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Impact of Chicken Manure Integration with Mineral Fertilizer on Soil Nutriments Balance and Maize (*Zea mays*) Yield: A Case Study on Degraded Soil of Lubumbashi (DR Congo)

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ABSTRACT

One of the most important challenges to continuously maximize crop production on limited areas of agricultural land is to maintain or enhance soil fertility. Organic fertilizer application is needed to replace nutrient removed by crop from the fields in order to restore crop production potential of a soil. But application of organic fertilizer alone insufficiently increases crop yield per area because the nutrient content of organic fertilizer is unbalanced. A trial was conducted in the Lubumbashi region to investigate the combined effects of mineral fertilizer and chicken manure application on the balance of minerals and maize yield. Three mineral fertilizer doses (0 kg NPK+0 kg urea, 150 kg NPK+100 kg urea, 300 kg NPK+200 kg urea) and four chicken manure quantities (0, 1.75, 3.5, 7 t ha^{-1}) have been tried. The combination of these factors gave a total of 12 treatments. According to obtained results nitrogen and phosphorus content before maize sowing is higher than those obtained after flowering. The present work confirms that integrated application of chicken manure and mineral fertilizers is more effective in increasing nutrient availability and maize performance than mineral or organic fertilizer applied alone. In contrast, applied doses of chicken manure have not improved soil nutriment balance sheet. Combined with the low dose of mineral fertilizers (150 kg NPK+100 kg urea), the amount of 7 t ha^{-1} of chicken manure resulted a better yield increase, which corresponds to 46% compared to the control, of which 16% only are due to mineral fertilizer application.

Key words: Mineral fertilizers, chicken manures, nutriment balance, maize yield

INTRODUCTION

Soils of sub-Saharan Africa have a low inherent fertility level associated with specific natural constraints for each agro-ecological zone. These deficiencies are key factors of agricultural production, they are ignored, so that low yields persist. Nutrients taken by crops from soil that is

already poor are not adequately replaced (Yossif and Ibrahim, 2013). However, maintenance of soil fertility is vital for the plant while its decline results in a progressive loss of yields (Mbonigaba, 2007). One of the promising ways out is to provide different types of soil fertilizers so as to increase the availability of soil nutrients (Palm *et al*., 1997). However, farmers usually apply mineral fertilizers to improve soil fertility and increase crop yields or the intensive application of inorganic fertilizers to several drawbacks for the plant and the future productivity of the soil. In addition, Muhammad *et al*. (2007) reported that the continued use of synthetic fertilizers deteriorates soil quality. For example, when nitrogen fertilizers are applied continuously it may leach below the root zone or pollute ground water causing some disease to humans. Useni *et al*. (2012) found out that the exclusive application of mineral fertilizers is generally effective in the early years of continuous application, there is indeed a performance decline after a few years because of soil properties degradation. One consequence of this trend is a generally unbalanced nutrient content in soil that eventually leads to a potential yield reduction. A correct soil nutrient balance is essential for healthy growth and high productivity of plants (Tonfack *et al*., 2009). Mineral fertilization application seems to be the appropriate solution but it is only effective if it exists in the soil a minimum rate of organic matter which, together with the clay, the clay-humic complex. The contribution of organic manure directly into the soil before or after the establishment of crops is yet an effective alternative practice. Organic fertilizers such as, animal manure, green manure and compost can be made to crops so as to increase crop yields. These types of fertilizers can on the one hand improve the physical and biological properties of the soil and on the other hand serve as a source of mineral elements (Abdelrazzag, 2002). Several anterior studies advocate a combined use of mineral and organic fertilizers as this synergy increases the availability of nutrients and improves their balance to achieve healthy growth and crops development (Hamden and Fadni, 2010; Melkamu, 2012). In occurrence the chicken manure is a naturally nourishing fertilizer for plants. Rich in nutrients such as nitrogen, phosphorus, calcium, potassium and magnesium, it is known for a long time for its excellent properties promoting plant growth. This study was conducted in order to assess the effects of mineral and organic fertilizers (applied alone or in combination) on the soil nutriment balance sheet and maize yield comportment.

