PRODUCTIVITY AND PROFITABILITY OF MAIZE (*ZEA MAYS* L.) AS AFFECTED BY PLANTING AND FERTILIZATION SCHEMES ON THE FERRALSOLS OF SOUTHERN TOGO
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ABSTRACT

A sustainable improvement of crop productivity and profitability in the current context of climate change and land degradation is necessary to meet food and cash needs of a ceaselessly growing population. To help achieve this aim, we carried out a 2-year experiment (2020 and 2021) at the University of Lomé Agronomic Experiment Station. The experiment was set up in a split-plot design with three (03) replicates. Two planting schemes (SC_1= 80 cm x 40 cm and SC_2 = 80 cm x 25 cm,) and four fertilization schemes: control (F_0= 0 kgha^{-1}); 200 kgha^{-1} of $N_{15}P_{15}K_{15}$ + 100 kg ha^{-1} of urea 46% of N (F_1), 6 000 kg ha^{-1} of chicken dungs (F_2) and 6 000 kg ha^{-1} small ruminant dungs (F_3) were the studied factors. Maize grain yield and profitability under each treatment were determined. The results analysis showed that the planting schemes, fertilization treatments and rainfall were significantly influenced the maize grain yields and profitability of its production. On 2-year average basis, maize grain recorded under SC_2 (80 cm x 25 cm) planting scheme were 31% higher than those obtained under SC_1. Average yield recorded under F_2 was higher than those of F_0, F_1 and F_3 by 60; 2 and 28% respectively. On 2-year average basis, the highest maize grain yields were observed under the SC_2F_1 (3.43±0.24 t ha^{-1}) and SC_2F_2 (3.39±0.18 t ha^{-1}) treatments, which were statistically similar and were respectively 112% and 109% higher than the lowest yield gotten under SC_1F_0 (1.59±0.23 t ha^{-1}). The highest profit (343 000 FCFA ha^{-1} =US$ 512.46) was registered under SC_2F_1 treatment. The adoption of SC_1F_1; SC_2F_1 and SC_2F_2 gave value/cost ratio (VCR) greater than 2 and were profitable; but the use of SC_2F_1 and SC_2F_2 was the most profitable and could be easily adopted by the producers whatever the socio-political or environmental conditions were. The application of SC_2F_1 and SC_2F_2 under Ikenne 9449 SR variety could be recommended to farmers in the first two years of cultivation on soil left in fallow for three years.

Keywords: Maize grains, planting and fertilization schemes, yield, profit and value cost ratio.

INTRODUCTION

Maize is the staple food crop for most people in Sub-Saharan Africa (SSA). It is grown in diverse agro-ecological zones and farming systems and consumed by people with diverse preferences and socio-economic backgrounds in SSA (Macauley & Ramadjita, 2015). It is also used for animal feeding, in the textile and pharmaceutical industries, in the production of biodegradable plastics and biofuel (Macauley & Ramadjita, 2015). In Togo, maize is one of the main food crops. It comes in third position after yam and cassava, but in the lead of cereal crops from the point of view of production. Despite, the efforts made in agriculture by the various stakeholders to improve its production and the assets available in the country to succeed in its cultivation, yields were still low. Since 2010, average maize grain yields at national level have never exceeded 1.50 t ha^{-1} (DSID, 2022). Low crop yields were mainly explained by climate variability, lack of water control, to low adoption of improved varieties and especially soil fertility decline. The need to improve crop yields on existing farmland became then an overriding and obvious objective.

To overcome the problem of yield decline, several studies have been carried out on mineral and organic fertilization (Bationo et al., 2004; Khalid et al., 2014; Mazinagou et al., 2022), farming practices and on adaptation to climate change (Amouzou et al., 2013; Sogbedji et al., 2017). Many of these studies had shown that the use of fertilizers is a key factor in modernizing agriculture in developing countries. According to FAO (2005), maintaining soil fertility would be the keystone in this context of food crops. However, studies on the effect of planting schemes or their interactions with different manures on crop yields are underdeveloped in Togo. With the problems of climate change that have been rife in recent years, some of these studies should be resumed by simultaneously considering key elements including the land degradation, climatic change, plant material and farming practices which have a great influence on crop production. Furthermore, the various proposals made in previous studies have a financial impact that the farmer who practices subsistence agriculture cannot support (Galla et al. 2011; Kasongo et al., 2013).

