ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 13, Issue, 01, pp. 61401-61406, January, 2023
https://doi.org/10.37118/ijdr.25913.01.2023

RESEARCH ARTICLE OPEN ACCESS

ASSESSMENT OF THE IMPACT OF ORGANIC AND MINERAL MANURE (BAT GUANO, TITHONIA DIVERSIFOLIA AND NPK) ON THE EVOLUTION OF SOME PHYSICO-CHEMICAL PARAMETERS OF SOIL FERTILITY DURING MAIZE CULTIVATION IN NGANDAJIKA/RDCONGO

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ARTICLE INFO

Article History:
Received 07th November, 2022
Received in revised form
21st November, 2022
Accepted 14th December, 2022
Published online 27th January, 2023

KeyWords:

Impact, Bat-guano, Tithonia diversifolia and NPK, fertility parameters, maize cultivation.

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ABSTRACT

Soil is a fundamental resource for man's life on earth, most of the goods he needs coming directly or indirectly from the soil. This is not done without compensation in favour of the soil, which loses its productive capacity over time. Compensation is made through the provision of both mineral and organic fertilizers to the soil. A trial was conducted in Ngandajika where it was applied to the soil, two organic fertilizers, Bat-guano and Tithonia diversifolia, *a mineral fertilizer, DAP for growing corn. At the end of this test, the following results were recorded: the pH was increased from 5.20 to 5.80 with the application of Tithonia diversifoia manure.* The carbon content increased from 2.3 to 2.93 Kg/Ha, the nitrogen content increased from 5.5 to 23.99 Kg/Ha with *Tithonia diversifolia*. As regards phosphorus, its content increased from 12.24 to 46.04 kg with NPK, potassium from 4.9 to 21.83 kg/ha with *Tithonia diversifolia* and calcium from 23.7 to 56.73 kg/ha with Bat-guano. Both organic and mineral fertilizers increase soil fertility.

Citation: ***Nkongolo M, Tshimbombo J. and Mukendi K. 2023.*** "Compliance to clinical handoff communication and its impact on patient safety in hemodialysis units*", International Journal of Development Research*, 13, (01), 61401-61406.

INTRODUCTION

Agricultural production is dependent on the state of soil fertility. It is currently well established that on the soil where a crop is planted for the very first time, one can claim to have a good harvest without having contributed anything. However, it is not the same for a field that has been under cultivation for several growing seasons on which, the harvest is removed from the production cycle by man without any compensation for the soil that is most involved, Production is falling more and more. This means there is a decline in fertility (Fairhust, 2015; Citeau et al, 2012). It is up to the farmer to make inputs of mineral and organic fertilizers throughout the farming cycle in order to restore to the soil what he loses with the harvests. It is clear that soil degradation occurs throughout the operating cycle (Mukalay 2016). Its physico-chemical parameters constituting its fertility are deteriorating. The addition of both organic and mineral fertilisers to the soil restores them for the continuity of its exploitation (MULAJI KYELA, 2011). It is with this in mind that this research was initiated with the objective of evaluating the impact of the contribution of some organic and mineral fertilizers on the evolution of certain physico-chemical parameters of the soil constituting its fertility. It was then conducted a Ngandajika trial of the cultivation of maize on which it was applied the organic manures of Bat-guano, *Tithonia diversifolia*, and that of DAP to verify their impact on the evolution of some physico-chemical characteristics of the soil. Soil samples were collected prior to field installation as well as after harvest. These samples were analysed in the laboratory for some physico-chemical characteristics of the soil to examine their evolution during cultivation. In addition to these analyses, crop growth and yield parameters were collected to determine the impact of these fertilizers on the development and production of the corn crop. This is the methodology used in this test.