MATERIALS AND METHODS

Description of the study area: The trial was conducted at Kassapa farm (altitude: 1274 m, latitude: 11°39'S and longitude 27°28'E) in Lubumbashi (Capital of copper) (11°39'S and 27°28'E).

Lubumbashi is the capital of Katanga province located in the southeast of the Democratic Republic of Congo. The climate is CW 6 type according to Koppen classification, characterized by a rainy season, dry season and two transition months. Annual rainfall amounts to 1270 mm with extreme values of 717 and 1770 mm. The average annual temperature is about 20°C (Malaisse, 1990). The primary vegetation in Lubumbashi is the miombo woodland. However, due to human activities, this woodland is in the peri-urban areas, replaced by secondary vegetation, consisting of a savanna (Palm *et al*., 1997). The soils of Lubumbashi and its surroundings are dominated by ferralsols, according to Naeem *et al*. (2006) classification, with pH water oscillating around 5.2. Soil analyzes gave the following results: available p = 0.0058% total N = 0.224%, S = 1.03%, Ca = 0.04%, Mg = 0.816% and organic matter = 1.72%.

Trial management: The biological material was composed of maize, Katanga variety obtained from the Faculty of Agricultural Sciences in Lubumbashi. This is an early variety giving yields

ranging from 6-8 t for intensive cultivation. Chicken manure produced in the farm DAIPN station Kilobelobe was applied as organic fertilizer. Thus, a sample of chicken manure was analyzed at UNILU, Faculty of Sciences according to the methods described by Kyela (2011). The compound fertilizer NPK (10-20-10) was used as basic fertilizer, urea 46% was applied like auxiliary fertilizer. The experiment was set in a 4×3 factorial arrangement. Treatments, in triplicate, included 4 doses of chicken manure (0, 1.75, 3.5 and 7 t ha^{-1}) and 3 doses of inorganic fertilizers (0, 300 kg NPK10-20-10+200 kg urea 46% as mineral fertilizer and 150 kg vulgarized NPK10-20-10%+100 kg urea 46% vulgarized as mineral fertilizer reduced half). The land was ploughed using a tractor 2 weeks before the burial of chicken manures. Maize grains were sown at 53333 plants ha^{-1}, at spacing of 75×25 cm. It should be noted that NPK spreading intervened during sowing but urea was applied at 30th day after sowing. To manage weeds, two weeding was carried out using the hoe at 15th and 45th day after sowing for the first and second weeding, respectively. Maize harvesting was done manually on May 26th, 2012. Maize cobs were sun dried to reduce the moisture content of the seeds. At harvest the average weight of grains per spike, 1000-grain weight and yield of maize grain were determined.

Statistical analysis: The raw data on vegetative and yield parameters were processed by analysis of variance (ANOVA) with post hoc test (Tukey test) for means separation. Changes in soil characteristics between the start of the test and the post flowering were calculated using the formula given by Useni *et al*. (2012):

$$X\ (\%) = \frac{X2\text{-}X1}{X1} \times 100$$

Where:
X1 = Parameter value at test beginning
X2 = Parameter value at the end

RESULTS

Characterization of chicken manure: The chicken manure does not contain stones, metals or plastic. However organic matter content is very high matter (97%) and there is only 3% of sand within the sample.

Phosphorus and the nitrogen belong to the major elements that the plant needs. Obtained result shows that the kitchen manure content more nitrogen (6%) and phosphorus (5.71%) than others major nutriments like calcium (1.15%) and potassium (0.21).

Soil properties dynamic under organic and inorganic fertilizers: The results of ANOVA analyzes have shown that there is no significant difference between treatments concerning nitrogen and phosphorus content. However, these contents have decreased after crop flowering comparing to their contents before the crop establishment.

Without chicken manure, the application of mineral fertilizer decreases nitrogen availability. In addition, the results change properties showed that phosphorus was less bio available to control treatment, chicken manure addition has increased its bio availability because of changes in properties of more than 100% were obtained (Table 1).