In a context of food insecurity and soil dégradation, it is essential to determine agricultural production techniques that should allow producers to sustainably increase, not only crop yields, but also to increase their incomes to improve their living conditions. Thus, the search for information concerning the response of maize to fertilizers according to the planting scheme seems essential. The objectives of this study were to: (i) evaluate the effect of planting and fertilization schemes on maize grain yield and (ii) determine the most profitable production technique.

MATERIAL AND METHODS

Experimental site

The study was carried out at the Lomé Agronomic Experiment Station (SEAL), located at the University of Lomé -Togo (6°22' N, 1°13'E; altitude = 50 m, slope less than 1 %). The soil type was a rhodic Ferralsol locally called “Terres de barre”, developped from the continental deposit (Saragoni *et al.,* 1992) and covered part of the arable land in the Ivory Coast, Ghana, Togo, Benin, and Nigeria (Louette, 1988). The climate of the experimental site is the guinean type, bimodal and allows for two maize cropping seasons, one from April to July and another from September to December. Annual rainfall at the site is between 800 and 1100 mm. The annual average temperature is between 24 and 27 °C (Worou, 2000; Somana *et al.*, 2001). At the onset of this experiment, the site has been under fallow for three years.

Soil and crop management

The experiment was set up during the first growing seasons (April to August) of two consecutive years (2020 and 2021). A split-plot design with three replications was used. Two planting schemes were in main plots and four fertilization treatments in the subplots. The two planting schemes used were: (i) 80 cm x 40 cm (SC_1) and (ii) 80 cm x 25 cm (SC_2). The four four fertilization treatments applied were: (i) control (F_0=0 $kgha^{-1}$); (ii) 200 $kgha^{-1}$ of NPK: 15-15-15 + 100 $kgha^{-1}$ of urea 46% N (F_1); (iii) 6 000 $kgha^{-1}$ of chicken dungs (F_2) and (iv) 6 000 $kgha^{-1}$ of small ruminant dungs (F_3). Fertilization treatment F_1 is a recommendation by the national agricultural extension services in Togo (Sogbedji *et al.*, 2017), and F_3 is a recommended FYM-based organic amendment by IFDC (2013). The maize varietie used for experiment was Ikenne 9449 SR (Ikenne). At the beginning of each cropping year, the experimental site was prepared through the following successive operations: clearing, blocks and plots demarcation and manually deep plowing. The maize was sown at four seeds per pocket, follow-up of thinning at two plants per pocket for SC_1 (giving a density of 62 500 plants ha^{-1}) and at one plant per pocket for SC_2 (with a density of 50 000 plants ha^{-1}) were carried out ten days after sowing. NPK: 15-15-15 fertilizer, chicken and small ruminant dungs were applied two weeks after sowing, while urea 46% N was applied at the beginning of flowering. Animal dungs were subjected to composting for three months before their application.

Data collection and analysis

Maize grain yields were determined from the three center rows of each experimental plot. The harvested cobs were dried and then shelled. The maize grain weights were taken when the moisture content of the grains was around 12%. The analysis of variance (ANOVA) of the data obtained was done by using the GenSTAT discovery edition 12 software at the 5% threshold and Duncan's test was used to discriminate the means at this threshold.

Economic analysis method

2-year average (2020 and 2021) profitability of maize production under each treatment (combination of planting schemes and fertilizers), was determined through a partial budget analysis. The profitability is the difference between outputs and inputs. Output consisted of the amount of cash values corresponding to the averge maize grain produced in the two years, which was assumed to be sold at 200 F CFA (US$ 0.30) kg^{-1}, the 2-year average sale price of maize grain at harvest (august) on the local market. The inputs consisted of the production costs under each treatment, including those for soil preparation, seeds, crop planting and related tasks, fertilizers and insecticid (Emacot 050 WG) purchase and their application, crop weeding. and crop harvesting and associated tasks. Labor costs were estimated at 2 000 F CFA (US$ 2.99 per person day (Detchinli and Sogbedji, 2015) and fertilizer costs were based on current prices which were determined to be 250 F CFA (US$ 0.37) kg^{-1}. Chicken dungs or small ruminant dungs was estimated at 20 000 F CFA (US$ 29.88) $Mgha^{-1}$ (Detchinli and Sogbedji, 2015).

