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Research Paper

Effects of Pig Manure, Sawdust, and Mineral NPK Fertilizer on the Performance of Pepper (*Capsicum annuum*) Grown in Yangambi, DR Congo

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ABSTRACT
This study tested the influence of pig manure, sawdust, and mineral fertilizer (NPK) on the performance of pepper (Capsicum annuum) grown in Yangambi, Democratic Republic of the Congo.
The results showed that plant height varied among treatments. Compared to the control (T0), treatments T3 and T2 increased plant height by 32% and 7%, respectively. Collar diameter also varied depending on treatments: T1 and T3 increased collar diameter by 35% and 30%, respectively, compared to T0, whereas T2 showed a similar effect to T0. Leaf area was influenced by treatments: only T1 showed a significant increase (24% compared to T0), while T2 and T3 had almost no effect.
Treatments T1 and T3 positively affected the number of fruits per plant, with increases of 7% and 6%, respectively, compared to T0. However, T2 reduced it by 3%. Fruit diameter was influenced by treatments: T1, T2, and T3 increased fruit diameter by 26%, 6%, and 47%, respectively. The same trend was observed for fruit length: T1, T2, and T3 increased fruit length by 41%, 15%, and 37%, respectively.
As with most parameters, fruit yield varied with treatments. T1, T2, and T3 increased yield by 66%, 20%, and 86%, respectively, compared to the control (T0).
Thus, under Yangambi conditions, the application of pig manure, sawdust, and mineral NPK fertilizer positively affected pepper yield (Capsicum annuum), as statistical analysis revealed highly significant differences among treatments.

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I. INTRODUCTION

The African population mainly depends on agriculture, and soils constitute the basis of their survival. In the 21st century, due to population growth, the major challenge in agriculture and food production is to achieve two simultaneous objectives:

(i) sustainability through soil and water conservation, and
(ii) increased production to meet the needs of a constantly growing population (DRC, 2005).

Sustainable soil fertility management in humid tropical zones remains relevant because most agricultural production in these tropical soils (as in developing countries) is still based on traditional shifting cultivation systems. Moreover, agriculture is mainly rain-fed and dependent on climatic hazards (high temperatures and heavy rainfall), as well as often unfavorable soil conditions (Duchaufour, 1988; Mambani, 2003) and natural processes leading to soil acidification and intense leaching (Kanyonkogole et al., 2005).
To increase agricultural production in highly weathered tropical soils, chemical fertilizers are often recommended. However, their use is not always effective due to farmers' socio-economic conditions and the weak buffering capacity of these soils (Malaji, 2010). Moreover, continuous use of mineral fertilizers is costly and

environmentally harmful, as it disrupts soil life, acidifies soils, depletes micronutrients, and leads to soil degradation and reduced yields (Reijntjes et al., 1995 cited by Bamba, 2003).
Studies have shown that local resources such as organic waste and natural materials can supply nutrients to plants and improve crop yields (Koy, 2009; Ruganzu, 2009; Kochi et al., 2010). Therefore, information is needed on crop responses to these amendments in tropical acidic soils.
Yangambi has several local resources that can improve soil fertility, including agro-industrial waste, household waste, farm manure, and agro-minerals. Recycling biodegradable waste into compost represents a promising strategy for improving soil productivity.
This study aims to evaluate the effect of pig manure, sawdust, and mineral NPK fertilizer on pepper performance in ferrallitic soils of Yangambi.

II. OBJECTIVE OF THE STUDY

The general objective of this study is to evaluate the effects of soil amendment using organic matter derived from wood collected in Yangambi and mineral NPK fertilizer on the performance of pepper grown in acidic ferrallitic soils of Yangambi, Tshopo Province, Democratic Republic of the Congo.
In line with this general objective, the following hypothesis was formulated, and the results of this study will help verify its validity:

- ✓ Organic materials derived from pig manure and sawdust may constitute a better alternative to water-soluble chemical mineral fertilizers, which are expensive and rapidly leached in soils with low cation exchange capacity (CEC) and in regions with high rainfall.

III. IMPORTANCE OF THE STUDY

This work has both socio-economic and scientific importance:

- ✓ **Socio-economic aspect :** It will help develop cost-effective techniques for vegetable farmers in order to properly manage their crops, achieve higher yields, and increase their income.
- ✓ **Scientific aspect :** It opens new research perspectives on strategies for valorizing locally available resources to improve the fertility of acidic soils. It also represents an effective means of environmental sanitation.