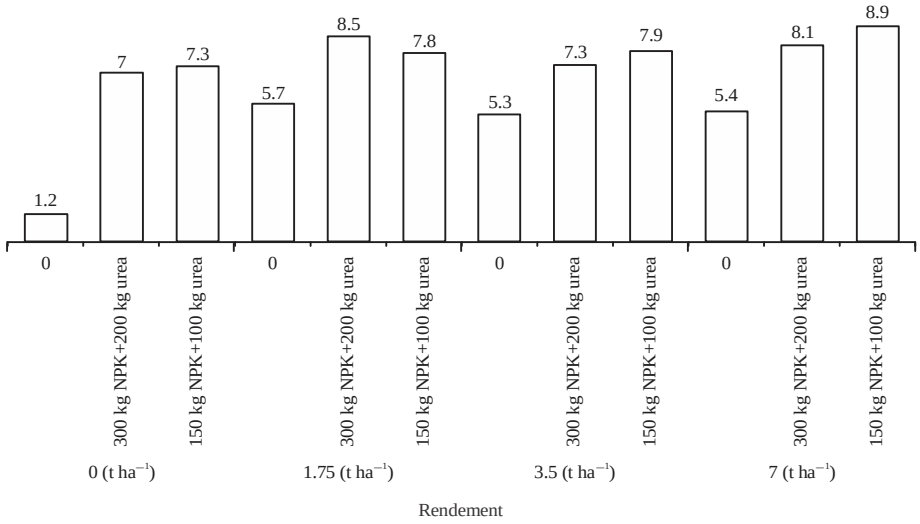

Fig. 1: Combined effects of chicken manure and inorganic fertilizers on maize yield (p=0.019)

Table 1: Baseline characteristics of the soil and effect of different treatments on N and P soil content

	Phosphorus		Nitrogen	
	Available (%)	Content change (%)	Total (%)	Content change (%)
	Initial content before the establishment of culture			
Treatments	0 .058	-	0.224	-
After flowering				
T0	0.004325	-25.4310345	0.04166667	-81.3988095
T1	0.003275	-43.5344828	0.01383333	-93.8244048
T2	0.00408333	-29.5977011	0.01733333	-100.018474
T3	0.005175	-100.020349	0.015	-100.014997
T4	0.00445833	-100.010241	0.01866667	-100.018664
T5	0.00461667	-100.015598	0.01533333	-100.01533
T6	0.00569167	-100.005691	0.0132	-100.013198
T7	0.00324167	-100.003241	0.014	-100.013998
T8	0.00518333	-100.005183	0.04	-100.039994
T9	0.00340833	-100.003408	0.05033333	-100.050313
T10	0.00319167	-100.003192	0.01766667	-100.017658
T11	0.00494167	-100.004941	0.01766667	-100.017664
P	0.079	-	0.964	-

Table 1 describes T0: No mineral fertilizers or chicken manure; T1: 150 kg NPK+100 kg urea, T2: 300 kg NPK+200 kg urea, T3: 1.75 t chicken manure T4: 1.75 t of chicken manure+150 kg NPK+00 kg urea, T5: 1.75 t of chicken manure+300 kg NPK+200 kg urea, T6: 3.5 t of chicken manure, T7: 3.5 t of chicken manure+150 kg NPK+100 kg urea, T8: 3.5 t of chicken manure+300 kg NPK+200 kg urea, T9: 7 t of chicken manure, T10: 7 t of chicken manure+150 kg NPK+100 kg urea and T11: 7 t of chicken manure+300 kg NPK+200 kg urea.

Effects of increasing doses of chicken manures, mineral fertilizers and their combination on the maize yield: Examination of Fig. 1 and 2 shows that the mineral fertilizers and chicken manure used alone or their combination influence significantly grain maize yield (p = 0.000 and 0.008). The results show that chicken manure increases the effect of