RESULTS AND DISCUSSION

Impact of the fertilisers used on the development and yield of the maize crop

$T0_{= Control,\ T1}$ = NPK, T_2 = Tithonia, T_3 = Bat-guano

Table 1. Effects of fertilisers on the development parameters of maize cultivation

Fertilisans	Lift rate	Diameter at collar (cm)	Height of plants (cm)	Leaf area (cm2)
T_1	85.83a	2.35a	124.17a	630.72a
Q_2	86.67a	2.30a	121.50a	525.35b
T_3	89.17a	2.32a	125.67a	602.17a
T_0	82.17a	2.28a	114.83b	476.52c
Average	85,96	2,31	121,54	558,69
Decision	NS	NS	S	S
C.V.	16,13	27,55	12,07	11,57

Growth parameters

1) **The lifting rate:** There is no significant difference in the discharge rate, all discharge rates are statistically similar: T0 (82.17) = T1 (85.83) = T2 (86.67) = T3 (89.17).
2) **The diameter at the collar:** There is no significant difference between the smokes for the diameter at the collar, all smokes have statistically the same diameter at the collar: T0 (2.28) = T1 (2.35) = T2 (2.30) = T3 (2.32).
3) **Plant height:** There is a significant difference between manures for plant height. Bat-guano, mineral fertilizer and Tithonia have a plant height statistically the same but higher than the control as follows: T3 (125.67cm) = T1 (124.17cm) = T2 (121.50cm) T0 (114.83cm).
4) **The hay surface:** There is a significant difference between leaf surface manure. Mineral fertilizer and bat-guano have a larger leaf area statistically than other manures as follows: T1 (630.72cm2) = T3 (602.17cm2) T2 (525.35cm2) T0 (476.52cm2)

Table 2. Fertilizer Effects on Corn Crop Yield Parameters

Fertilisers	No of epi/pl.	Number of seeds/ear	Weight of 1000 seeds (g)	Yield (Mg/ha)
NPK	1.33a	387.45a	214.83a	3.85a
Tithonia	1.33a	356.10b	212.33a	3.01b
Bat-guano	1.29a	390.97a	218.83a	3.21b
Witness	1.27a	333.58c	211.67a	1.63c
Average	1,24	366,77	214,42	2,16
Decision	NS	S	NS	S
C.V.	3,92	14,57	10,56	25,78

T0 = Control, T1 = Mineral fertilizer, T2 = Tithonia, T3 = Bat-guano

Performance Parameters (Production)

1) **Number of ears per plant:** There is no significant difference in the number of heads per plant, T0 (1.27) = T1 (1.33) = T2 (1.33) = T3 (1.29).
2) **Number of seeds per ear:** The difference between manure is significant for the number of seeds per ear, bat guano (390.97) and NPK (387.45) statistically have the same number of seeds per ear as Tithonia (356.10), which has it statistically larger than the control (333.58).
3) **The weight of a thousand grains:** There is no significant difference between the manures for the weight of a thousand seeds. All these fumes give statistically similar values: T0 (211.67) = T1 (214.83) = T2 (212.33) = T3(218.83).
4) **The yield:** In terms of yield, there is a significant difference between manures. NPK has statistically higher yield than other manures as T1 (2, 85Mg.ha-1) T3 (2.21 Mg.ha-1) = T2 (2.01Mg.ha-1) T0 (1.63 Mg.ha-1).

Influence of the application of organic and mineral manure on the physico-chemical characteristics of the soil: The table shows the pH and soil content of some mineral elements before fertilizer application and after maize harvest.

Table 1. Soil sample analysis results before and at the end of the 2014 test (crop season B 2014)

Car.phys.ch.du sol	Initial state	End state		
		Ba.gu.	Titho.	NPK
pH	5,20	5,50	5,80	5,60
C(ppm)	0,51	0,62	0,65	0,42
N(ppm)	1,21	3,77	5,33	3,92
P(ppm)	2,75	8,61	8,45	10,23
K(ppm)	1,10	3,42	4,85	4,64
Ca(ppm)	5,26	12,61	10,96	3,10

Legend: Soil Car.phys.ch.=Physico-chemical characteristics of the soil; Ba.gu.= Bat guano; Titho.= *Tithonia diversifolia*; ppm=parts per million

Some soil properties on depth (0-30 cm) before and at the end of the 2014 B season trial. Before the application of fertilisers, the pH is 5.20 after the corn harvest, it is 5.50 where the bat guano was applied, 5.80 where the Tithonia diversifolia *was* and 5.60 where the NPK was applied. The soil content of some mineral elements C, N, P and Ca is expressed in parts per million (ppm) before application of fertilisers and after maize harvest.

Table 2. shows the chemical composition of the soil that is converted to Kg/ha, reflecting the state of soil fertility before fertilizer application and after corn harvest, as well as the increase in pH and nutrient content after corn harvest.