1. ENVIRONMENT, MATERIALS, AND METHODS

The experiment was conducted at the INERA Yangambi research center in the Democratic Republic of the Congo. No GPS coordinates were recorded. The average geographic coordinates are: 24°29' East longitude, 0°48' North latitude, and 470 m altitude (1982). The experiment was carried out from February to August 2024.
The climate is of type Af according to the Köppen classification, with:

- ✓ Annual rainfall > 1800 mm
- ✓ Mean annual temperature between 23 and 26°C
- ✓ High relative humidity ranging from 81% to 90%
- ✓ Annual sunshine of approximately 1925 hours (about 45% of total radiation) (Erpicum, 2005)

The soil of the experimental site is a ferralsol, corresponding to the Oxisol order according to Soil Taxonomy. It is poor in humus but rich in iron and aluminum oxides (Dbin, 1981). Its pH generally ranges between 4 and 5. Its cation exchange capacity is low, remaining below 16 cmol(+).kg^{-1} (Roose, 1980). The clay fraction is dominated by kaolinite (Duchaufour, 1988).
The natural vegetation of Yangambi was a dense evergreen rainforest, which is now largely degraded and replaced by secondary anthropogenic formations (Manil, 1953). The experimental site was a fallow land dominated by *Imperata cylindrica*, *Cynodon dactylon*, and *Panicum maximum*, with some scattered plants of *Sida acuta*.
Apart from basic agricultural tools used for land preparation, pig manure obtained from a pig farm in Bangala district and well-decomposed sawdust collected from a local carpentry workshop were used as organic amendments. Mineral NPK fertilizer was used as inorganic fertilizer, while pepper (variety California Wonder) served as the test plant.
The experimental design was a randomized complete block design with four treatments and three replications. Plots measured 6 m in length and 4 m in width, with 1 m spacing between plots.
The symbols T0, T1, T2, and T3 represent the four fertilizer treatments defined as follows:

- ✓ **T0:** absolute control (no fertilizer applied)
- ✓ **T1:** pig manure treatment
- ✓ **T2:** sawdust treatment
- ✓ **T3:** mineral NPK fertilizer treatment

The application method and dosage were based on literature data. Some studies conclude that the method of application of organic (composted waste) and mineral fertilizers does not significantly affect their efficiency. However, Dick and McCoy (1933 in Mulaji, 2010) distinguish application methods and their effects.

According to these authors, surface application of compost improves soil structure and reduces leaching and erosion compared to incorporation methods. Surface application also reduces nitrogen competition between plants and soil microorganisms in the root zone.

The diversity of composts makes it difficult to establish general rules for their use. Moreover, it is difficult to provide precise guidelines on application rates. Recommended doses range from 5 to 150 t/ha depending on compost type and soil conditions (Gobat et al., 1998; N'Dayegamiye et al., 2005; Honfy-Collins, 2006; Mulaji, 2010, etc.).

In this study, treatments were applied by incorporating well-decomposed pig manure and sawdust at a depth of 10 cm one week before planting at a rate of 6 tons of dry matter per hectare. Mineral NPK fertilizer was applied at a rate of 160-140-140, with one quarter applied as basal fertilizer and another quarter during full vegetative growth (three weeks after transplanting) in furrows around the plants.

Observations focused on plant height growth, leaf area, collar diameter, fruit quality, and fruit yield. These variables were measured on a sample of four randomly selected plants per plot, excluding border plants.

Fruit quality was assessed based on breeder-defined characteristics, including fruit color, shape, length, and diameter.

Harvesting was done progressively as fruits reached maturity. Yield was weighed using a precision balance after each harvest. Some fruits were randomly selected to determine average fruit weight.

1.1. Statistical Analysis of Data

One-way analysis of variance (ANOVA) was performed using Statistica 6.0 software. Comparison of treatment means at a 5% significance level was carried out using Tukey's post-hoc test.

