Productive and economic potential assessment of maize (*Zea mays* L.) varieties under fertilizers influence in the coastal zone of Togo

Abstract

The sustainable improvement of maize productivity and smallholders' incomes to contribute to food security is the objective of this study carried out over two consecutive years (2020 and 2021) at the University of Lomé Agronomic Experiment Station. The experiment was set up in a split-plot design, composed of sixteen (16) treatments in three (03) replicates each. Four varieties: Ikenné (V_1) Tzee (V_2), Sotubaka (V_3) and Sammaz 52 (V_4) and four fertilization schemes: 0 kgha^{-1} (F_0); 200kgha^{-1} of NPK:15-15-15+100kgha^{-1} of urea 46%N (F_1); 6 000kgha^{-1} of chicken dungs (F_2) and 6 000kgha^{-1} of small ruminant dungs (F_3) were the studied factors. Maize grain yields were determined, and an economic analysis was done. The results analysis showed that varieties and fertilization schemes significantly affected maize grain yields. Sotubaka (V_3) was the most productive variety during the two years of experiment. The average yield obtained under V_3 (3.56±0.65 t ha^{-1}) was higher than those of Ikenné, Tzee and Sammaz 52 varieties respectively by 20, 57 and 5%. The average yield recorded under F_2 was higher than those of F_0, F_1 and F_3 by 54, 3 and 17% respectively. On a 2-year average basis, the application of 200kgha^{-1} of NPK:15-15-15+100kgha^{-1} of urea 46%N (F_1) gave the highest maize grain yields under V_1 (3.43±0.13 t ha^{-1}) and V_2 (2.60±0.15 t ha^{-1}); while the highest maize grain yields under V_3 (4.29±0.12 t ha^{-1}) and V_4 (3.95±0.11 t ha^{-1}) were obtained with the supply of 6 000kgha^{-1} of chicken dungs (F_2). On the same 2-year average basis, the highest profits were obtained under Ikenné (343 000 FCFA ha^{-1}=US$ 512.46) and Tzee (177 000 FCFAha^{-1}=US$ 264.45) with the application of F_1. For Sotubaka (480 000 FCFAha^{-1}=US$ 717.14) and Sammaz 52 (415 000 FCFAha^{-1}=US$ 620.03), the highest profit was obtained with the application of F_2. For successful maize cultivation, it was advisable to use F_1 for Ikenne and Tzee varieties and F_2 for Sotubaka and Sammaz 52 varieties.

Key words: Maize grain, Variety, Fertilization scheme, Yields, Profit.

1. Introduction

Agriculture, the engine of economic growth in most countries of sub-Saharan Africa (SSA), was characterized by a most of smallholder farmers and low crop productivity. This decline in productivity is mainly due to the physical degradation of soil surface horizons [1]; climatic variability; low adoption of improved varieties [2] and the potential genetic degradation of varieties used by the producers. The problem of soil-fertility depletion in smallholder farms was the fundamental biophysical root cause for declining per capita food production in sub-Saharan Africa [3]. Agricultural smallholders in SSA apply insufficient amounts of nutrients in their farms, leading to overuse of soil nutrient stocks by plants' overuse of soil nutrient stocks, which leads to the gradual depletion of nutrients in the soil and their eventual degradation [4]. Diagnostic studies on the use of fertilizers in Africa revealed that their use was low, mainly because of their high cost, production abroad, unit quantities and high transport costs [5; 6].

Maize is the staple food crop most widely practiced in SSA [2], particulary in Togo, where maize is one of the main food crops. 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} [7]. Low crop yields were primarily explained by climate variability, lack of water control and especially soil fertility decline. Studies in SSA [8; 9] indicated that soil fertility degradation particularly in terms of poor mineral and organic soil content was the major cause of food shortages, decreased livestock productions and poverty.

To solve the problem of soil chemical degradation leading to a lack of nutrients for plants, several authors [10; 11] showed that improving soil fertility through the nutrient inputs in mineral or organic form increased water efficiency and crop yields. For Mosier *et al*. [12], applying fertilizers was an essential lever to meet the increased food demand. Using organic manures maintains or improves soil fertility with excellent crop yields and this, in a sustainable way [13; 14; 15]. Smallholder farmers in SSA were more inclined to organic matter namely farm yard manure (FYM), toward restoring soil fertility than synthetic fertilizers because of their unavailability and/or inaccessibility together with increasing costs [16]. In addition to the adverse effects of land degradation on food security in SSA, this region was further impacted by climate change as demonstrated by Lansigan *et al.* [17]. Several studies [18; 19] clearly indicated that climate change and variability were a threat to global socio-economic development primarily through its negative impact on the agricultural sector.

Concrete research-development efforts are therefore needed in SSA to overcome these constraints through soil fertility restoration, maximization of nutrient and water use efficiency and identification of resilient crop varieties [20]. It is in this perspective that this study was carried out with the aim of finding production techniques, which could sustainably improve maize productivity and profitability in the current context of climate change and degradation of soil fertility. The specific objectives of the study were: (i) to determine the most productive maize variety; (ii) to evaluate the effect of fertilizers on maize grain yield and (iii) to determine the most profitable production strategy.

2. Material and methods

2.1 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 of 50 m, slope less than 1 %). The soil type was a rhodic Ferralsol locally called “Terres de barre,” developped from the continental deposit [21]. This type of soil represents 47% of the soils of the maritime region [22] and covers part of the arable land in Ivory Coast, Ghana, Togo, Benin, and Nigeria [23; 24]. 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 [20]. Annual rainfall at the site is between 800 and 1100 mm. The annual average temperature is between 24 and 27°C [22; 25].

The experimental plot was under fallow for three years. Before the maize sowing in April 2020, initial soil properties including total C, and total N levels, exchangeable base concentrations (Ca^{++}, Mg^{++}, Na^{+}, and K^{+}), pH, cation exchange capacity (CEC), and soil texture were determined on the first 20 cm soil layer (0-20 cm depth) on the experimental site. It was done through twenty-four (24) composite soil samples obtained by using the standard methods of the International Institute for Tropical Agriculture [26]. These composite soil samples were analyzed at the Laboratory of Soil Water Plant Fertilizer of the Togolese Institute for Agronomic Research (LSEVE-ITRA). The soil of the experimental site is slightly acidic (pH=6.77) and has low total C (0.55%) and total N (0.05%) levels. It is sandy and contains 79.82% sand, indicating that this soil is well drained with low contents of P (42 mg kg^{-1}) and K (58.84 $mg.kg^{-1}$) contents. Its CEC is very low (2.86 $cmol.kg^{-1}$), as are the exchangeable bases Ca^{++}, Mg^{++}, Na^{+} and K^{+}, with respective values of 32.23; 4.19; 1.22 and 1.51 $cmolkg^{-1}$ (table 1).

