

Research Application Summary

Tomato yield and economic performance under organic and mineral fertilizer applications in coastal Togo

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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 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 N₁₅P₁₅K₁₅ + 100 kg of urea (46% N) corresponding to N76P30K30 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 cropping periods with three tomato crops each. 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 to 131% 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 11000 to 15500 USD) were recorded when fertilizers were applied, and lower returns (typically in the range of 250 to 3000 USD) were obtained with no fertilization, with the highest economic return under the V1F₃ combination during the February to May cropping period.

Keywords: Cropping period, ferralsols, fertilization regime, net cash return, Togo, tomato

Résumé

Les efforts de recherche visant à améliorer la production de légumes sont encore nécessaires au Togo. Nous avons évalué le rendement de la tomate (*Solanum lycopersicum*) et les rendements économiques associés sous trois stratégies de gestion de la fertilité du sol dans une étude de 3 ans. Trois variétés de tomates ont été utilisées, dont : MONGAL-F₁ (V1), SUMO-F₁ (V2) et COBRA 26-F₁ (V3). Les régimes de fertilisation étaient : aucune application d'engrais comme contrôle (F₁), application de 200 kg de N₁₅P₁₅K₁₅ + 100 kg d'urée (46% N) correspondant à N76P30K30 ha⁻¹ (F₂) et application de fumier de ferme (FYM) au taux de 6 Mg ha⁻¹ (F₃). La période de 3 ans a été segmentée en deux périodes de culture avec les trois variétés de tomates chacune. Les rendements en fruits frais des tomates ont été collectés et ont été utilisés pour déterminer le rendement net en espèces par le biais d'une analyse budgétaire partielle pour chaque combinaison variété - régime de fertilisation. Pour toutes les variétés de tomates, les rendements moyens des trois cultures étaient de 93 à 131 % et de 109 à 144 % plus élevés pour les régimes de fertilisation F₂ et F₃, respectivement, par rapport au rendement du control (F₁), et les rendements moyens du régime F₃ étaient supérieurs de 7,5 % en moyenne à ceux du régime F₂. Indépendamment du régime de fertilisation, les rendements moyens

de MONGAL-F1 étaient de 6 à 24 et de 16 à 31 % supérieurs aux rendements sous SUMO-F₁ et COBRA 26-F₁, respectivement, et les rendements de SUMO-F1 étaient de 6 à 10 % supérieurs à ceux de COBRA 26-F₁. Des rendements économiques plus élevés (généralement compris entre 11000 et 15500 USD) ont été enregistrés lorsque des engrais ont été appliqués, et des rendements plus faibles (généralement compris entre 250 et 3000 USD) ont été obtenus sans fertilisation, avec le rendement économique le plus élevé sous la combinaison V1F₃ pendant la période de culture de février à mai.

Mots clés : Période de culture, ferralsols, régime de fertilisation, rendement monétaire net, Togo, tomate

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 (*Solanum lycopersicum* Mill) is one of the most produced vegetables in the world, ranking second after potato (Kalbani *et al.*, 2016).

As tomato 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, being 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 production with associated non-economic sale prices along with important postharvest losses. Some constraints to vegetable production are water deficiency/quality, poor soils, lack of 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 Togo, 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 coastal 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-year average rainfall of 470 mm, and a second season from September to December with a 25-year average rainfall of 200 mm. At the onset of this experiment, the site had been under continuous mineral (NPK) fertilized maize cropping.

Soil and crop management. A 3-year (2016-2019) split-plot experiment was conducted 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 nine 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 N₁₅P₁₅K₁₅ + 100 kg of urea (46% N) corresponding to N₇₆P₃₀K₃₀ 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 grown during the three years of experimentation in two periods typically embedded in the two cropping seasons. The first period was from October to January and the second from 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 N₁₅P₁₅K₁₅ 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 delivered 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.

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 the then prevailing prices which were 220 F CFA kg⁻¹ (US\$0.44) for both N₁₅P₁₅K₁₅ and urea. Farmyard manure cost was determined to be 20 000 F CFA Mg⁻¹ (US\$40.0).

Results and discussions

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 agrees with mean yield range of 10 to 30 Mg ha⁻¹ reported by Rajya *et al.* (2015) and Tesfay *et al.* (2018) and 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 (first variety), 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 the second variety (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 of 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	Net cash profit	Crop 1	Crop 2	Crop 3	Mean	Net cash profit
V1F ₁	10.64 ^c	11.94 ^b	10.81 ^c	11.13 ^c	2183	7.74 ^b	13.03 ^c	11.91 ^b	10.90 ^c	6243
V1F ₂	17.94 ^b	23.10 ^a	23.98 ^b	21.67 ^b	14467	21.97 ^a	24.80 ^b	28.88 ^a	25.21 ^b	28775
V1F ₃	22.79 ^a	24.25 ^a	26.02 ^a	24.35 ^a	17623	22.09 ^a	27.49 ^a	30.07 ^a	26.55 ^a	30859
Mean	17.12	19.76	20.27	19.05		17.27	21.77	23.62	20.88	
V2F ₁	10.65 ^c	9.71 ^c	8.83 ^b	9.73 ^c	496	8.24 ^c	11.17 ^b	8.57 ^b	9.33 ^b	3370
V2F ₂	21.23 ^b	19.74 ^b	21.83 ^a	20.93 ^b	13572	15.29 ^a	22.67 ^a	24.06 ^a	20.67 ^a	21878
V2F ₃	23.58 ^a	23.63 ^a	22.57 ^a	23.26 ^a	16308	13.86 ^b	23.23 ^a	24.83 ^a	20.64 ^a	21466
Mean	18.49	17.70	17.75	17.98		12.46	19.02	19.15	16.88	
V3F ₁	9.73 ^b	11.15 ^c	8.48 ^b	9.79 ^c	578	6.96 ^c	11.03 ^b	9.36 ^b	9.12 ^c	3398
V3F ₂	16.06 ^a	17.66 ^b	22.94 ^a	18.89 ^b	11134	13.47 ^b	20.49 ^a	21.68 ^a	18.55 ^b	18122
V3F ₃	16.63 ^a	22.58 ^a	22.28 ^a	20.50 ^a	13006	14.23 ^a	22.55 ^a	23.35 ^a	20.04 ^a	20446
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 $\alpha = 0.05$

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, but fluctuated between cropping period. The three varieties responded positively to fertiliser application with a higher response to organic fertilizer and a better performance for V1, indicating that the variety-fertilization regime interaction was important. 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, the balance was positive in all cases, indicating that there was profit or net gain. However, the data sets reveal that higher net returns (typically ranging from 11000 to 15500 USD) were recorded when fertilizers were applied, and lower returns (typically in the range of 250 to 3000 USD) were obtained with no fertilization. For the three varieties and within each of the two cropping period, net returns were consistently higher (6500 to 15400 USD) with the F₃ fertilization regime as compared to returns (5500 to 14300 USD) when the F₃ fertilization regime was used. Net returns were consistently higher for the second cropping period (February to May) with values typically ranging from 3000 to 15400 USD in comparison to those (250 to 8800 USD) 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 (15429.323 USD) was recorded for the V1 (MONGAL-F₁ variety) combined with the F₃ (FYM-based) fertilization regime.

Conclusion

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 fertiliser application 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 evident and was strongly affected by fertilization schemes, 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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