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Short Term Effects of the Shea Tree Caterpillars (*Cirina butyrospermi* Vuillet) Manure on the Chemical Properties of the Soil in the Soudanian Area of Burkina Faso

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Authors' contributions

This work was carried out in collaboration between all authors. Authors KC and MG conducted the field study, data collection and statistical analysis of the data and the writing of the manuscript. Author HBN framed, oriented and corrected the manuscript. Authors APKG and JTY corrected and contributed to manuscript formatting. All authors read and approved the final manuscript.

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ABSTRACT

Aims: There is an acute decrease in soil productivity in the soudano-sahelian areas of West Africa. This has called for research to develop mitigation measures in order to restore soil fertility. The aim of this study was to determine the effects of the manure of shea tree caterpillars on the chemical parameters of the soil.
Methodology: To achieve that aim, 2 experiments were conducted, an in-pot trial with 8 treatments (T0 to T7) and a field trial with 3 treatments (T1 to T3) were set up.
Results: The treatments T5 (5T ha^{-1} of caterpillar manure + 150 kg ha^{-1} of NPK) and T4 (5 T ha^{-1} of caterpillar manure) showed significant and positive effects ($P = 0.05$) on pH, C and N. The treatment T1 of the in-pot trial (1.5 T ha^{-1} of caterpillar manure) (pH=5.78), had a significant effect only on the pH, compared with the absolute control T0 (no fertilizer, pH = 5.64) and the treatment T7 (farmers' practice, 150 kg ha^{-1} of NPK and 50 kg ha^{-1} of urea, pH=5.35). The caterpillars manure did not show any significant short-term effect on the total phosphorus and the total potassium neither in-pot nor in the field trial.
Conclusion: For a best valorization of the caterpillar manure produced in situ in the shea tree fields, there must be an appropriate combination with mineral fertilizers and application near seed-holes.

Keywords: In-pot trial; field trial; caterpillar manure; soil fertility.

1. INTRODUCTION

Cropping systems in Burkina Faso are characterized by an intensive use of the soil, open grazing pastures and the burning of crop residues. With the high increase of the population and the speed of extension of the cotton production, there is an increase of cultivated areas along with an over-exploitation of soils.

The consequence of these practices is the fast deterioration of the soils fertility [1,2].

To restore the capacity of production of the soils, this research suggested various technologies which consist among other things in using manure, compost and litter [3,4,5,6].

As animal manure is concerned, some works showed that they are a great significant supply of organic matter [7,8,9,5]. The works talking about the analytic characterization of the animal manure showed some variations which were often observed among the same species and following the physiological growth as the contents in major elements (N, P and K) and the trace elements (Fe, Mg, Cu, Zn, B, Mo) are concerned [10,11,12,7,13]. Then, the composition of the animal manure varies according to the species of the animal, the food intake and the fodder (water content, structural sugars content) [8].

In Burkina Faso, the shea tree caterpillars, very rich in proteins, have an important place in the rural families' life in the part West and in the economy of the country. During the larval cycle, the caterpillars live exclusively on the leaves biomass of the shea tree and excrete an important quantity of manure in the soil. The chemical characterization of caterpillar manure (CM), coming from the digestion of the leaves of the shea tree, showed that it contains respectively 477.7 and 10.8 g kg^{-1} of carbon and nitrogen with a C:N ratio of 44 [14]. This knowledge about the chemical composition of the CM inspired this work which has the aim to study the effects of the CM on the soil fertility and on the crops yield. With that aim in mind, some tests were done as well in station as in real conditions of culture. This article gives the evolution in the short term of the chemical parameters under different treatments combining or not CM at different dose to chemical fertilizers.