Table 1: Soil physical and chemical properties at the onset of the experiment

Parameters	Values
pH (H_2O)	6.77
MO (%)	0.95
C total (%)	0.55
N total (%)	0.05
NO_3-N ($mgkg^{-1}$)	2.30
P available ($mgkg^{-1}$)	42
K available ($mgkg^{-1}$)	58.84
Exchangeable bases ($mmolkg^{-1}$)	
Ca^{2+}	32.23
Mg^{2+}	4.19
Na^{+}	1.22
K^{+}	1.51
Total CEC ($cmolkg^{-1}$)	2.86
Sable content (%)	79.82
Silt content (%)	7.40
Clay content (%)	12.78

2.2 Material

2.2.1 Biological material

Four maize varieties were used as biological material: Ikenne 9449 SR (Ikenne), TZEE W pop STR QPM (Tzee), Sotubaka, and Sammaz 52. Table 2 presents the characteristics of the four varieties.

Table 2: Varieties characteristics

Varieties	Genetic nature	Breeder	Maintainer	Height (cm)	Grain colour	Production cycle (days)	Potential yield (t.ha^{-1})	References
Ikenne 9449 SR (Ikenne),	Composite	CIMMYT/ IITA	ITRA	190-210	White	90-100	5	[27; 28]
TZEE W pop STR QPM (Tzee)	Composite	IITA	ITRA	170-185	White	80-85	3.50	[28]
Sotubaka	Composite	IER	ITRA	210-230	Yellow	100-110	6	[28]
Sammaz 52	Improved population	MENKIR ABEBE	IAR, Zaria	190-195	Orange	95 (medium)	6	[29]

2.2.2 Fertilizers:

Four types of fertilizers such as NPK: 15-15-15; Urea 46%N; chicken dungs, and small ruminant dungs were used in this experiment.

2.3 Methods

2.3.1 Experimental design

The experiment took place during the first growing seasons (April to August) of two consecutive years (2020 and 2021). The trial was set up using a split-plot design with three replications of each treatment. The main plots included the varieties: Ikenne (V_1), Tzee (V_2), Sotubaka (V_3) and Sammaz 52 (V_4) and the sub-plots, the fertilization schemes: 0 kgha^{-1} (F_0); 200kgha^{-1} of NPK:15-15-15 + 100 kgha^{-1} of urea 46%N (F_1); 6 000 kgha^{-1} of chicken dungs (F_2) and 6 000 kgha^{-1} of small ruminant dungs (F_3). Twelve (12) main plots (9m x 7.40m) and forty-eight (48) subplots (4m x 3.20m) were delimited. The distance between the blocks is equivalent to that between the plots and which was 1m. Each experimental unit contains five lines separated from each other by 0.80 m.

Samples of 100 g of chicken dungs and small ruminant dungs were taken and analysed at the Laboratory of Soil-Water-Plant-Fertilizer of the Togolese Institute for Agronomic Research (LSEVE-ITRA). The chemical composition of animal waste is recorded in the table 3.

Table 3: Chemical composition of small ruminant and chicken dungs

Parameters	Small ruminant dungs	chicken dungs
pH (H_2O)	9.03	8.42
MO (%)	28.67	34.18
Total C total (%)	16.63	19.83
Total N (%)	1.05	1.70
Total P (mg/kg)	1 280.85	8 217.40
Exchangeable bases (mmolkg^{-1})		
Ca^{2+}	294.13	333.66
Mg^{2+}	79.62	168.08
Na^{+}	25.50	32.48
K^{+}	19.43	24.19

The quantity of N in eau manure was determined and was recorded in table 4

Table 4: N amount corresponding to fertilizers amount used

Fertilization schemes	Nutrients form				N (Nitrogen)
	Chicken dungs	Small ruminant dungs	$N_{15}P_{15}K_{15}$	Urea (46%N)	
	Quantity ($kgha^{-1}$)				
F_0	0	0	0	0	0
F_1	0	0	200	100	76
F_2	0	6000	0	0	102
F_3	6000	0	0	0	63

2.3.2 Soil and crop management

At the beginning of each growing season, the experimental site was prepared through the following successive operations: clearing, deep plowing, levelling, and demarcation of blocks and plots. The maize seeds were sown on April 10, 2020, and April 20, 2021 at three seeds per pocket, follow-up of thinning at one plant per pocket, giving a density of 50 000 plants ha^{-1} was carried out ten (10) days after sowing. NPK: 15-15-15, chicken, and small ruminant dungs were applied to the plants on the 15th day after sowing. Animal dungs were subjected to composting for three months before application. The urea 46% N was applied at the beginning of flowering (42nd day after sowing). The mineral and organic fertilizers were applied in a localized mode at around 5 cm from the foot of the plants and at a depth varying from 3 to 5 cm. Two weeding and one hilling were carried out, respectively, on the 14th, 30th, and 50th day after sowing. Two insecticide treatments against the caterpillars were done. The harvests took place on 14th August 2020 and 21th August 2021.

2.3.3 Data collection

Maize grain yields were determined from the three centre lines 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%.

2.3.4 Data analysis

The analysis of variance (ANOVA) of the data obtained was done by using the GenSTAT discovery edition 12 software at the 5% threshold ($P=0.05$) and Duncan's test was used to discriminate the means at this threshold.