The value/cost ratio (VCR) is also determinated under each treatment in order to identify the most profitable one. VCR is the ratio of the value of the yield increase over the control to the cost of the fertilizer used. According to the CDI and IFDC (2014), the VCR must be at least equal to 2 to allow farmers to cover the direct costs related to the use of fertilizers on the farm.

RESULTS AND DISCUSSIONS

Effect of planting and fertilization schemes on maize grain yield

Table 1 shows the maize grain yields from the 2-year experiment. On 2-year average basis, the application of 200 kgha-1 of NPK:15-15-15 + 100 $kgha^{-1}$ of urea 46% N (F1) and 6 000 $kgha^{-1}$ of chicken dungs (F_2) with the adoption of the SC_2 gave the highest maize grain yields. These yields under SC_2F_1 (3.43±0.24 t ha^{-1}) and SC_2F_2 (3.39±0.18 t ha^{-1}) are statistically identical and are respectively 112% and 109% higher than the lowest yield (1.59±0.23 t ha^{-1}) obtained under control (F_0) with the adoption of the 80 cm x 40 cm planting scheme (SC_1). The planting scheme 80 cm x 25 cm (SC_2) gave the highest maize grain yields in 2-yr experiment.

The highest maize grain yields obtained under SC_2F_1 and SC_2F_2, on the 2-year average basis could be explained by the effect of cropping precedents; the rapid mineralization of these fertilizers and the nutrient richness of chicken dungs than those for small ruminants dungs and to their rear-effect. According to Useni *et al.* (2012), the exclusive application of mineral fertilizers is generally effective only during the first years of continuous inputs; there is often a decline in yield after a few years of application due to the degradation of soil properties. In contrast, the use of organic manure, especially poultry manure improves not only the yield but also soil chemical parameters (Gomgnimbou *et al.*, 2019). It was shown that chicken dungs were of great potential for improving soil nutrient availability and were able to provide the amount of nutrients needed for crops compared to the control (Kimuni *et al.*, 2014). The application of compost increased then crop yields and thus contributes to improving food availability (Ouedraogo *et al.*, 2000).

The adoption of SC_2 gave the highest maize grain yields under all the fertilization treatments. This planting scheme helped the maize plants to use sufficiently the nutrients released during the decomposition of fertlizers to express their performance. Despite the reduced gap between plants on the line with SC_2, this planting scheme would promote good aeration between the plants and would therefore allow a better use of the nutrients provided to them for their growth and development. the results of this study are like those of Hasan *et al* (2018) and Zarea *et al.* (2005) who showed that reducing the planting scheme increases crop yields.

Table 1. Maize grain yields from 2-year average under different treatments.

Planting schemes	Fertilization treatments				Means	F.pr	CV (%)
	F_0	F_1	F_2	F_3			
	Maize grain yields in t ha^{-1}						
SC_1 (80 cm x 40 cm)	1.59±0.23c	2.61±0.17a	2.77±0.27a	2.08±0.14b	2.26±0.51b	0.012	17.80
SC_2 (80 cm x 25 cm)	2.25±0.19c	3.43±0.24a	3.39±0.18a	2.74±0.17b	2.95±0.53a	<.001	15.60
Means	1.92±0.41c	3.02±0.45a	3.08±0.48a	2.41±0.42b	2.61±0.62	<.001	16.30

F_0 = 0 kgha^{-1}; F_1= 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N; F_2= 6 000 kgha^{-1} of chicken dungs and F_3= 6 000 kgha^{-1} of small ruminant dungs. CV= Coefficient of variation. The data were discriminated in the horizontal direction; except the average values of the planting schemes, which were discriminated in the vertical direction (P=0.05). Values that are followed by the same letters are statistically identical.

