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EFFECTS OF POULTRY MANURE ON SOIL PHYSICOCHEMICAL PROPERTIES AND MAIZE YIELDS IN THE SUDANO-SAHELIAN ZONE OF BURKINA FASO

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Abstract: Maize is an important cereal with the availability of sown areas and the popularization of improved varieties, but its production remains low in Burkina Faso. These low maize yields are explained by the low rainfall and the lack of nutrients in the soil. To compensate for the lack of nutrients for the plant, improving soil fertility with the addition of nutrients in mineral or organic form could allow the efficient increase in soil water and yields. This study was conducted to evaluate the effects of poultry manure on soil physicochemical characteristics and maize yields. A Fisher block device was installed in a real environment, on a Fisher block plot divided into four (04) blocks composed of four (04) treatments (T1, T2, T3 and T4) based on poultry manure with or without mineral fertilizer. All poultry droppings treatments affected soil chemistry during the trial. The T4 treatment raised the soil acidity from 6.0 to 6.55, and the carbon content increased by 19% in the soil of the T4 treatment. The nitrogen content increases by 13% in the T4 treatment. Compared to the assimilable P content, the soil content taken from the T1 control treatment, in the T2 and T3 treatments fell by 36%. At the 45th Day after sowing (DAS), the maize plants of the T4 treatment (FV+ 5t/ha/3 years of manure) grew faster with 51.11cm compared to those from the T1 treatment. The T4 and T3 treatments had the highest average numbers of grains per ear with 446 and 435 grains/ear, respectively. The maize straw yield from the T4 treatment increased by 1850 kg/ha and by 700 kg/ha for the grain yield. Poultry manure in combination with mineral fertilizer could contribute to improving soil fertility and ensuring the sustainability of maize cropping systems under Sudano-Sahelian soil and climate conditions.

Keywords: Burkina Faso; maize yield; physico-chemical; poultry droppings.

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INTRODUCTION

Agriculture in the tropical countries of sub-Saharan Africa is characterized by low productivity. Small farmers apply insufficient amounts of nutrients on their farms, leading to overexploitation of soil nutrient stocks by plants. This leads to progressive depletion of nutrients in the soil and their eventual degradation (Olukemi and Makinde, 2014). In Burkina Faso, low crop yields are largely explained by rainfall patterns marked by pockets of drought, poor spatial and temporal distribution of rainfall and poor soil nutrient content, which justifies the use of mineral fertilizers. For Mosier et al. (2004), the provision of fertilizers is an essential lever to meet the increase in demand for food. To compensate for the chemical degradation of soils leading to a lack of nutrients for plants, several authors (Kaho et al., 2011 ; Useni et al., 2014) have shown that improving soil fertility through mineral or organic nutrient inputs can increase water efficiency and crop yields. The use of organic manure maintains or improves soil fertility with very good crop yields in a sustainable way (Li et al., 2012 ; Khalid et al., 2014 ; Sikuzani et al., 2014). Poultry manure accounts for between 26.46 and 35.72% of organic manure production and contributes to fertilizing nearly 4.50% of the total cultivated areas of farms in western Burkina Faso (Coulibaly et al., 2018). Organic manure based on poultry manure is an inexpensive fertiliser, rich in nitrogen, phosphorus and potassium (Biekre et al., 2018) that could be used in combination with mineral fertiliser to improve soil productivity and increase crop yields. One of the major risks of using only mineral fertilizers is soil acidification. This is why exclusive organic or organo-mineral manure based on manure could be an alternative for producers (Abbas et al., 2011). In this dynamic, the formulation of fertilizer doses for the optimization of crop yields and the maintenance of soil fertility is essential for sustainable agriculture. The objective of this study was to evaluate the effects of poultry manure on improving maize productivity.