Table 2. State of soil fertility before and after fertilization and changes in soil physico-chemical characteristics

Car.phys.ch.du sol	Initial state	End state			Increase (%)		
		Ba.gu.	Titho.	NPK	Ba.gu.	Titho	NPK
pH	5,2	5,5	5,8	5,6	5,7	11,5	7,6
C(kg/ha)	2,3	2,80	2,93	1,89	21,5	27,4	-18
N(kg/ha)	5,5	17	23,99	17,64	211,7	340,6	223,9
P(kg/ha)	12,4	38,76	38,00	46,04	212,8	206,7	271,5
K(kg/ha)	4,9	15,40	21,83	20,88	211,6	341,9	322,6
Ca(kg/ha)	23,7	56,73	49,30	47,40	139,7	108,3	100,3

Soil physico-chemical characteristics, Ba.gu. Bat guano, *Titho:* The increase in pH with tithonia is higher (11.50%), followed by NPK (7.60%) and finally bat-guano (5.70%). The increase in soil carbon content is greater with tithonia (27.40%) followed by bat guano (21.50%) and finally, it is negative for NPK (-17.60%). While the nitrogen is greater for tithonia (340.60%) followed by NPK (223.90%) and finally bat-guano (211.70%). The increase in phosphorus content is higher for NPK (271.50%), followed by bat guano (212.80%) and finally tithonia (206.70%) while that in potassium is higher for tithonia (341.90%) followed by NPK (322.60%) and finally bat guano (211.60%). The increase in calcium content is greater for bat guano (139.70%) followed by tithonia (108.26%) and finally n NPK (100.30%). Examination of Tables I. and 2. leads us to the conclusion that, overall, there is an increase in the physico-chemical characteristics of the soil with the exception of carbon, the content of which decreases after the harvest of the maize crop, on plots fertilized with NPK mineral fertilizer.

Evaluation of the quantity consumed and lost under fertiliser application

Table 1. Fertilizer Input and Nutrient Consumption

Type of soil	Initial state	State after ap.de ferti.			Qty Cons & Lost		
		Ba.gu.	Titho	NPK	Ba.gu.	Titho	NPK
pH	5,20	5,50	5,80	5,60	5,50	5,80	5,60
C(kg/ha)	2,30	2302,30	792,30	2,30	2299,50	789,37	0,41
N(kg/ha)	5,50	725,50	325,50	22,50	708,50	301,51	4,86
P(kg/ha)	12,40	918,40	58,40	29,40	879,64	20,40	24,14
K(kg/ha)	4,90	124,90	334,90	21,90	109,50	313,07	1,02
Ca(kg/ha)	23,70	231,70	313,70	23,70	174,97	264,40	23,10

Legend: Car.phys.ch. of the soil:Physico-chemical characteristics of the soil, Ba.gu. :Bat guano, Titho. :*Tithonia diversifolia,* State after ap. de ferti.: State after application of fertilizers, Qty cons. and lost: Quantity consumed and lost.

The amount consumed and lost is large for the carbon on the plot smoked in bat guano (2299.50kg/ha) then comes that lost on Tithonia (789.39kg/ha) and finally the NPK (0.41kg/ha). The amount consumed and lost for nitrogen is large for bat guano (708.50kg/ha), followed by Tithonia (301.51kg/ha) and then NPK (4.86 kg/ha). It is 879.64kg/ha for phosphorus on bat guano larger than on NPK (24.14kg/ha) and finally on Tithonia (20.40kg/ha). However, it is (313.07kg/ha) for potassium on Tithonia, 109.50kg/ha on bat guano and 1.02kg/ha on NPK.

Assessment of soil water holding capacity with bat-guano and *Tithonia diversifolia*

Tables 1. and 2. respectively show the water holding capacity of bat-guano, Tithonia diversifolia *outside the soil and the water holding capacity of these two organic materials in the soil.*

Table 1. Bat-guano and Tithonia diversifolia *water holding capacity* outside the soil

Trait.	B.g.	T.D.
C.R.water(g)	19,12	0,55

Legend: trait.= treatment, C.R.water=water holding capacity B.g.=Bat guano, T.d.=*Tithonia diversifolia,*

Outside the soil, bat-guano has a retention capacity of 19.12 g of water/100g of material higher than that of *Tithonia diversifolia* of 0.55g of water/100g of material.