2. MATERIALS AND METHODS

2.1 Study Area

The study was done in the village of Banankélédaga (10°11'N, 4°06W) and in Bobo-Dioulasso (11°11'N, 4°17'W), province of Houet, Burkina Faso. Banankélédaga is located 15 km away from Bobo-Dioulasso. These sites have a soudanian climate with an average rainfall between 1000 and 1200 mm per year [15]. This climate is characterized by two distinct seasons: a rainy season from May to September, during which blows the monsoon and a dry season from

October to April, during which blows the harmattan.

The soils are ferruginous tropical type with sandy limon texture or clayey sandy type [16]. There are also other soil types such as tropical ferruginous soils, oxidized gley and swamplands.

2.2 Caterpillar Manure and Mineral Fertilizers

The collection of CM was carried out in Bobo-Dioulasso. The CM were collected using plastic cling films spread over the soil beneath the crown of the shea tree hosting caterpillars. As mineral fertilizers, we used commercial complex NPK (15-15-15) and urea (46% N).

2.3 Experimental Design

Two experimental systems were set up: an in-pot trial in the research station in Bobo-Dioulasso and a field trial in Banankélédaga.

The in-pot trial was designed in Fisher randomized blocks [17], with eight (8) treatments in three (03) replicates.

Perforated plastic pots of 9 liters of capacity were used, to prevent water log in case of a strong rainfall. Ten (10) kg of soil was put in each pot to grow maize plants, as per El Gharous et al. [18] The CM and the mineral fertilizer treatments were applied as it follows:

- T0 : Control (without CM, NPK and urea),
- T1 : Caterpillar manure (1.5 T ha^{-1}),
- T2 : Caterpillar manure (1.5 T ha^{-1}) + NPK (150 kg ha^{-1}),
- T3 : Caterpillar manure (1.5 T ha^{-1}) + NPK (150 kg ha^{-1}) + Urea (50 kg ha^{-1}),
- T4 : Caterpillar manure (5 T ha^{-1}),
- T5 : Caterpillar manure (5 T ha^{-1}) + NPK (150 kg ha^{-1}),
- T6 : Caterpillar manure (5 T ha^{-1}) + NPK (150 kg ha^{-1}) + Urea (50 kg ha^{-1}),
- T7 : NPK (150 kg ha^{-1}) + Urea (50 kg ha^{-1}).

Regarding the field trial, the experiment was also designed in Fisher randomized blocks [18] including three (3) treatments in three (3) replicates. Treatments were applied to elementary plots of 5 m x 4 m (20 m²) in the field of a maize producer in Banankélédaga. The treatments were as it follows:

- T1: NPK (150 g ha^{-1}),
- T2: NPK (150 kg ha^{-1}) + Caterpillar manure (5 T ha^{-1}),
- T3: NPK (150 kg ha^{-1}) + Urea (50 kg ha^{-1}) (Farmer approach).

The fertilizer doses for these treatments were based on the works of Coulibaly et al. [19] for caterpillar manure and Gomgnimbou [20] for NPK and Urea.

2.4 Experimentation Conducting and Soil Sampling

With regard to the in-pot trial, the CM was weighted prior to application in the pots containing ten (10) kg of soil. The maize variety SR21 was sown in the pots on August 14th, 2015. About 3-4 seeds were sown per pot, and 15 days after sowing (DAS), seedlings were thinned out to 2 per pot before supplying the NPK complex for treatments T2, T3, T5, T6 and T7.

The urea was supplied to the maize at 40 DAS in the treatments T3, T6 and T7. Two turnings over of the soil in the pots were done in order to lighten the soil. Pots were watered during October to early November due to scarce rainfall. The soil was sampled 113 DAS after mixing the whole soil content of each pot.

Concerning field trial, the same maize variety SR21 was sown on the 8^{th} of July 2015. NPK and urea were supplied respectively on the 15^{th} and 40^{th} DAS. The CM was supplied at the appropriate proportion of 5 t ha^{-1}, be it 80 g per seed-hole at the 40^{th} DAS. The soil sampling was performed after the harvest on November 5^{th}, 2015. These soil samples were taken from the soil 0-20 cm depth.