EXPERIMENTAL

Presentation of the study site: The description of the physical environment takes into account the geographical location, climate, vegetation, fauna, relief and soil of the commune of Niaogho. The commune of Niaogho is located in the central-eastern part of the country, precisely in the province of Boulgou. The climate of the commune, or even of the entire region, belongs to the Sudano-Sahelian agroclimatic domain with an average annual temperature of 28°C. The annual rainfall is between 750 and 900mm. The current vegetation is of the shrub savannah type to be planted with a discontinuous herbaceous carpet. The main plant formations encountered are Vitellaria paradoxa, Parkia biglobosa, Anogeisus leicarpus, Lannea microcarpum, Afzelia africana, Balanites aegyptiaca, among others. The soils of the commune of Niaogho are raw mineral soils that are not very well developed by erosion and leached ferruginous soils as well as hydromorphic soils.

Material: The plant material used in the experiment was maize (Zea mays) of the Barka variety from the Farako-Bâ research station (Sanou, 2007). The fertilizing material consisted of two types (organic and mineral fertilizers). These fertilizers used are poultry droppings and NPK mineral fertilizers (20-10-10) and Urea (46%N).

Méthodology: The factor studied was fertilization taken at four (04) levels of variation. The trial was conducted in a real environment from 2022 to 2023, on a plot cultivated each season for the last five (05) years with a Fisher block device divided into four (04) blocks. Each block is composed of four (04) T1, T2, T3 and T4 treatments, i.e. a total of sixteen (16) elementary plots. The four (04) treatments included:

T1: 150 Kg/ha of NPK + 50 Kg/ha of Urea;

T2: 150 Kg/ha of NPK + 50 Kg/ha of Urea + 3t/ha of chicken droppings

T3: 150 Kg/ha of NPK + 50 Kg/ha of Urea + 4t/ha of chicken droppings

T4: 150 Kg/ha of NPK + 50 Kg/ha of Urea + 5t/ha of chicken droppings

The maize was sown in a continuous row with a spacing between pockets of 40cm and a spacing between the rows of 80cm (80cm x 40cm) at a rate of 2 to 3 seeds per pocket at a depth of 3 to 5 cm. Fertilisers (droppings, NPK, and Urea) were applied.

Soil Sampling: Soil samples were taken with an auger prior to ploughing in each elementary plot. Samples were taken from the depth of 0-20 cm, which generally corresponds to the layer of soil worked in tropical areas (Feller 1979; Feller, 1995). In these elementary plots, samples were taken diagonally at three points and mixed to make a composite sample by treatment and repetition, for a total of sixteen (16) samples.

Analysis of Physical Parameters: The hydrometric method was used to determine the particle size in three fractions. The observed density provides an estimate of the silt + clay fraction and the clay fraction.

Chemical Analysis of Soil Samples: The analyses concerned pH, assimilable phosphorus (P-ass), organic carbon (C), total nitrogen (N-total) and available potassium (K-available). They were carried out at INERA's Soil-Water-Plant Laboratory. The pH was measured from a suspension of soil in water by the electrometric method with a glass electrode pH meter (AFNOR, 1999). The organic carbon content was determined according to the method of Walkley and Black (1934). Organic matter content was determined from organic carbon using the multiplier of 1.724 (Keeney and Nelson, 1982). Determination of total nitrogen (N-total) and available potassium (K-available): samples are digested in a mixture of sulfuric acid, selenium and hydrogen peroxide (H_2SO_4-Se-H_2O_2) at 450°C for 4 hours, according to the method of Walinga et al. (1995). Assimilable phosphorus (P-ass) was extracted using the Bray-1 method (Bray and Kurtz, 1945).

Components of Corn Yield: Total tassel weight, straw yield and grain yield were measured from data collection on a delineated 4 m2 area in each elementary plot. Yield components such as the number of panicles per rice plant, the number of grains per panicle were also evaluated. The number of grains per ear and the weight of 1000 grains, the straw yield and the maize grain yield were evaluated.

Data Analysis: The data collected were processed using the Excel 2013 spreadsheet and subjected to an analysis of variance. Means of the variables were compared using the Newman-Keuls test at the 5% probability level using the GenStat Edition12 software, version 2009.