2.3.5 Economic analysis method

The average profitability of maize production in the two years (2020 and 2021) from each treatment (combination of varieties and fertilization schemes), was determined through a partial budget analysis. Profitability is the difference between output and inputs. The output consisted of the amount of cash values corresponding to the average maize grain produced in the two years, which was assumed to be sold at 200 F CFA (US$0.30) kg^{-1}, the average sale price of maize grain at harvest (august) on the local market of the two years. The inputs consisted of the production costs under each treatment, including those for soil preparation, seeds, crop planting, and related tasks, fertilizers, and insecticide (Emacot 050 WG) purchase and their application, weeding, and crop harvesting and associated tasks. Labor costs were estimated at 2 000 F CFA (US$2.99) per person day [30], and fertilizer costs were based on current prices, which were determined to be 250 F CFA (US$ 0.37) kg^{-1}. Chicken and small ruminant dungs was estimated at 20 000 F CFA (US$ 29.88) ton each one [30].

Table 5: Labor costs for the different activities carried out under each treatment

Planting operations	F_0	F_1	F_2	F_3
	Person-day per ha^{-1}			
Soil preparation	24	24	24	24
Sowing, and related works	10	10	10	10
Weeding and ridging	32	32	32	32
Fertilizers, and insecticide application	8	18	13	13
Harvesting; and related works	35	35	35	35
Total labor	109	119	114	114
Total labor cost (F CFA ha^{-1})	218 000 (US 325.70)	238 000 (US$ 355.58)	228 000 (US$ 340.64)	228 000 (US$ 340.64)

1 US$= 669.325 of West Africa franc CFA on https://fr.coinmill.com/USD_XOF.html, 29/09/2022 at 20h 02
F_0 = 0 kg ha^{-1}; F_1= 200 kg ha^{-1} of NPK: 15-15-15 + 100 kg ha^{-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

3. Results and Discussion

3.1 Maize varieties performance

The maize grain yields obtained under the different varieties used for the experiment were recorded in Table 6. They ranged from 2.31±0.51 to 3.91±0.61 t ha^{-1} and 2.16±0.58 to 3.20±0.66 t ha^{-1} respectively in the first year and second year of the experiment. The average maize grain yields for the two years obtained under these varieties varied from 2.24±0.55 to 3.56±0.65 t ha^{-1}. The varieties had a significant effect on maize grain yields. Yield differences observed between varieties were due to their genetic characteristics and their potential yields. Indeed, Sotubaka (V_3) and Sammaz 52 (V_4) varieties having the highest and same potential yield (6 t ha^{-1}) gave yields which are statistically identical and were higher than those obtained under Ikenné (V_1) and Tzee (V_2); varieties having respectively 5 t ha^{-1} and 3.50 t ha^{-1} as potential yields.

For the two years of the experiment, the highest maize grain yield was obtained under the Sotubaka variety. This performance could be explained by the genetic characteristics of this variety wich allowed it to use nutrients supply more efficiently than Sammaz 52 variety. In addition, V_3 was a long cycle variety and this cycle (115 days) could contribute to getting the highest yield under normal rainfall conditions with the application of appropriate nutrients. But when comparing the yield differences between the two years under each variety, it should be more reassuring to succeed in maize production in the current climate change context by using the Tzee variety which is a short cycle variety (85 days) and if applicable, Ikenné and Sammaz 52 varieties which were medium cycle varieties. Indeed, the cumulative rainfall obtained in the period from April to August 2020 (342.50 mm) in the study area was lower than that recorded in the year 2021 (540.90 mm) at the same period; but the rainfall for the year 2020 was better distributed in the growing season than that of the year 2021. This situation also explained the superiority of the maize grain yields of the first year compared to those of the second year. Some studies demonstrated the dynamics of rainfall and its effects on maize grain yield [31] or its effects on maize varieties performance [20].

In terms of the varietal performance determined from the ratio of yields obtained under varieties to their potential yields, Tzee was the best performing variety. It was followed by Sotubaka and Ikenné. Sammaz 52 was the least successful. This varieties performance was the result of their ability to adapt to environmental conditions of the study area. Thus, it appeared that Tzee variety was better adapted to the climatic and edaphic conditions of the production site than the other varieties. This difference in the expression of potential productive of the varieties would also be linked to their genetic characteristics, which enabled them to better exploit the resources of the growing environment. According to Senan *et al.* [32], if a difference was observed between varieties within a season, it is due to the variety alone. Other authors [33] showed that yield of each crop could also depend on the natural environment characteristics, the plant material used, its origin and the production techniques applied. These authors indicated that the diversity of these factors would reflect the high variability of yields produced by tomato lines.

Table 6: Maize grain yields under varieties for each year and 2-year average

Years	Varieties				Averages	P	CV (%)
	Ikenné (V_1)	Tzee (V_2)	Sotubaka (V_3)	Sammaz 52 (V_4)			
	Maize grain yields in t ha^{-1}						
Year 1 (2020)	3.23±0.56b	2.31±0.51c	3.91±0.61a	3.68±0.52a	3.28±0.79	<.001	16,8
Year 2 (2021)	2.68±0.59b	2.16±0.58c	3.20±0.66a	3.12±0.66a	2.79±0.76	<.001	17,4
2-year average	2.95±0.53b	2.24±0.55c	3.56±0.65a	3.40±0.61a	3.04±0.74	<.002	15,6

CV= Coefficient of variation. The data were discriminated in the horizontal direction (P=0.05). Values that were followed by the same letters are statistically identical.