2.5 Analysis of Soil Chemical Parameters and Data

All the soil samples were analyzed in the GRN-SP laboratory (Management of the Natural Resources and the Production System) of INERA (Environment and Agricultural Researches Institute) in Farako-Ba (Bobo-Dioulasso). The parameters analyzed were pH_Water, pH_KCl, total carbon, total nitrogen, total phosphorus, total potassium, assimilable phosphorus and available potassium.

Before the dosage of the chemical parameters, the soil samples were dried in the shade, weighted, crushed and sifted two times: a sifting at 2 mm and another one at 0.5 mm.

The pH_Water and the pH_KCl of the soils were measured according to the ratio soil/solution of 1:2.5 through a suspension process of the sample respectively in a distilled water and in a KCl solution in agreement with the French Agency for Standardization [21]. The carbon was determined through the method of Walkley and Black [22]. The total nitrogen was determined through mineralization according to Kjeldahl method. The mineralization to determine the total phosphorus is the same as the one of the total nitrogen. The dosage was done by an automatic colorimeter in SKALAR. The assimilable phosphorus was extracted following Bray I method [23] by a solution of ammonium fluoride (NH_4F) 0.03 M and of chloric acid 0.025 M, in a ratio of extraction soil/solution of 1/7. To dose the potassium in a flame spectrophotometer, soil samples were mineralized as described previously, using a hot concentrated solution of sulfuric acid in the presence of a catalyst.

The data generated were analyzed with the software XLSTAT 2015.4.01.21575 and the test of Newman-Keuls was used for the comparison of the averages of the measured variables on the threshold of 5%.

3. RESULTS

3.1 Effect of the Caterpillar Manure on the Soil pH

The results showed that the soils of the different treatments of the in-pot are acidic with a pH_Water varying between 5.29 (T2) and 5.98 (T4) (Fig. 1). The highest pH (in water and in KCl) (P = 0.05) was found for the treatment T4. The difference between the treatments T4 and T2 was significant for the pH_Water as well as for the pH_KCl.

The Fig. 2. shows that, in the rural area, the supply of CM had no significant effect (P = 0.05) on the pH_Water of the soil. Conversely, the pH_KCl of the treatment T2 (5T ha^{-1}) CM and 150 kg ha^{-1} of NPK) was significantly higher (P = 0.05) than those of the other treatments.

3.2 Effect of Caterpillar Manure on C, N and C:N Ratio of the Soil

The Table 1 shows that for in-pot trial, the contents in C of the soils were between 0.46% (T7) and 0.80% (T5). About the N, the contents varied between 0.03% and 0.04% for N. As for the C:N ratio, it was between 16.03 (T6) and 19.12 (T4). We noted that the treatments T4 (5T ha^{-1} of caterpillar's manure) and T5 (5 T ha^{-1} + 150 kg ha^{-1} of NPK) lead to contents in C and in N significantly higher (P = 0.05) by comparison with the other treatments.

Table 1. Effect of caterpillar manure on C, N and C:N ratio of the soil in the in-pot trial

Treatments	C (%)	N (%)	C:N
T0	0.48^{b}	0.03^{b}	16.54
T1	0.52^{b}	0.03^{b}	17.38
T2	0.53^{b}	0.03^{b}	17.50
T3	0.59^{b}	0.04^{a}	15.58
T4	0.78^{a}	0.04^{a}	19.12
T5	0.80^{a}	0.04^{a}	18.11
T6	0.50^{b}	0.03^{b}	16.03
T7	0.46^{b}	0.03^{b}	16.48
Probability	0.0001	0.0001	0.053
Significant	S	S	NS