RESULTS AND DISCUSSION

Effect of treatments on the physical properties of the soil

Table 1 gives the particle size composition of the soils. The results show a significant variation between treatments in terms of total clay content. The clay content fell in the soil of the T1 control treatment with 11.76% and in the T2, T3 and T4 treatments with 10.78%, 10.80% and 10.49% respectively after cultivation. After culture, total silt levels decreased significantly in the T1 treatment with 13.73%. Contrary to what can be observed in the control treatment (T1), the silt levels are higher in the soil before cultivation with 14.38% and also decrease in the soils of the T2, T3 and T4 treatments with 14.09%, 14.15% and 14.12% respectively. However, the levels of sand collected are not significantly different, both before cultivation and after cultivation.

Table 1. Results of Particle Size Analysis

Treatments	Total clays %	Total silts %	Total sands %
Pre-treatment	11.76a±0.57	14.38a±0.57	74.51±0.10
T1	11.12a±0.05	13.73b±1.15	74.51±0.05
T2	10.78b±0.05	14.09a±1.21	74.51±0.05
T3	10.80b±0.05	14.15a±1.14	74.56±0.05
T4	10.49b±0.05	14.12a±2.12	74.38± 0.05
Probability	***0.046***	***0.049***	***0.134***
Signification	***S***	***S***	***NS***

Legend: T1 = 150 kg/ha of NPK + 50 kg/ha of Urea,
T2 = FV + 3t/ha/year of manure, T3 = FV + 4t/ha/2 years of manure,
T4 = FV + 5t/ha/3 years of manure. NS = not significant, S = significant.

Effect of treatments on soil chemical properties

Table 2 presents the results of the analysis of soil chemical parameters according to the pre- and post-cultivation treatments. In general, there is no significant variation between treatments in terms of water pH or C/N ratio before and after culture. The pH values show that the soils of the site are slightly acidic. The C/N ratios oscillate between 10 and 11. There is a significant difference between the carbon and nitrogen values of soils before and after cultivation. The soil carbon level taken up in the control treatment increases by 13% compared to that of the soil before cultivation. This increase in carbon content is 11% in the soil of the T2 treatment, 15% in T3 and 19% in the T4 treatment. The same is true for total nitrogen. The organic nitrogen content increased by 11% in the control treatment after culture and by 7% in the T2 treatment. This increase is 5% in the soil of treatment T3 and 13% in treatment T4. There are highly significant differences between the soil from the plot before cultivation and the soil from the plots under cultivation for phosphorus and potassium content. Compared to the assimilable P content observed in the soil collected before cultivation, the content of the soil collected in the T1 control treatment in the T2 and T3 treatments fell by 36%. On the other hand, there was an 8% increase in the T4 treatment.

Table 2. Chemical Characteristics of Soil According to Treatment

Treatments	pH	Carbon (%)	Nitrogen (%)	C/N	Phosphorus (mg/kg)	Potassium (mg/kg)

Before cultivation	6.00±0.07	0.39b±0.03	0.040b±0.01	10.24±0.31	6.21a±0.09	84.23b±3.72
T1	6.45±0.01	0.51b±0.01	0.050a±0.01	11.10±0.13	2.90b±0.03	85.8b±3.40
T2	6.52±0.02	0.49b±0.01	0.046ab±0.01	11.13±0.17	2.89b±0.04	83.9b±8.06
T3	6.54±0.03	0.53b±0.01	0.048ab±0.01	11.02±0.11	2.78b±0.04	115.9a±9.27
T4	6.55±0.01	0.56a±0.01	0.054a±0.00	11.26±0.11	7.31a±0.04	118.4a±8.06
Probability	***0.121***	***0.047***	***0.042***	***0.469***	***0.001***	***0.001***
Signification	***NS***	***S***	***S***	***NS***	***HS***	***HS***

Legend: T1 = 150 kg/ha of NPK + 50 kg/ha of Urea, T2 = FV + 3t/ha/year of manure, T3 = FV + 4t/ha/2 years of manure, T4 = FV + 5t/ha/3 years of manure. NS = not significant, S = significant, HS = highly significant, pH water = potential for hydrogen ions. Organic C = Organic carbon. C/N = Ratio of carbon to nitrogen. N-total = total nitrogen.