Table 2. Soil water holding capacity with bat-guano and *Tithonia diversifolia*

Trait.	B.g.	T.D.	DAP	B.G.+DAP	T.D.+DAP	Tem.	Dec.	C.V.(%)
C.R.water(g)	46.60a	28.14c	27.71c	33.79b	30.33c	27.27c	S	9,54
Acc.C.R.%	70,88	3,20	1,61	23.90	11,22			

Caption: B.g.=Bat guano, T.d.=*Tithonia diversifolia,* B.g.+DAP=1/2(Bat guano+DAP), T.d.+DAP=1/2(*Tithonia diversifolia*+DAP), Tem.= Control, Dec.= Decision, C.V.=Coefficient of variation, C.R.water(g)= Soil water holding capacity expressed in grams of water per 100g of soil.
Acc.C.R.%=Increase in soil water capacity relative to control
Source: Analysis/O.C.C Mbujimayi

Bat guano gives the soil statistically a greater water capacity (46.60g/100g soil) than the association B.g.+DAP (33.79g/100g soil), then the other manures tested have statistically the same water capacity,the T.d.+DAP (30.33g/100g soil)= to T.d. (28.14g/100g soil)=DAP (27.71g/100g soil)= control (27.27g/100g soil). The increase in the water capacity of the soil with bat-guano is of the order of 70%, followed by that of B.g.+DAP (23.90%) and then those of the other fertilizers.

DISCUSSION

The evolution of the rains and temperatures recorded in this season has been good. In terms of volume, rainfall distribution and known temperatures, these conditions did not constitute a constraint on the development of the corn crop, which developed normally. The germination, emergence, flowering and fruiting requirements were covered, which allowed the conduct of this non-disruptive trial related to climate change and made the following observations. For the cultivation of maize, the effects of these fertilizers are presented in the following order, whether they are growth parameters such as those of yield, the NPK overall comes first, followed by the Bat-guano and then the *Tithonia diversifolia* and finally the control, these results are explained by the richness of the mineral fertilizer NPK, which contains all the basic nutrients that well meet the growth and yield needs of the cultivation of maize. Bat-guano, behaves more like a mineral fertilizer than an amendment compared to *Tithonia diversifolia* and contains more diversity of mineral elements. It also contains microorganisms that also affect other soil characteristics. (Nkongolo et al., 2016a). Compared with some soil fertility parameters, their evolution is formulated as follows: (1) The intake of Bat-guano, *Tithonia diversifolia* and NPK allowed the pH to be adjusted from 5.2 to 5.5 with Bat-guano, to 5.8 with tithonia and to 5.6 with NPK, respectively. This adjustment is due to calcium ions (Ca^{+2}) contained in these organic fertilizers which have reduced the acidity of the soil. These findings are in line with the results recorded in Haut-Katanga, according to which the contribution of organic matter to the soil increases its pH (Mukalay, 2016). Agricultural use of organic manure-free tropical soils naturally leads to acidification (Pearson 1975; Soltner 1994; Harter 2007). In particular, mineral fertilizer (NPK) inputs also increased pH, leading to phosphorus ions that combine with free Al^{+3} ions (being an origin of soil acidity) to form insoluble complexes and thus contribute to reducing soil acidity (Iyamuremye and Dick, 1996). (2) The results recorded on the content of the mineral elements tested show an increase in the level of these nutrients, after the application of manures used as follows.

The increase in nitrogen content is in the order of 211.7% with bat-guano, 340.5% with Tithonia and 223.9% with NPK. The contribution of these fertilizers (organic and nitrogen-containing minerals) to the soil increases their nitrogen content, as Kimetu experimented with nitrogen-rich organic manure on maize cultivation in Kenya, respectively. Karimou observed this with the Bat guano on the cultivation of green lettuce in Burkina Faso. This was found in the *Tithonia* diversification on maize cultivation in Kinshasa, DRCongo (Kimetu 2001; Karimou 2012; Lele et al 2016). The increase in phosphorus content is 212.8% with the soil input of Bat-guano, 206.7% with that of Tithonia and 271.5% with NPK. These results are explained by the fact that not only does organic matter contribute this mineral element, it also mobilizes and makes available the complexed phosphorus in the soil (Sridhar et al., 2006; Kisinyo et al., 2011; Ikerra et al., 2011). The carbon content of the soil increases with the addition of bat-guano and *Tithonia diversifolia*. The ^{first} increases the soil carbon content by 21.5% from the initial content. While Tithonia increases it by 27.4%, and NPK intake decreases the carbon content of the soil. Organic matter intake increases the level of soil organic carbon (Hénin, 1945; Hilhors and Toulmin, 2000). This fact explains the results recorded with bat-guano and Tithonia, the NPK (mineral manure) can only reduce the level of organic carbon as long as it is not associated with a humiferous amendment. Naturally, farming soil without organic matter reduces organic carbon so much that it is important not to do without it mainly in tropical regions (Chukwuka et al, 2009; Vanlauwe et al., 2015; Nkongolo, 2016).