S : Significant ; NS : Not significant; Values in each column with the same letter are not statistically different according to Fisher's test at 5% level. T0 : control ; T1 : caterpillar manure (1,5 T ha^{-1}) ; T2 caterpillar manure (1,5 T ha^{-1}) + NPK (150 kg ha^{-1}) ; T3 : caterpillar manure (1,5 T ha^{-1}) + NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) ; T4 : caterpillar manure (5 T ha^{-1}) ; T5 : caterpillar manure (5 T ha^{-1}) + NPK (150 kg ha^{-1}); T6 : caterpillar manure (5 T ha^{-1}) + NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) ; T7 : NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1});

About the field trial, it was the treatment T3 (150 and 50 kg of respectively NPK and of urea) which had the low contents in the C (0.44%) and in the N (0.03%) if compared to the other treatments (Table 2). The analysis of the variance shows that this treatment was significantly different (P = 0.05) for its arameters comparatively to the other treatments.

Table 2. Effect of caterpillar manure on C, N and C:N ratio of the soil in the field trial

Treatments	C (%)	N (%)	C:N
T1	0.57^{a}	0.04^{a}	15.81
T2	0.57^{a}	0.04^{a}	16.01
T3	0.44^{b}	0.03^{b}	16.45
Probability	0.016	0.036	0.558
Significant	S	S	NS

S : Significant ; NS : Not significant; Values in each column with the same letter are not statistically different according to Fisher's test at 5% level. T1: NPK (150 kg ha^{-1}); T2: NPK (150 kg ha^{-1}) + caterpillar manure (5 T ha^{-1}); T3: NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) (Farmers approach).

The difference between the treatments about the C:N ratio was not significant on the threshold of 5% as well for the in-pot trial as in the field trial.

3.3 Effect of Caterpillar Manure on Phosphorus (P) and Potassium (K)

The results show that the difference was not significant on the threshold of 5% between the treatments for the total P and for the total K in the in-pot trial (Table 3) as well as in the field trial (Table 4). Field trial showed also non-significant differences for the available P and the available K. However, about in-pot trial, the treatment T3 had the highest available P content (39.75 mg kg^{-1} of soil) in comparison to the other treatments. About the K available, treatment T4 (77.71 mg kg^{-1} of soil) was the highest content comparatively to the other treatments. About these two latter parameters, the analysis of the variance showed a significant difference (P = 0.05) between the various treatments.

4. DISCUSSION

The results of the trials in-put as well as in the field showed that the supply of CM or its combination mineral fertilizers, led to a significant short term increase (P = 0.05) of the pH and carbon and nitrogen contents of the soil comparatively to the control and the farmers' approach (150 kg ha^{-1} of the NPK and 50 kg ha^{-1} of the urea). Our results are in accordance with those obtained by many previous studies [24,25,26]. The study of Yolanda and Fidel et al. [26] showed that the pH of the soil is positively correlated with the quantity of organic matter applied. According to Li and Han et al. [24], the combination of organic and mineral fertilizers has the effect of keeping the soil pH at normal level.

Furthermore, it has been shown that CM contained a high carbon and nitrogen contents [14]. Therefore, it is understandable that the application of the CM leads to a significant increase of soil carbon and nitrogen contents. Also, this CM supply seems to raise soil pH. Although, no significant effect was a tendency increase of C:N ratio for the treatment T4 (5 T ha^{-1} of CM). For these results, it can be hypothesized that the mineralization of CM in the soil is slow. Such a slow process of mineralization may allow the plant to have progressive availability of the different chemical elements present the CM.

The application of CM had no significant effect on the total P and K of the soil, in both in in-pot trial and field trial. According to Adeleye and Ayeni et al. [27], the initial content of the CM could be an explanatory factor. Indeed, [27] showed that CM was poor in P and in K comparatively to its carbon and nitrogen.