Average weight of 1000 grains and average number of grains per ear depending on the treatments.

Table 3 shows the variations in the average number of grains per ear and the average weight of 1000 grains as a function of treatment. The average number of grains per ear varied significantly from one treatment to another. The T4 and T3 treatments had the highest average numbers of grains per ear with 446 and 435 grains/ear, respectively. The lowest number of grains per ear was obtained with the T1 treatment (373 grains/ear). For the weight of 1000 grains, there was no significant difference between the treatments. The T2 treatment had the lowest weight of 1000 grains (220g). The T3 treatment differed slightly from the other treatments with the highest weight of 1000 grains (250g).

Table 3. Number of grains per ear and Average weight of 1000 grains

Treatments	Number of grains per ear	1000 grit weight (g)
T1	373.0c±5.48	240.0±55.98
T2	425.5b±4.20	220.0±21.60
T3	435.8ab±16.36	250.0±66.83
T4	446.8a±5.44	245.0±31.09
Probability	***<.001***	***0.602***
Signification	***HS***	***NS***

Legend : T1 = 150 kg/ha NPK + 50 kg/ha Urea, T2 = FV + 3t/ha/year of manure, T3 = FV + 4t/ha/2 years of manure, T4 = FV + 5t/ha/3 years of manure, NS=Not significant, HT=Highly significant

Maize grain and straw yields as a function of treatment

The results are presented in Table 4. There are significant differences between the treatments compared for both straw yields and maize grain yields. The maize straw yield of the T4 treatment varied significantly with 6300 kg/ha compared to that of the other treatments. The maize straw yield from the T4 treatment increased by 1850 kg/ha compared to that of the T1 control treatment. The lowest maize straw yield was obtained with the T1 treatment (4450 kg/ha). The same observation is made with maize grain yields. There is also an increase in grain yields from the T4 treatment. In fact, the grain yield increased by 700 kg/ha, compared to that of the T1 treatment. Treatment T4 had a higher maize grain yield (3575 kg/ha) than that of the other treatments. The lowest maize grain yield also comes from the T1 treatment (2875 kg/ha).

Table 4. Average Grain and Straw Yields of Maize

Treatments	Straw yield (kg/ha)	Grain yield (kg/ha)
T1	4450.42b±65.74	2875.35b±70.82
T2	5675.28ab±108,59	3175.54ab±87.22
T3	5625.17ab±46.48	3238.76ab±90.25
T4	6300.81a±71.58	3575.37a±87.21
Probability	***0.038***	***0.040***
Signification	***S***	***S***

Legend: T1 = 150 kg/ha NPK + 50 kg/ha Urea, T2 = FV + 3t/ha/year of manure, T3 = FV + 4t/ha/2 years of manure, T4 = FV + 5t/ha/3 years of manure, NS=Not Significant

Effect of treatments on soil physical parameters

Clay levels dropped in the T1 control treatment soil as well as in the T2, T3 and T4 treatments. This could be linked to the accumulation of soil under the grasses, which acts as a physical barrier. Yaméogo (2012) concluded that this was probably due to the nature of the geological bedrock, which is more favourable to the production of this fraction than to the formation of clays, and to the high rainfall that favours the leaching of clays. The silt content is higher in the soil prior to planting compared to the T1, T2, T3 and T4 levels in the corn soil. This could be related to the density of the vegetation cover of the sites which constitutes a barrier against erosion and therefore could retain the silt. This density likely contributed to a reduction in the velocity of runoff and consequently water erosion, which could explain the retention and accumulation of silt. A similar trend was observed at the Torokoro site with Andropogon species in a fallow land (Sanogo, 2014). Indeed, this author has shown that this grass blocks the fine soil and stabilizes it on the surface horizons of the soil.