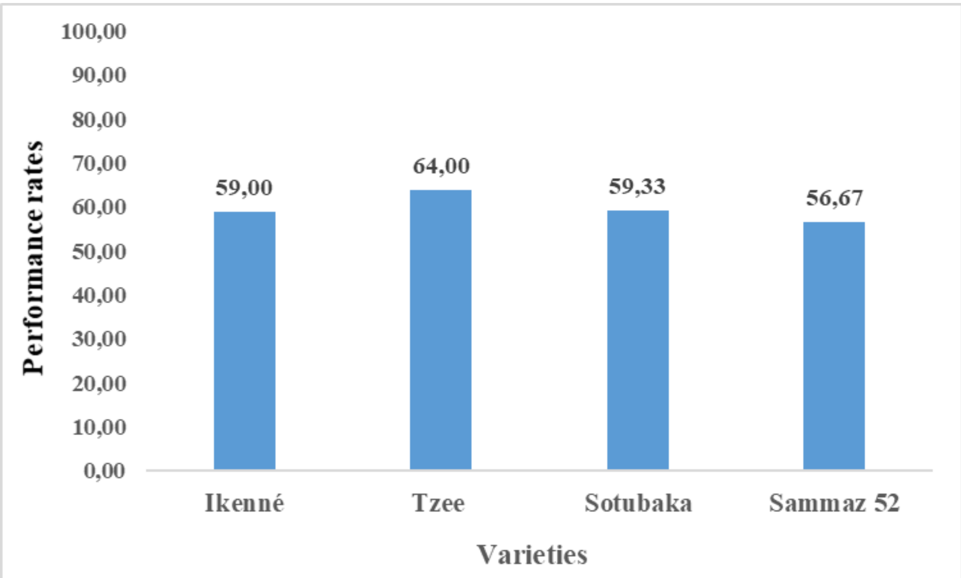

Figure 1 : Performance rates of each varietie

3.2 Effect of fertilization schemes on maize grain yield

Table 7 presents maize grain yields obtained under fertilization schemes. The analysis of variance showed that fertilization schemes significantly influenced maize grain yields during the two years of the experiment. In the first year, the highest maize grain yield (3.72±0.61 t ha^{-1}) was obtained with the supply of 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N (F_1), but this yield was statistically identical to that obtained with the application of 6 000 kgha^{-1} of chicken dungs (F_2). On the other hand, in the second year of cultivation, the highest maize grain yield (3.31±0.60 t ha^{-1}) was recorded with the application of F_2. On 2-year average basis, the application of 6 000 kgha^{-1} of chicken dungs (F_2) gave the highest maize grain yield (3.50±0.58 t ha^{-1}). This yield was higher than those obtained under control (F_0), 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N (F_1) and 6 000 kgha^{-1} of small ruminants dungs (F_3) respectively by 53; 3 and 17%.

The superiority of maize grain yields in the first year compared to the second year was due to the poor distribution of rainfall. Indeed, the cumulative rainfall obtained in the period from April to August 2020 (342.50 mm) in the study area was lower than that recorded in the year 2021 (540.90 mm) during the same period; but the rainfall for the 2020 year was better distributed on the growing season than that of the 2021 year. Several authors [34; 35] demonstrated the impact of rainfall on grain maize yield. The highest maize grain yield obtained in the first year of cultivation with the application of 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N (F_1) could be explained by the rapid mineralization of this manure and by the effect of previous crops. This contributed to make available to the plants at the right time, enough of the nutrients necessary for their growth and development. The advantage of fertilizers was that they improved not only the yield but also the crop residues (biomass) that was used as organic fertilizer by the previous crop [36].

The highest maize grain yields were observed with the application of 6 000 kgha^{-1} of chicken dungs (F_2) in two cropping years and their average could be explained; not only by the rapid mineralization of chicken dungs than small ruminant dungs; but also; by the residual effect of this manure applied in the first year. Kabrah *et al.* [37] proved the significant effect of organic matter on the number of grains per cob and the average weight of maize grain in the second cropping season compared to the first cropping season.

Table 7: Maize grain yields under fertilization schemes for each year and 2-year average

Years	Fertilization schemes				Averages	P	CV (%)
	F_0	F_1	F_2	F_3			
	Maize grain yields in t ha^{-1}						
Year 1 (2020)	2.77±0.58b	3.72±0.61a	3.69±0.66a	2.96±0.64b	3.28±0.79	<.001	18.10
Year 2 (2021)	1.78±0.45c	3.07±0.54ab	3.31±0.60a	2.99±0.52b	2.79±0.76	<.001	18.80
2-year average	2.27±0.45c	3.40±0.52a	3.50±0.58a	2.98±0.54b	3.04±0.74	<.001	17.70

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 (P=0.05). Values that were followed by the same letters are statistically identical.

3.3 Effect of variety and fertilization scheme interaction on grain maize yield.

The results of the response of maize varieties to different fertilization schemes; in terms of maize grain yields, were presented in Table 8. The maize grain yields varied from 2.08±0.14 to 4.71±0.13 t ha^{-1} and from 1.42± 0.12 to 3.86±0.14 t ha^{-1}, respectively, in the first and second year of the experiment. The average yields of the two years varied from 1.75±0.11 to 4.29±0.12 t ha^{-1}. Overall, maize grain yields under each variety-fertilization scheme interaction in the first year of production were higher than those of the second year. The highest maize grain yields were recorded in the first year of production under Ikenné (3.80±0.19 t ha^{-1}); Tzee (2.78±0.15 t ha^{-1}), and Sammaz 52 (4.18±0.16 t ha^{-1}) with the application of 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N (F_1). In the same year, the application of 6 000 kgha^{-1} of chicken dungs (F_2) gave the highest maize grain yield under Sotubaka (4.71±0.13 t ha^{-1}). On the other hand, in the second year of production, the highest yields were recorded under the four varieties with the application of F_2. On 2-year average yields basis, the highest yields under Ikenné (3.43±0.13 t ha^{-1}) and Tzee (2.60±0.15 t ha^{-1}) were obtained with the supply of F_1 while the application of F_2 gave the highest yields under Sotubaka (4.29±0.12 t ha^{-1}) and Sammaz 52 (3.95±0.11 t ha^{-1}).

The yields of the second year experiment were negatively impacted by rainfall. This could explain the superior maize grain yields in the first year compared to those in the second year under different interactions. According to Baulcombe *et al.* [38], the vulnerability of farming systems to climate variability leads to economic instability and food insecurity risks. The highest yields recorded in the first year under Ikenné, Tzee and Sammaz 52 varieties with the application of mineral fertilizers (F_1) would be due; not only; to the rapid mineralization and the availability of nutrients to the plants at the right time; but also to the back-effect of previous crops and especially to the production cycles of its varieties. Indeed, Tzee being a short cycle variety (85 days); Ikenné (90 days) and Sammaz (95 days) being medium cycle varieties, this fertilizer (F_1) permitted to provide the maize plants, at the right time; the nutrients necessary for their growth and development. As the Sotubaka variety had a long cycle (115 days), the application of 6 000 kgha^{-1} of chicken dungs (F_2), due to its richness in nutrients and its faster mineralization than small ruminant dungs, permitted to obtain the highest maize grain yield. The highest maize grain yields obtained in the second year under all varieties with the application of chicken dungs (F_2) could be explained by the rapid mineralization and nutrient richness of this organic manure and by the back-effect of this manure brought in the first year. It showed that the use of organic manure especially poultry manure improved not only the yield but also soil chemical parameters [39; 40]. The superiority of maize grains yields with the application of chicken dungs (F_2) over those obtained with application of mineral fertilizer (F_1) in the second year, under the varieties had been shown by Useni *et al*. [41]. Indeed, these authors [41] found in their study that the exclusive application of mineral fertilizers is generally effective only during the first years of continuous inputs; there is often a yield decline after a few years of application due to the degradation of soil properties.