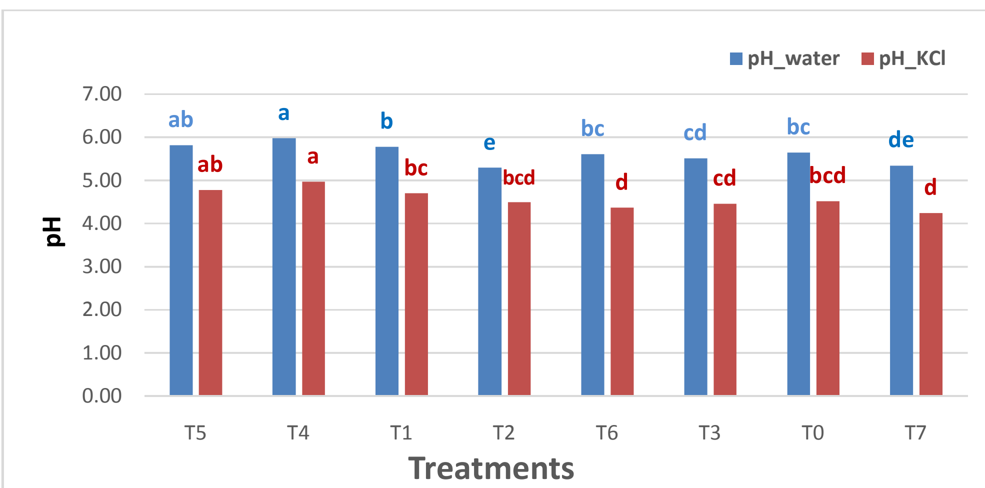

Fig. 1. Effect of caterpillar manure on the soil pH in the in-pot trial

Values with the same letter in the histogram of the same color are not significantly different at the probability threshold of 5% according to the Fisher's test.

T0 : control ; T1 : caterpillar manure (1,5 T ha^{-1}) ; T2 caterpillar manure (1,5 T ha^{-1}) + NPK (150 kg ha^{-1}) ; T3 : caterpillar manure (1,5 T ha^{-1}) + NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) ; T4 : caterpillar manure (5 T ha^{-1}) ; T5 : caterpillar manure (5 T ha^{-1}) + NPK (150 kg ha^{-1}); T6 : caterpillar manure (5 T ha^{-1}) + NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) ; T7 : NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}).

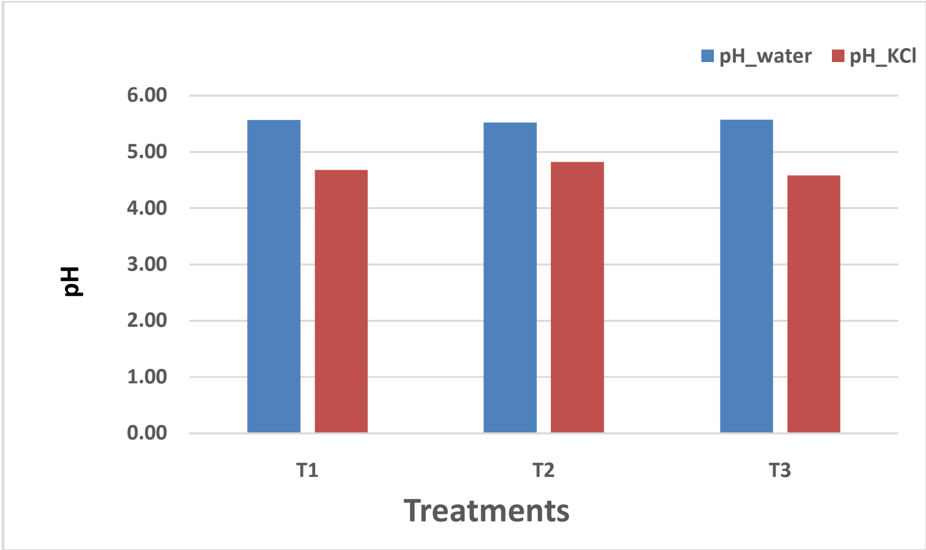

Fig. 2. Effect of the caterpillar manure on the soil pH in the field trial

T1: NPK (150 kg ha^{-1}); T2: NPK (150 kg ha^{-1}) + caterpillar manure (5 T ha^{-1}); T3: NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) (Farmers approach).