Effect of treatments on soil chemical parameters

Some treatments have induced significant effects on the chemical parameters of the soil. Concerning the pHeau, the lowest value was observed in the soil of the T1 plot (NPK + Urea). This is because mineral fertilisers have an acidifying effect on the soil. These results are consistent with those of Taonda et al. (1995) and Koulibaly et al., (2014) who showed that cultivation with ploughing and agricultural practices incorporating mineral fertilizers without organic restitution on tropical ferruginous soils contribute to soil acidification (Agbede et al. 2008). Unlike mineral fertilizers, the addition of organic fertilizers such as poultry manure improves the pH of the soil (Nyembo et al., 2014). Hence the pH values of the different treatments is higher than the initial pH of the site. These results are similar to those of Gani (2014) who found that poultry manure improves soil pH, concentrations of organic matter, nitrogen, phosphorus, potassium, calcium, and magnesium compared to NPK fertilizer alone. These observations confirm those of other studies (Adeleye et al., 2010; Imasuen et al., 2015) who also concluded that the pH of soils fertilized by poultry manure improved compared to the control. The level of organic carbon and nitrogen increases significantly in the treatments after maize is planted. A high proportion of C is thought to be related to the clay and silts present. The free organic carbon, represented by this fraction, participates effectively in soil fertility, by feeding the microbial biomass responsible for mineralization processes (Soltner, 2003). Microbial activity is more intense in soil collected from corn compared to soil collected before cultivation. Our results show that poultry manure would have improved the level of organic C in the soil. The high nitrogen content could be explained by the accumulation of organic matter in the soil. The nitrogen content of the soils under maize cultivation is high. This can be justified by the fact that plants from the T1, T2, T3 and T4 treatments do not use enough mineral elements, in particular nitrogen, for the growth of the plant. The low nitrogen content before maize is planted could be explained by the decrease in the accumulation of organic matter, but also by tillage, which leads to a loss of nitrogen through mineralization and water erosion (Koulibaly, 2011). The phosphorus that can be assimilated in the soil depends on the quantities provided by fertilization by fertilizers, and on the quantities exported by crops and crops, phosphorus being not very mobile in the soil. It has been observed that poultry manure alone gives a higher phosphorus content of the T4 treatment (FV + 5t/ha/3 years of manure) than that of the site before maize cultivation. This situation is linked to the contribution of this element by poultry droppings. Indeed, the work of Farhad et al. (2009) and Gomgnimbou et al. (2016) attest that poultry droppings are rich in phosphorus. The low quantities of phosphorus obtained at the level of treatments: T1 (150 kg/ha of NPK + 50 kg/ha of Urea), T2 (FV + 3t/ha/year of manure) and T3 (FV + 4t/ha/2 years of manure) would be due to the assimilation of phosphorus by the crops. The total K content in the soils of the T3 (FV + 4 t/ha of manure) and T4 (FV + 5 t/ha of manure) treatments is high. The increase in total K availability could be explained by the amount of poultry manure added to the soil from the T4 and T3 treatments. The work of Enujeke, (2013); Imasuen et al. (2015) showed that poultry manure is rich in potassium.

Poultry manure is a source of organic matter that could lead to better water retention and nutrient availability. In the same agroecological zone, the results of the work of Gomgimbou et al. (2016) showed that the use of poultry manure would improve nutrient availability and create favourable conditions (water and air availability) for the proper development of the plant's roots. Poultry droppings may improve soil structural stability and water retention capacity. Our results are similar to those obtained by Gomgimbou et al. (2016), in the same agroecological zone, who showed that poultry droppings are an excellent organic fertilizer for crops. On the other hand, poultry droppings that are not properly decomposed could increase the risk of disease attacks, drought and toxicity to crops and reduced yields. In addition, improper application of poultry manure could lead to the risk of pathogen introduction or increase soil salinity.