Potassium and calcium levels increased by (211.6% and 139.7%) with bat-guano, (341.9% and 108.26%) with Tithonia, and mineral fertilizer (322.6%). The soil intake of these three fertilizers increases its potassium content in proportion to their chemical composition in this element. These organic and mineral fertilizers increase the content of mineral elements in the soil, while increasing the yield of corn (Stoorvogel and Smaling, 1990; Soltner, 1994; Kathuku et al, 2011).

The amount consumed and lost of nutrients is high for carbon on the plot smoked with the beaten guano (229,50kg/ha), followed by that lost on the Tithonia (789,39kg/ha) and finally by the NPK (0,41kg/ha). The amount consumed and lost for nitrogen is large for bat-guano (708.50 kg/ha), followed by Tithonia (301.51 kg/ha) and finally NPK (4.86 kg/ha). It is 879.64 kg/ha for phosphorus on the bat-guano larger than on the NPK (24.14 kg/ha) and finally on the Tithonia (20.40 kg/ha). However, it is (313.07kg/ha) for potassium on Tithonia, 109.50kg/ha on guano bat and 1.02kg/ha on NPK. This is because the Guano bat behaves as a mineral fertilizer that releases nutrients rapidly, whereas *Tithonia diversifolia* (organic matter releases them slowly and gradually, NPK being a chemical fertilizer, is a chemical concentrate that releases them quickly and makes them available for cultivation when applied at the right time, thus minimizing losses (Stoorvogel and Smaling 1993; Nkongolo 2016). It is observed that the amount of nutrients lost is greater than that consumed by the crop and residual moisture. This is explained, on the one hand, by the sandy-clayey nature of the soil and, on the other hand, by the different routes of loss of these nutrients, in particular, leaching, volatilization, erosion etc. (Pieri, 1989; Pelzer et al. 2012; Ferguson J., 2015).

Faced with the characteristics of Ngandajika soils, in particular the exchangeable aluminum which is present in a high proportion on the clay-humic complex, the supply of calcium by these organic fillings allows the exchange of the first element against the second element on the complex. This results in the formation of $Al(OH)_3$, which is a weak base that is not very dissociable with the increase in pH (Stoorvogel et al., 1993; Harter, 2007). On the other hand, the supply of these fertilizers also makes it possible to raise the content of Mg,K, which are below the deficiency threshold in the Ngandajika soil and thus increase its EEC. As regards phosphorus, its content increases with the use of these fertilizers which, not only supply this mineral element, but also these organic manures mobilize and make available the complexed phosphorus in the soil (Iyamuremye et al., 1996; Frossard et al., 2004). Thus, the main limitations of Ngandajika soils that are chemical in nature can be lifted. The reduction of acidity, allows the increase of the nutrient content.