Table 3. Effect of caterpillar manure on P and K of the soil in the in-pot trial

Treatments	**Total P**	**Available P**	**Total K**	**Available K**
	Mg kg^{-1} sol			
T0	81.46	1.57^{b}	877.97	50.10^{b}
T1	82.42	2.02^{b}	963.84	59.10^{ab}
T2	139.01	21.69^{ab}	871.75	56.84^{ab}
T3	88.92	39.75^{a}	712.11	54.91^{ab}
T4	115.92	1.69^{b}	837.99	77.71^{a}
T5	142.82	29.26^{ab}	937.53	71.93^{ab}
T6	133.27	16.37^{ab}	924.51	60.69^{ab}
T7	122.13	19.31^{ab}	851.12	49.13^{b}
Probability	0.157	0.010	0.875	0.013
Significant	NS	S	NS	S

S: Significant; NS: Not significant; Values in each column with the same letter are not statistically different according to Fisher's test at 5% level.

T0 : control ; T1 : caterpillar manure (1,5 T ha^{-1}) ; T2 caterpillar manure (1,5 T ha^{-1}) + NPK (150 kg ha^{-1}) ; T3 : caterpillar manure (1,5 T ha^{-1}) + NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) ; T4 : caterpillar manure (5 T ha^{-1}) ; T5 : caterpillar manure (5 T ha^{-1}) + NPK (150 kg ha^{-1}); T6 : caterpillar manure (5 T ha^{-1}) + NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) ; T7 : NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1})

Table 4. Effect of caterpillar manure on P and K of the soil in the field trial

Treatments	**Total P**	**Available P**	**Total K**	**Available K**
	Mg kg^{-1} soil			
T1	90.08	4.08	904.34	69.69
T2	99.69	4.06	858.37	89.27
T3	93.93	3.24	805.44	76.43
Probability	0.261	0.390	0.276	0.163
Significant	NS	NS	NS	NS

T1: NPK (150 kg ha^{-1}); T2: NPK (150 kg ha^{-1}) + caterpillar manure (5 T ha^{-1}); T3: NPK (150 kg ha^{-1}) + urea (50 kg ha^{-1}) (Farmers approach); NS: Not significan

An analysis of the data about the assimilable P and the available K in the vegetation pot and in the rural area, showed that the effects of the CM on these chemical parameters of the soil are not enough. established. A tendency to improvement of the available K of the soil through a supply of 5 T ha^{-1} of CM can be noted. However, these results must be interpreted cautiously.

It can be inferred from this study that the effect of CM on the soil content in chemical elements depends on the proportions supplied. The dose of 5T ha^{-1} of the CM is the one that could have a significant effect on the chemical parameters of the soil comparatively to the dose of 1.5 T ha^{-1}. However, this dose of 5 T ha^{-1} would be difficult to obtain, due to the limited potential of CM production, estimated was 3.8 T ha^{-1} in plots which a high density of shea trees. The option of organo-mineral fertilization (with 1.5 T ha^{-1} of CM) which shows interesting results in the short term, needs to be deepened in order to allow a better re-use of CM produced in situ.

5. CONCLUSION

This study on the CM showed that in the short term, it improves the pH, the soil carbon and the nitrogen content. The effect on phosphorus and potassium was not significant in the short term. The effect of the CM on the soil fertility was significant when the appropriate dose (5 T ha^{-1}) was supplied. As it was difficult to obtain important quantities of CM, it is preferable to apply it near the crop in order to cover big areas. It is also desirable to combine mineral fertilizers to CM, especially when CM quantities produced in the field are not sufficient. Such a combination will make a good organo-mineral fertilizer for crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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