On 2-year average basis, the highest yields obtained under the Ikenné and Tzee with the application of mineral manure (F_1) could be explained by the effect induced by this manure on yields in the first year, which was clearly higher than that induced in the second year by the chicken dungs under these two varieties. On the other hand, the effect induced by this mineral manure (F_1) under Sammaz 52 in the first year was lower than that induced by the chicken dungs in the second year under this variety. It should be noted that maize grain yields obtained in the first year under Ikenné, Tzee, Sammaz 52 with the application of 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N (F_1) were higher than those obtained with the supply of 6 000 kgha^{-1} of chicken dungs (F_2) to these varieties respectively by 4; 20 and 1%. However, in the second year, the application of chicken dungs (F_2) to Ikenné, Tzee, Sammaz 52 gave maize grain yields that were higher than those obtained with application of mineral manure (F_1) respectively by 3; 2 and 11%.

The superiority of the yields obtained under Sotubaka with the application of 6 000 kgha^{-1} of chicken dungs (F_2) was not only due to the richness in nutrients of the chicken dungs; but also to the cropping cycle of this variety which allowed it to use efficiently the nutrients supplied. The use of short (Tzee) and medium (Ikenné) cycles varieties whose potential yields were less than or equal to 5 t ha^{-1} with the application of 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N (F_1) would give the highest maize grain yields over the first two years of cultivation. For long (Sotubaka) or medium (Sammaz 52) cycles varieties with potential yields greater than 5 t ha^{-1}, the application of 6 000 kgha^{-1} of chicken dungs (F_2) seems more advantageous under good rainfall conditions.

Despite the above, and particularly under conditions in the study area, the species by itself cannot guarantee high yields, so it is necessary to accompany its sowing with adequate fertilization practices, which have implicit techniques that, in addition to improve plant nutrition [42; 43; 44], followed by practices that help conserve the soil, with consequent benefits [45: 46; 47]. The edaphic factors studied in this research may have a direct effect on maize grain yield [48; 49; 50], as reported by studies focused on the influence of soil conditions on productivity in environments such as the one in our study [51; 52; 53].

Table 8: Maize grain yields under treatments for each year and 2-year average

Varieties	Fertilizers				P	CV (%)
	F_0	F_1	F_2	F_3		
Maize grain yields in t ha^{-1}						
Year 1 (2020)						
Ikenné (V_1)	2.73±0.18b	3.80±0.19a	3.64±0.21a	2.74±0.20b	0.045	16.60
Tzee (V_2)	2.08±0.14b	2.78±0.15a	2.30±0.16b	2.10±0.12b	0.031	15.40
Sotubaka (V_3)	3.22±0.13c	4.12±0.19b	4.71±0.13a	3.61±0.11c	0.008	16.00
Sammaz 52 (V_4)	3.05±0.17b	4.18±0.16a	4.12±0.12a	3.38±0.14b	0.009	15.20
Year 2 (2021)						
Ikenne (V_1)	1.77±0.16c	3.05±0.15ab	3.15±0.13a	2.74±0.17b	0.003	16.10
Tzee (V_2)	1.42±0.12b	2.42±0.20a	2.46±0.22a	2.34±0.20a	0.035	17.40
Sotubaka (V_3)	2.01±0.13c	3.42±0.12b	3.86±0.14a	3.52±0.16b	<.001	16.00
Sammaz 52 (V_4)	1.92±0.12c	3.40±0.14b	3.78±0.15a	3.37±0.13b	0.002	15.70
Means of the two years						
Ikenne (V_1)	2.25±0.12c	3.43±0.13a	3.39±0.12a	2.74±0.15b	0.003	16.20
Tzee (V_2)	1.75±0.11b	2.60±0.15a	2.38±0.15a	2.22±0.16a	0.035	17.00
Sotubaka (V_3)	2.61±0.13c	3.77±0.13b	4.29±0.12a	3.57±0.12b	0.002	15.50
Sammaz 52 (V_4)	2.49±0.12c	3.79±0.11a	3.95±0.11a	3.37±0.13b	0.002	15.10

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 (P=0.05). Values that were followed by the same letters are statistically identical.

3.4 Economic analysis of maize production techniques

The average balances (difference between outputs calculated from average yields and inputs) obtained under the different treatments were presented in Table 9. They were all positive and had almost kept pace with the evolution of maize yields grains obtained.

For Ikenné, the highest profit (343 000 FCFA ha^{-1} or US$ 512.46) was obtained with the application of 200 kgha^{-1} of NPK: 15-15-15 + 100 kgha^{-1} of urea 46% N (F_1). This profit under V_1F_1 was higher than those under V_1F_0; V_1F_2 and V_1F_3 by 70; 14 and 102% respectively. The highest profit (177 000 FCFAha^{-1} or US$ 264.45) under Tzee, was also recorded with the supply of F_1. This profit under V_2F_1 was higher than those of V_2F_0, V_2F_2 and V_2F_3 by 74; 81 and 168% respectively. For Sotubaka, the application of 6 000 kgha^{-1} of chicken dungs (F_2) gave the highest profit (480 000 FCFAha^{-1} or US$ 717.14). This profit is higher than those obtained under V_3F_0; V_3F_1 and V_3F_3 respectively of 75; 17 and 43%. The highest profit (415 000 FCFA ha^{-1} or US$ 620.03) under Sammaz 52, was obtained with the application of F_1. This profit was higher than those obtained under V_4F_0; V_4F_2 and V_4F_3, respectively 66; 1, and 40%.