With respect to soil water retention capacity, the results show that the bat-guano induces an increase in this parameter of about 70% compared to the control. These results explain the development of maize cultivation as well as the production obtained despite the effects of climate change observed, which were characterized by drought and abundant rainfall during this growing season. It is therefore observed that for the various fertilizations used, the Guano bat is placed first, followed by its association with the DAP, then come the association *Tithonia diversifolia*+DAP, the *Tithonia diversifolia* and the control which confer overall the same capacity for retention of soil water. Bat guano is an organic material with multiple virtues, it also increases the water retention capacity of the soil as found in Anonyme (2014b) and Nkongolo (2019). While *Tithonia diversifolia* due to its nitrogen and sugar richness produces transient products that disappear, leaving no humus that can increase structural stability and water retention capacity (Anonymous 2014b). These facts explain the results obtained on the water retention capacity of the soil. In the remainder of this study, after assessing the impact of all these fertilizers on soil fertility, it is also appropriate to examine their impact on maize cultivation. In fact, with respect to the growth parameters: there is no significant difference between the manures for the rate of emergence. All manures have statistically similar values, T_1 (85.83) = T_2 (86.67) = T_3 (89.17) = T_0 (82.17). This result is likely due to the heterogeneity of the soil with respect to its fertility, not reflecting the impact of fertilizers on this parameter. The same applies to the diameter at the collar. With regard to plant height, there is a significant difference between manure. Bat-guano, NPK, and Tithonia diversifolia had statistically higher plant height than the control as follows: T_3 (125.67cm) = T_1 (123.17cm) = T_2 (121.50cm) ≥ T_0 (114.83cm). This result is essentially related to the richness of these three mineral and organic fertilizers compared to the control on which nothing has been brought that could improve fertility (Kimani, 2003; Nkongolo, 2016). Compared with the foliar surface, there is a significant difference between the manures. NPK and bat-guano have a statistically larger leaf area than other manures as follows: T1 (630.72cm2) = T3 (602.17cm2) ≥ T2 (525.35cm2) ≥ T0 (476.52cm^2).

This result is probably due to the richness of these two fertilizers as reported below.

With respect to the production parameters (yield), the following was observed: There was no significant difference between the manures respectively for the number of ears per plant, the weight of a thousand seeds. These two parameters give statistically similar values for all manures. The first parameter is a more variety-related characteristic, on which the manure would have no perceptible effect. The difference between the manures is significant for the number of seeds per ear and the yield. Bat-guano and NPK have statistically the same number of seeds per ear more than other manures as follows: T_3 (390.97) = T_1(387.45) ≥ T_2 (356.10) ≥ T_0 (333.58). In relation to yield, the situation is as follows: NPK yields statistically higher than other manures as follows: T1 (2.85Mg.ha-1) ≥ T3 (2.21 Mg.ha-1) = T2 (2.01Mg.ha-1) ≥ T0 (1.63 $Mg.ha^{-1}$). The high base-element content of NPK and the richness of bat-guano are the basis for these results (Soltner, 1994). In short, the input of fertilizers used not only affected the physico-chemical characteristics of the soil, but also affected the parameters of development and yield of the corn crop, as was the case in previous trials.

CONCLUSION

During this growing season, the volume and distribution of rainfall, as well as the temperatures recorded, allowed a good evolution of the maize crop and the test was well conducted. The objective of this study was to assess the impact of manure from *Tithonia diversifolia*, bat-guano and mineral fertilizer (NPK) on some soil properties, and also to confirm the results recorded on the cultivation of maize in the previous trials. On completion of analyzes on soil samples taken before the crop is grown and after harvesting. The results are as follows: pH readjustment for all fertilizers and increased nutrient content with both organic materials. For NPK, the increase in nutrient content was recorded mainly for the 3 basic elements. The carbon content of the soil has increased with the bat-guano and *Tithonia diversifolia* manures and thus results in an increase in the content of the organic matter of the soil. This necessarily translates into improved structure (structural stability) and increased soil water retention capacity. In fact, the Guano bat and its association with the DAP increase the water retention capacity of the soil more than all the other fumures tested which have the same mean value of this parameter. Soil nitrogen, phosphorus, potassium and calcium levels increase with the addition of these organic fillings. Thus, the addition of these organic manures to the soil improves its fertility, and these manures can be recommended to agricultural producers in the Ngandajika region. The *Tithonia diversifolia* grows easily, it is found around fields, along roads, it is within reach of producers. Its use can be done without difficulty, and it also has the advantage of being a bio-pesticide for many crop pests and corn in particular (Thomas, 2004). The bat-guano cannot pose the problem of availability, with the presence of caves in the region and the development of bat breeding techniques (Fabianek et al. 2015). Like other trials, these manures increase the yield of maize cultivation and are a response to the problem of the fall in agricultural production, a key cause of the food crisis in the Ngandajika region. In conclusion, it may be concluded that the contribution of these manures does indeed have the advantage of improving, not only the growth and yield of the maize crop, but also of some physico-chemical and biological properties of the soil. They can thus be recommended to Ngandajika growers to solve the problem of soil fertility.

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