Effect of Treatments on Corn Yield Components

Treatments T4 and T3 had the highest average kernel counts per ear. This could be explained by the fact that these treatments provided the right conditions and nutrients for the plants to accumulate large amounts of nutrients. These results are similar to those found by Farhad et al (2009) who showed that the high yields in number of grains were recorded by the treatments that received the highest doses of poultry manure. The low number of grains per ear obtained with the T1 treatment (150 kg/ha NPK + 50 kg/ha Urea) could be explained by the low proportion of mineral elements in the soil. The combination of poultry manure with urea therefore ensures both immediate availability and availability over time of nutrients for the formation of maize grains. Improving soil phosphorus levels could help with corn cob formation and faster grain setting. The same observation was made by Kaboré (2014) on sorghum. Available phosphorus would be available to corn plants for ear formation and corn graining. The maize straw yield from the T4 treatment increased significantly compared to that of the T1 control treatment. The synergistic effect of these two fertilisers leads to an increase in biomass production, which translates into high yields. According to Nyembo et al. (2014), poultry manure has great potential for improving soil nutrient availability and providing nutrients needed for maize cultivation. Indeed, the addition of poultry droppings (5 t/ha) added to mineral fertilizers (150 kg/ha of NPK + 50 kg/ha of Urea) greatly increases the availability of nutrients and promotes water accumulation. Thus, the combined addition of poultry manure and mineral fertilizers reduces nutrient losses and increases the efficiency of nitrogen fertilizers (Jan, 2018). This performance in straw yields could be explained by the fact that poultry manure combined with mineral fertilizer releases important nutrients essential for maize growth and ensures a high water retention capacity of the soil. Indeed, the combined use of these fertilisers would improve the availability of nutrients and create favourable conditions (water and air availability) for the proper development of the roots. These results are consistent with those found by Farhad et al (2009) who demonstrated that the weight of stem biomass increases with the dose amount of poultry droppings. This strong performance obtained at the level of the T4 treatment in straw yield could be explained by the fact that poultry droppings released nutrients essential for plant nutrition, which resulted in the large quantity of biomass (Kolawole et al., 2009). These results are also in line with those of Amos et al. (2013) who had obtained an improvement in the biomass production of feed maize with poultry droppings in Nigeria. The T4 treatment had a higher corn grain yield than the other treatments. Zydelis et al. (2019) and Jan (2018) showed that the combined use of poultry manure and mineral manure would increase maize grain yield compared to the application of organic or mineral manure alone. Indeed, several authors (Zeinabou et al., 2014; Somda et al., 2017) showed that the combination of mineral and organic fertilisation led to an increase in plant yields. These results are in agreement with those of Imasuen et al. (2015) who had observed an improvement in yields following the use of poultry manure on sorghum, yam, taro, jute and okra respectively. Since nitrogen is the most important fertilizer for plants and poultry manure is rich in nitrogen, its combination with urea could increase corn kernel yield in the T4 treatment. Our results are similar to those of other studies on various cereals (Akanza et al., 2014; Nyembo et al., 2014 and Akanza et al., 2015).

CONCLUSION

The present study is a contribution to the improvement of maize productivity with the use of poultry manure combined with mineral manure. Mineral fertilisers are expensive and their exclusive and prolonged use degrades the soil. Clay and silt levels dropped in the T1 control soil as well as in the T2, T3 and T4 treatments after cultivation. The results of the study show that the addition of poultry manure combined with mineral fertilization has improved the chemical properties of the soil and the productivity of maize. The level of organic carbon, nitrogen and potassium increases in the soils after cultivation. On the other hand, there is a decrease in the level of phosphorus available in the soil after corn is planted. In fact, the best performance in grain and straw yields of maize was recorded by the T4 treatment (FV + 5 t/ha of manure) compared to the T1 treatment (150 kg/ha of NPK + 50 kg/ha of Urea) (absolute control) and compared to the other treatments. Poultry manure combined with mineral fertiliser improves maize yields. The combination of poultry droppings and mineral manure seems to be a way to guarantee optimal availability of nutrients, particularly in carbon, nitrogen and potassium. In perspective, it would be interesting to undertake economic studies on the profitability of this production system.

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