The highest profits obtained under the different interactions variety and fertilization scheme were correlated with the highest maize grain yields obtained under each interaction. But under the combinations of Sotubaka or Sammaz 52 variety and organic, the profits were maibly correlated with inputs and secondly, maize grain yields. This study indicated that to succeed the maize production, it should be better to use F_1 for Ikenne, Tzee, and Sammaz 52 varieties, but for the Sotubaka variety apply F_2.

Table 9: Mean partial balance for each treatment

Varieties	Fertilization schemes	Labor cost	Seeds cost	Fertilizers cost	Insecticide cost	Total Input	Out put	Balance
		F CFA ha^{-1}						
Ikenné	F_0	218 000	10 000	0	20 000	248 000	450 000	202 000 (US$ 301.80)
	F_1	238 000	10 000	75 000	20 000	343 000	686 000	343 000 (US$ 512.46)
	F_2	228 000	10 000	120 000	20 000	378 000	678 000	300 000 (US$ 448.21)
	F_3	228 000	10 000	120 000	20 000	378 000	548 000	170 000 (US$ 253.99)
Tzee	F_0	218 000	10 000	0	20 000	248 000	350 000	102 000 (US$ 152.39)
	F_1	238 000	10 000	75 000	20 000	343 000	520 000	177 000 (US$ 264.45)
	F_2	228 000	10 000	120 000	20 000	378 000	476 000	98 000 (US$ 146.42)
	F_3	228 000	10 000	120 000	20 000	378 000	444 000	66 000 (US$ 98.61)
Sotubaka	F_0	218 000	10 000	0	20 000	248 000	522 000	274 000 (US$ 409.37)
	F_1	238 000	10 000	75 000	20 000	343 000	754 000	411 000 (US$ 614.05)
	F_2	228 000	10 000	120 000	20 000	378 000	858 000	480 000 (US$ 717.14)
	F_3	228 000	10 000	120 000	20 000	378 000	714 000	336 000 (US$ 502.00)
Sammaz 52	F_0	218 000	10 000	0	20 000	248 000	498 000	250 000 (US$ 373.51)
	F_1	238 000	10 000	75 000	20 000	343 000	758 000	415 000 (US$ 620.03)
	F_2	228 000	10 000	120 000	20 000	378 000	790 000	412 000 (US$ 615.55)
	F_3	228 000	10 000	120 000	20 000	378 000	674 000	296 000 (US$ 442.24)

1 US$= 669.325 of West Africa franc CFA on https://fr.coinmill.com/USD_XOF.html, 29/09/2022 at 20h 02
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

4. Conclusion

At the end of this study conducted for two years on ferralsol left fallow for three (03) years whith the aim to improve maize productivity and producer incomes sustainably, it showed that the application of 200 kgha^{-1} of NPK:15-15-15 + 100 kgha^{-1} of urea 46% N (F_1) gave the highest maize grain yields and profit under the Tzee and Ikenné varieties. In contrast, the highest maize grain yields and profit under the Sotubaka and Sammaz 52 varieties were obtained with 6 000 kgha^{-1} of chicken dungs (F_2). For successful maize cultivation, it is recommended to use F_1 for Ikenne and Tzee varieties and F_2 for Sotubaka and Sammaz 52 varieties on soil left fallow for three (03) years. However, the effectiveness of chicken dungs is conditioned by their availability, hence the need to promote chicken/poultry farming to ensure its availability.

References

1. Mapangui A. Étude de l'organisation et du comportement de sols ferralitiques argileux de la Vallée du Niari. Conséquences sur l'évolution physique sous culture de manioc en mécanisé depuis 15 ans. Thèse Université Pierre et Marie Curie-Paris VI, 246p ; 1992.
2. Macauley H, Ramadjita T. Les cultures céréalières: riz, maïs, millet, sorgho et blé. Document de référence. Dakar, Sénégal. 38p ; 2015.

3. Sanchez PA, Shepherd KD, Soule MJ, Place FM, Buresh RJ, Izac A-MN, Mokwunye A U, Kwesiga FR, Ndiritu CG, Woomer PL. Soil fertility replenishment in Africa: an investment in natural resource capital. In: Buresh R.J., Sanchez P.A. and Calhoun F. (Eds.), Replenishing Soil Fertility in Africa. SSSA Special Publication. Soil Science Society of America, Madison, WI, 1997; 51 : 1 – 46. DOI : https://doi.org/10.2136/sssaspecpub51.c1.

4. Olukemi TA, Makinde EA. Soil nutrient dynamics, growth and yield of green maize and vegetable cowpea with organic-based fertilization. Arch. Agron. Soil Sci. 2014; 60(2): 183-194. DOI: https://doi.org/10.1080/03650340.2013.775422

5. Kherallah M, Delagde C, Gabre-Madhin E, Minot N, Johnson M. Reforming agricultural markets in Africa. Baltimore, USA, IFRI and Johns Hopkins University Press, 224p; 2002.

6. Kelly AV, 2006. Factors affecting demand for fertilizers in sub Saharan Africa. Africa fertizers summit, Ibadan, Nigeria. World Bank papers. Agriculture and Rural Development, Discussion p23. 2006; 23:90. Accessed on 10 September 2022. Available: https://www.inter-reseaux.org/wp-content/uploads/10_Kelly-Factors_Affecting_Demand_for_Fertilizer.pdf.

7. DSID (Direction des statistiques agricoles, de l'informatique et de la documentation). Rapport du bilan de la campagne agro-pastorale 2021-2022 au Togo. 60p ; 2022.

8. Bationo A, Waswa B, Abdou A, Bado BV, Bonzi M, Iwuafor E, Kibunja C, Kihara J, Mucheru M, Mugendi D, Mugwe J, Mwale C, Okeyo J, Olle A, Roing K, Sedogo M. Overview of long term experiments in Africa. In Lessons learned from long-term soil fertility management experiments in Africa. Bationo A, Waswa B, Kihara J, Adolwa I, Vanlauwe BKoala S. Eds, Springer, New York London. 1-26; 2012.

9. IFDC (International Fertilizer Development Center). Mainstreaming pro-poor fertilizer access and innovative practices in West Africa, IFAD Technical Assistance Grant No. 1174 report. Muscle Shoals, Alabama; 2013.

