.57a	23.26a	14121	13.86b	23.23a	24.83a	20.64a	18428
Mean	**18.49**	**17.70**	**17.75**	**17.98**		**12.46**	**19.02**	**19.15**	**16.88**	
V3F1	9.73b	11,15c	8,48b	9.79c	-58	6.96c	11.03b	9.36b	9.12c	2208
V3F2	16.06a	17.66b	22.94a	18.89b	9464	13.47b	20.49a	21.68a	18.55b	15481
V3F3	16.63a	22.58a	22.28a	20.50a	11149	14.23a	22.55a	23.35a	20.04a	17573
Mean	**14.14**	**17.13**	**17.90**	**16.39**		**11.55**	**18.02**	**18.13**	**15.90**	

¶ Means within the same column followed by the same letter are not significantly different at P = 0.05.

Regardless of fertilization treatment, overall 3-crop mean tomato yields were 19.05, 17.98 and 16.39 Mg ha^{-1} for the V1, V2 and V3, respectively, in the first cropping period, and 20.88, 16.88 and 15. 90 Mg ha^{-1} for V1, V2 and V3, respectively, in the second cropping period (Table 1). Overall mean yield with V1 increased by 6 and 16% as compared to yields for V2 and V3, respectively, while the V2-based yield was 10% superior to that under V3, during the first cropping period. In the second cropping period, mean yield for V1 was 24 and 31 % higher as compared to yields with V2 and V3, respectively, and the V2-based yield was 6% over the yield under V3. These results indicate that within the cropping period, yield potential was consistently highest and lowest for V1 and V3, respectively, and fluctuates between cropping period. The three varieties responded positively to fertilization scheme with a higher response to organic fertilizer and a better performance for V1, indicating that the variety-fertilization regime interaction was measurable. Such variety effects on tomato yield as well as positive crop-fertilization regime interactions were reported by Kochakinezhad et al. 2012 and Ilupeju et al. 2015.

Partial Budget Analysis

Results of the balance of outputs (cash values of tomato fresh fruit mean yield) and corresponding inputs (total costs associated with production) for the three crops within each cropping period are presented in Table 1. On a per hectare basis, except the V2F1 and V3F1 combinations during the first cropping period, the balance was positive in all other cases, indicating that there was profit or net gain. The data sets reveal that higher net returns (typically ranging from 9500 to 27000 USD ha^{-1}) were recorded when fertilizers were applied, and lower returns (typically in the range of -131 to 4700 USD ha^{-1}) were obtained with no fertilization. For the three varieties and within each of the two cropping periods, net returns were consistently higher (15304 to 26944 USD ha^{-1}) with the F3 fertilization regime as compared to returns (9464 to 25069 USD ha^{-1}) when the F2 fertilization regime was used. Net returns were consistently higher for the second cropping period (February to May) with values typically ranging from 2200 to 26944 USD ha^{-1} in comparison to those (-131 to 15304 USD ha^{-1}) for the first cropping period (October to January) primarily because of the higher tomato sale price in the second cropping period. Overall the highest net return (26944 USD ha^{-1}) was recorded for the V1 (MONGAL-F1 variety) combined with the F3 (FYM-based) fertilization regime.

CONCLUSIONS

Enhancement of soil fertility is needed for tomato production in the area of study if high yields are to be achieved. The three varieties responded positively to fertilization scheme with a higher response to organic fertilizer and a better yield-based performance for the MONGAL-F1 variety regardless of cropping timing. The economic profitability of tomato cropping was in general evident and strongly affected by fertilization scheme, crop variety and cropping timing. Tomato production using organic (FYM) based fertilization regime and MONGAL-F1 variety preferably during the February to May cropping period appears to be the best management practices that improve the crop yield and maximize the economic returns in the study zone.

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