Economic analysis of maize grain production techniques

Results of the partial balance (difference between outputs and inputs) and the value/cost ratios were presented in Table 2. On 2-year average basis, the profits were positive under all the treatments and the highest profit (343 000 FCFA=US$512.46) were got under the adoption of the 80 cm x 25 cm (SC_2) with application of 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N (F_1). As for the value/cost ratios (VCR), the application of SC_1F_1; SC_2F_1 and SC_2F_2 200 gave VCR greater than 2; while the application of SC_1F_2 ; SC_2F_3 to maize plants gave VCRs located between 1.5 and 2. The application of SC_1F_3 to maize plants gave the lowest VCR which was less than 1. The highest VCR (4.91) was got under SC_2F_1.

The positives balances got under all treatements showed that their use in the first two years of cultivation on land left fallow for three years was profitable. This highest profit registraded under SC_2F_1 could be explained, not only by the better yields obtained under this treatment; but also, by the low production costs linked to the use of this mineral manure compared to the production costs linked to the use of organic manures. The value cost ratios greater than 2 under SC_1F_1; SC_2F_1 and SC_2F_2 showed that these treatments were profitable and could be easily adopted by producers (CDI and IFDC, 2014; Mankoussou *et al.*, 2017). But in an unstable political and socioeconomic environment or in regions more sensitive to drought (where the risk is much higher) at least a VCR of 3 is needed before producers could dare to take the risk of investing in the use of the fertilizers (FAO and IFA, 2000; CDI and IFDC, 2014). In these conditions, only SC_2F_1 and SC_2F_2 treatment could be used by the farmers. The adoption is reluctant for SC_1F_2 and SC_2F_3 which had their VCR between 1.5 and 2; but SC_1F_3 treatment must be rejected because his VCR was below 1.5 (Mankoussou *et al.*, 2017).

Table 2. Partial balance and value/cost ratios of each treatment.

Parameter	SC_1F_0	SC_2F_0	SC_1F_1	SC_2F_1	SC_1F_2	SC_2F_2	SC_1F_3	SC_2F_3
	F CFA ha^{-1}							
Output	+318 000	450 000	522 000	686 000	554 000	678 000	416 000	548 000
Input	-248 000	248 000	343 000	343 000	378 000	378 000	378 000	378 000
Labor	218 000	218 000	238 000	238 000	228 000	228 000	228 000	228 000
Seeds	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000
Fertilizer	0	0	75 000	75 000	120 000	120 000	120 000	120 000
Pesticide	20,000	20 000	20 000	20 000	20 000	20 000	20 000	20 000
Balance	**70 000 US$104.58**	**202 000 US$301.80**	**179 000 US$267.43**	**343 000 US$512.46**	**176 000 US$262.95**	**300 000 US$448.21**	**38 000 US$56.77**	**170 000 US$253.99**
VCR	**0**	**0**	**2,72**	**4,91**	**1,97**	**3,00**	**0,82**	**1,92**

1 USD = 669,325 of West Africa franc F CFA, 29/09/2022 at 20h 02. VCR=Value cost ratio. SC_1 = Cropping scheme 80 cm x 40 cm SC_2 = Cropping scheme 80 cm x 25 cm. F_0 = 0 $kgha^{-1}$; F_1= 200 $kgha^{-1}$ of NPK: 15-15-15 + 100 $kgha^{-1}$ of urea 46% N; F_2= 6 000 $kgha^{-1}$ of chicken dungs and F_3= 6 000 $kgha^{-1}$ of small ruminant dungs.

CONCLUSION

At the end of this study, whose aim is to sustainably improve the productivity and profitability of maize production, it appears that the application of 200 $kgha^{-1}$ of NPK:15-15-15 + 100 kg ha^{-1} urea 46% N (F_1) and 6 000 kg ha^{-1} of chicken dungs (F_2) with the adoption of the 80 cm x 25 cm (SC_2) planting scheme improved significantly maize grain yield in the first two years of cultivation. But the use of SC_2F_1 treatment gave the highest profit and the highest value/cost ratio. SC_1F_1; SC_2F_1 and SC_2F_2 treatments were profitable; but SC_2F_1 and SC_2F_2 were the most profitable and could be easily adopted by the producers in any political or environmental conditions. The application of these treatments under Ikenne 9449 SR variety could be recommended to the farmers in the first two years of cultivation on soil left fallow for three years.

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