10. Kaho F, Yemefack M, Feujio-Tegwefouet P, Tchanthaouang JC. Effet combiné de feuilles de Tithonia diversifolia et des engrais inorganiques sur le rendement du maïs et les propriétés d'un sol ferralitique au centre du Cameroun. Tropicultura. 2011; 29 (1) : 39 – 45.

11. Useni SY, Baboy LL, Kanyenga LA, Assani BL, Mbuyi KM, Kasanda MN, Mbayo Kyongo LJ, Mpundu MM, Nyembo KL. Problématique de la valorisation agricole des biodéchets dans la ville de Lubumbashi: identification des acteurs, pratiques et caractérisation des déchets utilisés en maraîchage. J. Appl. Biosci. 2014; 76: 6326-6337. DOI: http://dx.doi.org/10.4314/jab.v76i1.5.

12. Mosier AR, Syers JK, Freney JR. Agriculture and the Nitrogen Cycle: assessing the impacts of fertilizer Use on food production and the environment. SCOPE 65, Scientific Committee on Problems of the Environment, of the International Council for Science, Island Press, London; 2004.

13. Li XH, Han XZ, Li HB, Song C, Yan J, Liang Y. Soil chemical and biological properties affected by 21-year application of composted manure with chemical fertilizers in a Chinese Mollisol. Can. J. Soil Sci. 2012; 92(3): 419-428.

14. Khalid AA, Tuffour HO, Bonsu B, Mensah PQ. Effects of Chicken Manure and NPK Fertilizer on Physical Properties of a Sandy Soil in Ghana. IJSRAS. 2014; 1(1): 1-5. DOI: http://dx.doi.org/10.12983/ijsras- 2014-p0001-0005.

15. Zahed Z, Mufti S, Kumar SS, Wani OA, Mushtaq F, Rasool R, Hossain A. Organic and inorganic mulches combination improves the productivity, quality and profitability of rainfed potato in the temperate himalayan region. Gesunde Pflanzen, 2022 ; 1-14.

16. Achieng JO, Ouma G, Odhiambo G, Muyekho F. Effect of farmyard manure, inorganic fertilizers on maize production on Alfisols and Ultisols in Kakamega, western Kenya. Agriculture and Biology Journal of North America. 2010; 5: 740-747.

17. Lansigan FP, de Los Santos WL, Coladilla JO. Agronomic impacts of climate variability on rice production in Philippines. Agriculture. Ecosystems and Environment. 2000; 28: 129 -137.

18. Wheeler TR, Craufurd PQ, Ellis PQ, Porter JR, Varaprasad PV. Temperature variability and yield of annual crops. Agriculture, Ecosystems & Environment. 2000; 80: 159-167.

19. Hatfield L, Boote KJ, Kimball BA, Ziska LH, Izaurralde RC, Ort D. Climate Impacts on Agriculture: Implications for Crop Production, Agronomy Journal. 2011; 103(2): 351-370.

20. Sogbedji MJ, Detchinli SK, Mazinagou M, Atchoglo R, Bona AK. Land degradation and climate change resilient soil and crop management strategies for maize production in Coastal Western Africa. IOSR Journal of Agriculture and Veterinary Science. 2017; 10 (6): 24-30.

21. Saragoni H, Poss R, Marquette J, Latrille E. Fertilization and succession of food crops in southern Togo: summary of a long-term experiment on barren land. Tropical Agronomy. 1992; 46: 107-120.

22. Worou SK. Dominant soils of Togo: Correlation with the World Reference Base. ISSN 1014-853. Fourteenth meeting of the West and Central African Soil Correlation Sub-Committee for Land Reclamation. Abomey, Benin, October 9-13. 2000 AG/AGL. pp 105-120. Accessed on 10 January 2022. Available at http://www.fao.org/3/a-y3948e.pdf.

23. Raunet M. Contribution à l'étude pédologique des terres de barre du Dahomey et du Togo. Agronomie Tropicale. 1973 ; 28 (11): 1049-1069

24. Louette D. Synthesis of research work on the fertility of barre lands in Benin and Togo. Montpellier, CIRAD-DSA. 34p; 1988.

25. Somana KA, Sedzro KM, Akakpo KE. Cassava production in Togo. WASNET No 8. Accra. pp: 24-28; 2001.

26. IITA (International Institute for Tropical Agriculture). Automated and Semi-automated methods for soil and plant analysis, Manual series 7. Ibadan, Nigeria; 2014.

27. Laba BS, Sogbedji JM. Identification of land degradation and climate change resilient soil and crop management strategies for maize production on West African ferralsols. International Invention Journal of Agricultural and Soil Science. 2015; 3(2):13-20.

28. CORAF (Conseil Ouest et Centre Africain pour la recherche et le développement agricole). Catalogue Régional des Espèces et Variétés Végétales CEDEAO-UEMOA-

CILSS. Dakar, Sénégal. 2017; pp 27-44. Accessed on 29 August 2022. Avaible: http://www.insah.org/doc/pdf/Catalogue_Regional_semences_vf_janv_2017.pdf

29. CORAF. Catalogue Régional des Espèces et Variétés Végétales CEDEAO-UEMOA-CILSS.Variétés homologuées 2016-2018. Dakar, Sénégal. 2019; pp 4-7. Accessed on 29 August 2022. Avaible: http://www.coraf.org/paired/wp-content/uploads/2019/11/Catalogue-Re%CC%81gional-des-Espe%CC%80ces.pdf

30. Detchinli KS, Sogbedji MJ. Yield performance and economic return of maize as affected by nutrient management strategies on ferralsols in coastal Western Africa. European Scientific Journal. 2015 ; 11 (27): 1857 – 7881.

31. Detchinli KS, Sogbedji JM. Assessment of the profitability and the effects of three maize-based cropping systems on soil health in Western Africa. American Journal of Agriculture and Forestry. 2014; 2(6): 321-329.