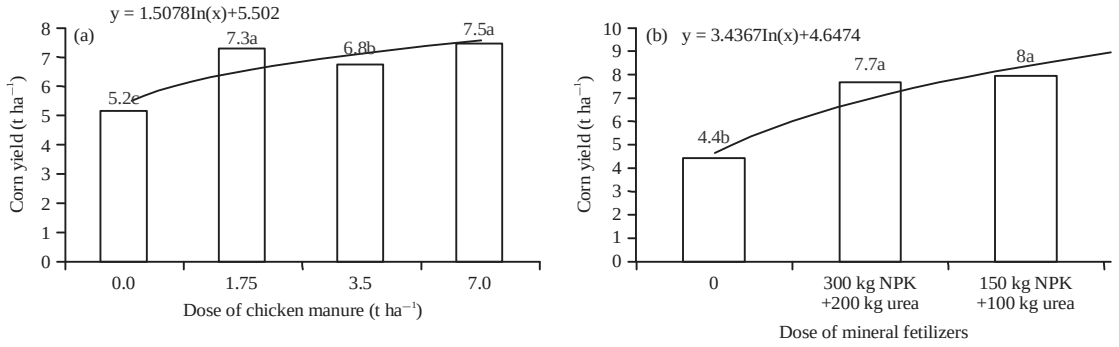

Fig. 2(a-b): Yield of *Zea mays* L. based on inputs from (a) Chicken manure (p = 0.08) and (b) Inorganic fertilizers (p = 0.000)

mineral fertilizers because maize yield decreases when mineral fertilizers are used alone. Contrarily, the highest maize yield is obtained with the combination 7 t chicken manure+150 kg NPK+100 kg urea.

DISCUSSION

In DR Congo and other tropical countries, research interest recently shifted to utilization of organic wastes as a nutrient source in crop production. This is due to the high cost and scarcity of mineral fertilizers. However, because of the huge quantity of the organic wastes required, it has become necessary to combine different types. It is also necessary to integrate chemical fertilizers into the organic sources to reduce the quantity required and enhance nutrient release. Therefore, studies are required into an integrated application of organic and inorganic fertilizers to investigate their combined effect on the soil nutriments balance sheet (Ayeni and Adetunji, 2010).

The chemical composition of chicken droppings reveals their great ability to improve soil quality and contribute to increase maize yields. Used organic fertilizer was highly rich in organic matter (97%). Previous studies have reported that in most African cities, household wastes are largely made up of organic matter from 40-90% (Kyela, 2011). High organic matter content also has a positive effect on soil physical properties known as soil tilth. Nutrient and organic matter content of the soil determines its fertility status. This is confirmed by Rahman and Parkinson (2007), who reported that soil organic matter is an important index of soil fertility. Soils with high organic matter content contain a greater abundance of water-stable aggregates and have a great exchange capacity for nutrients. Soils with good tilth have better structure, water-holding and nutrient absorption capacities (MOSES., 2012). Previous phrases would explain the high grain maize yield obtained in this study.

Regarding nitrogen and phosphorus content (major nutriments), obtained results indicate respective contents of 6 and 7%. The chemical composition of chicken droppings used in the study showed that they could be valued as a fertilizer because of their fertilizing potential. These first results are therefore useful data for the understanding and appreciation of the following results allow seeing significant improvements in the fertility of the soil (Akanza and Yoro, 2003). The chemical properties of the soil before planting were determined (Table 1). The results indicate that it is a rather poor soil in organic matter (N = 0.224% and p = 0 .058%). This soil belongs to the subclass of ferralitic soils (Akanza and Yao-Kouame, 2011). After flowering, analyses of soil samples were focused on nitrogen and phosphorus. The results of the ANOVA showed that there are

significant differences between treatments regarding the nitrogen and phosphorus content. Indeed, the overall trend shows a decrease of content of soil nitrogen and phosphorus after flowering. According to Kyela (2011), nitrogen is a highly mobile element and the contribution of organic matter to offset these losses can sometimes increase its bioavailability. Furthermore, mineral fertilizer application without chicken manure reduces bioavailable phosphorus because it is complexed with aluminum, against the release of organic acids due to the chicken manure contribution allowed the release of phosphorus blocked by aluminum and iron (Kyela, 2011). In addition the results of changing levels showed that phosphorus was less bioavailable when any fertilizer has been applied (T0) and plots with different doses of the mineral fertilizers (T1 and T2) and the contribution of chicken manure has allowed to increase its bioavailability as the variation of its content is -100%. The same results for nitrogen were, however obtained from T2 to T11, showing its high availability. The variation of the phosphorus content of -100% was obtained by the treatment receiving mineral fertilizers coupled to chicken manures. The general trend shows that mineral fertilizer applied in integration with chicken manure increases nutriments availability and grain maize yield is linked to nutriment availability.

Concerning soil nutriment balance, it is evident that chicken manure application doesn't increase soil nutriment balance sheet. But nutriments became more available when chicken manure is added. Applied doses of chicken manure didn't allow to replace in soil the nutriments removed by crop. Or when soil nutrients are out of balance, a crop can become attractive to insect pests. A plant grown in mineral-balanced soil first will produce simple metabolic compounds, which are made into secondary metabolic compounds that promote vegetative/reproductive growth and enhanced insect and disease-resistance (MOSES., 2012).

Maize yield ranged from 1.2-8.9 t ha^{-1} between treatments (Fig. 1 and 2). Without mineral fertilizers, manure doses of 1.7 and 7 t ha^{-1} gave high yields, 7.3 and 7.5 t ha^{-1}, respectively. This performance increase is due to the improvement of soil quality and nutrient release as it has been shown by Borggaard (1983). As against the control treatment and the one that received the dose of manure (3.5 t ha^{-1}) gave low yields (5.2 and 6.8 t ha^{-1}, respectively). Deblay (2006) and Kyela (2011) considered that acidic pH, toxicity of aluminum and magnesium, nutrient deficiency (Ca, Mg, P, K, Zn and B) reduction in biomass and activity of the microorganisms and unavailability of phosphorus these together cause the significant performance drop of maize yield. The performance increase rate due to chicken manure (7 t ha^{-1}) addition is 30.6% compared with the control treatment. Combining half dose of chemical fertilizers with manure, the yield reached 8.9 t ha^{-1} and the rate of improvement achieved in comparison with the absolute indicator T0 is 86.5%. Assessing the effects of chicken droppings on the growth and yield of maize, Ayeni and Adetunji (2010) reported that the chicken manure (10 t ha^{-1}) combined with the reduced level of NPK (100 or 200 kg NPK) promote good maize growth and high grain maize yield. As part of this study, the combined contribution of the full dose of mineral fertilizers and chicken manure has improved maize yield to 85.1% compared to the control treatment. The performance analysis showed that manure applying, with or without mineral fertilizers, improves maize yield.

Similar results were obtained in the Ivory Coast on cassava (Bakayoko *et al*., 2007). However, authors advocate the view that to establish a system of viable and sustainable production, a contribution of 20 t ha^{-1} manure is recommended (Compere *et al*., 1991; Akanza and Yao-Kouame, 2011).

In reference to the obtained results of the present study, chicken manure seems to reinforce the action of mineral fertilizers improving soil fertility. Indeed, these organic matters with clay form the clay-wetland complex that retains the nutrients that the plant needs and making them more efficient mineral fertilizers (Akanza and Yoro, 2003). To maintain or increase soil productivity, it is important to bring mineral fertilizers in synergy with chicken manure (if possible at the highest dose: 7 t ha^{-1}). Minerals Fertilizer alone cannot maintain long-term soil productivity as they lead to the depletion and degradation.

CONCLUSION

Integration of mineral with organic fertilizer improves phosphorus and nitrogen availability to achieve healthy growth and development of the crop. It increases maize grain yields, because nutrient availability is improved. The results of this test showed that chicken manure doses significantly increase maize yields compared to plots fertilized with mineral fertilizers and the control but the applied doses of chicken manure don't improve soil nutriment balance sheep. Application of 7 t ha^{-1} of chicken manure combined with 150 kg NPK+100 kg urea has created better conditions for maize growth and nutrition, thereby increasing the yield. The dose of 1.75 t ha^{-1} of chicken manure applied alone achieved the average maize grain yield of 7.3 t ha^{-1}. This dose is recommended knowing the low income of farmers in the study area. This experiment showed that chicken manure has great potential for improving the availability of nutrients in soil and can provide the amount of nutrients required for maize growth without inorganic fertilizer, which is capital for small farmers in the study area. Further studies are however needed to assess the residual effects and contributions of repeated application of chicken manure.

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