32. Senan S, Mamadou D, Daouda D, Tschannen A, Olivier G. Performance de six cultivars de tomate Lycopersicon esculentum Mill. Contre la jaunisse en cuillère des feuilles, le flétrissement bactérien et les nématodes à galles. Sciences & Nature. 2007; 4(2): 123-130

33. Coulibaly DN , Fondio L, N'gbesso FDPM, Doumbia B. Evaluation des performances agronomiques de quinze nouvelles lignées de tomate en station au centre de la Côte d'Ivoire. nt. J. Biol. Chem. 2019 ; Sci. 13(3): 1565-1581. DOI: https://dx.doi.org/10.4314/ijbcs.v13i3.29

34. Sogbedji JM, van Es HM, Agbeko KL. Cover cropping and nutrient management strategies for maize production in Western Africa. Agronomy Journal. 2006; 98: 883-889.

35. Amouzou KA, Ezui KS, Sogbedji JM. Impacts of climate variability and soil fertility management strategies on maize grain yield on ferrralsols in Coastal. Western Africa, Journal of Renewable Agriculture.2013; 1(3): 44-52.

36. Bationo A, Hartemink A, Lungu O, Naimi M, Okoth P, Smaling E, Thiombiano L. African Soils: Their Productivity and Profitability for Fertilizer Use. Background paper for the Africa Fertilizer Summit in Abuja, Nigeria; 9-13. June 2006.

37. Kabrah V, Vao NR, Dea GB, Couloud JV. Effet de l'apport d'engrais et de la matière organique sur le rendement en grains chez le maïs. Cahiers Agriculture. 1996; 5: 189-93.

38. Baulcombe D, Crute I Davies B, Dunwell J, Gale M, Jones J, Pretty J, Sutherland W, Toulmin C, Green N. Reaping the benefits: science and the sustainable intensification of global agriculture. Roy. Soc. London; 2009.

39. Sikuzani YU, Ilunga GM, Mulembo TM, Katombe BN, Lwalaba JLW, Lukangila MAB, Lubobo AK, Longanza LB. Amélioration de la qualité des sols acides de Lubumbashi (Katanga, RD Congo) par l'application de différents niveaux de compost de fumiers de poules. J. Appl. Biosci. 2014; 77: 6523-6533.

40. Gomgnimbou PKA, Bandaogo AA, Coulibaly K, Sanon A, Ouattara S, Nacro BH. Short-term effects of chicken manure application on maize (*Zea mays* L.) yield and chemical characteristics of ferralitic soil in the southern Sudanian zone of Burkina Faso. International Journal of Biological and Chemical Sciences. 2019; 13(4): 2041-2052. DOI: https://dx.doi.org/10.4314/ijbcs.v13i4.11.

41. Useni SY, Baboy LL, Nyembo KL, Mpundu MM. Combined effects of organic wastes and inorganic fertilizers application on yield of three varieties of Zea mays L. grown in the region of Lubumbash. Journal of Applied Biosciences. 2012; 54: 3935–3943.

42. Olivares B, Hernández R, Arias A, Molina JC, Pereira Y. Zonificación agroclimática del cultivo de maíz para la sostenibilidad de la producción agrícola en Carabobo, Venezuela. Revista Universitaria de Geografía. 2018; 27 (2): 139-159. https://n9.cl/i0upn

43. Olivares B. Tropical conditions of seasonal rain in the dry-land agriculture of Carabobo, Venezuela. La Granja: Journal of Life Sciences. 2018; 27(1): 86-102. http://doi.org/10.17163/lgr.n27.2018.07

44. Olivares B, Parra R, Cortez, A. Characterization of precipitation patterns in Anzoátegui state, Venezuela. Ería. 2017; 3 (3): 353-365. https://doi.org/10.17811/er.3.2017.353-365

45. Olivares B. Description of soil management in agricultural production systems of sector Hammock in Anzoátegui, Venezuela. La Granja: Revista de Ciencias de la Vida. 2016; 23(1): 14–24. https://doi.org/10.17163/lgr.n23.2016.02

46. Olivares B, Cortez A, Parra R, Lobo D, Rodríguez M.F, Rey JC. Evaluation of agricultural vulnerability to drought weather in different locations of Venezuela. Rev. Fac. Agron. (LUZ). 2017; 34 (1): 103-129. https://n9.cl/d827w

47. Olivares B, Hernández R, Coelho R, Molina JC, Pereira Y. Análisis espacial del índice hídrico: un avance en la adopción de decisiones sostenibles en los territorios agrícolas de Carabobo, Venezuela. Revista Geográfica de América Central. 2018; 60(1): 277-299. https://doi.org/10.15359/rgac.60-1.10

48. Olivares B, López-Beltrán M, Lobo-Luján D. Cambios de usos de suelo y vegetación en la comunidad agraria Kashaama, Anzoátegui, Venezuela: 2001-2013. Revista Geográfica De América Central. 2019; 2(63): 269-291. https://doi.org/10.15359/rgac.63-2.10

49. Olivares B, Paredes F, Rey J, Lobo D, Galvis-Causil S. The relationship between the normalized difference vegetation index, rainfall, and potential evapotranspiration in a banana plantation of Venezuela. SAINS TANAH - Journal of Soil Science and Agroclimatology, 2021; 18(1): 58-64. http://dx.doi.org/10.20961/stjssa.v18i1.50379

50. Olivares B, Vega A, Calderón MAR, Rey JC, Lobo D, Gómez JA, Landa BB. Identification of Soil Properties Associated with the Incidence of Banana Wilt Using Supervised Methods. Plants. 2022; 11(15): 2070. https://doi.org/10.3390/plants11152070

51. Olivares BO, Rey JC, Perichi G, Lobo D. Relationship of Microbial Activity with Soil Properties in Banana Plantations in Venezuela. *Sustainability*. 2022; 14(20): 13531. https://doi.org/10.3390/su142013531

52. Olivares BO, Calero J, Rey JC, Lobo D, Landa BB, Gómez JA. Correlation of banana productivity levels and soil morphological properties using regularized optimal scaling regression. *Catena*. 2022; 208: 105718. https://doi.org/10.1016/j.catena.2021.105718

53. Olivares BO, Araya-Alman M, Acevedo-Opazo C, Rey JC, Canete-Salinas P, Kurina FG, Balzarini M, Lobo D, Navas-Cortes JA, Landa BB, Gomez JA. Relationship Between Soil Properties and Banana Productivity in the Two Main Cultivation Areas in

Venezuela. *J Soil Sci Plant Nutr*. 2020; 20 (3): 2512-2524. https://doi.org/10.1007/s42729-020-00317-8