IV. RESULTS AND DISCUSSION

3.1. Vegetative parameters

Table 1. Vegetative parameters (cm)

Blocs Traitements	Bloc I	Bloc II	Bloc III	$\sum$	$\bar{X}_{trait}$	$\bar{X}_{rel}$
T0	31,0	32,5	51,5	115	38,33a	1,00
T1	35,5	47	32,5	115	38,33a	1,00
T2	42	38	43,5	123,5	41,17a	1,07
T3	53	52,5	46,8	152,3	50,77b	1,32
$\bar{X}_{bloc}$	40,4	42,5	43,6			

Caption:

T0: Control (No amendment), T1: pig manure, T2: wood sawdust, T3: NPK mineral fertilizer; X: Mean; Xtreatment: Treatment mean; Xblocks: Block mean; Xrel: Relative mean (Treatment/Control). Means per treatment followed by different letters within a column are significantly different at $p < 0.05$.

The analysis of Table 2 shows that the final height growth achieved by pepper plants varied from one treatment to another. Under T3 (NPK fertilizer), plants reached an average height of 50.77 cm; under wood sawdust (T2), it was 41.17 cm; while under T1 (pig manure) and the absolute control without fertilizer (T0), it was 38.33 cm. This shows that T3 and T2 resulted in growth increases of 32% and 7%, respectively, compared to T1 and T0. This allows the following ranking: T3 > T2 > T1 = T0.

The performance of the mineral fertilizer compared to the other treatments may be explained by the fact that it directly supplies essential mineral elements required in sufficient quantities to meet the crop's nutritional needs.

One-way ANOVA performed on final plant height at the end of the experiment revealed a highly significant difference ($p < 0.001$; Appendix 1) among treatments.

Multiple comparison tests of means (Appendix: Table 2) highlight two groups of means (a, b); treatments T2 (wood sawdust) and T3 (NPK mineral fertilizer) form the group with higher means, followed by T1 (pig manure), while the control (non-fertilized) ranks last.

The low average final height in the control soil (T0) can be attributed to characteristic factors of acidic soils: low pH, aluminum toxicity, and nutrient deficiencies (Ca, Mg, P, K, B, and Zn).

3.2.Collardiameter

Table 2. Collar diameter (mm)

Blocs Traitements	Bloc I	Bloc II	Bloc III	∑	$\bar{X}_{trait}$	$\bar{X}_{rel}$
T0	5,5	7,2	5,8	18,5	6,2a	1,00
T1	8	7,1	9,8	24,9	8,3b	1,35
T2	6,2	5,8	6,7	18,7	6,2a	1,01
T3	7,3	8,1	8,6	24	8,0c	1,30
$\bar{X}_{bloc}$	6,75	7,05	7,725	-	-	

Caption:

T0: Control (No amendment), T1: pig manure, T2: wood sawdust, T3: NPK mineral fertilizer; X: Mean; Xtreatment: Treatment mean; Xblocks: Block mean; Xrel: Relative mean (Treatment/Control). Means per treatment followed by different letters within a column are significantly different at $p < 0.05$.

From this table, it appears that collar diameter varied depending on the treatments. The highest value was obtained under T1 (pig manure), with an average of 8.3 mm. Under T3 (NPK mineral fertilizer), the average collar diameter obtained was 8.0 mm. Under T2 and T0, this parameter averaged 6.2 mm. This shows that T1, T3, and T2 resulted in collar diameter growth gains of 35%, 30%, and 1%, respectively, compared to T1 and T0.

One-way ANOVA performed on the mean values at the end of the experiment shows that there are highly significant differences (Appendix 2) between the treatments applied regarding their effects on pepper collar diameter. The mean comparison test highlights the superiority of treatments T1 and T3 over the others. This allows the following ranking: T1 > T3 > T2 > T0.

The performance of pig manure compared to the other treatments can be explained by its richness in nutrients, particularly nitrogen contained in pig urine, which may have promoted active microbial life necessary for the decomposition of organic matter, leading to the formation of more stable humus and improved soil properties.

BOKWALA (2019) obtained the highest plant vigor of 7.3 mm under the combination of mineral fertilizer and compost, which remains lower than the highest collar diameter value obtained under pig manure in our experiment (8.3 mm).

3.3.Leafarea

Table 3. Leaf area obtained (cm²

Blocs **Traitements**	**Bloc I**	**Bloc II**	**Bloc III**	$\bar{X}_{trait}$	$\bar{X}_{rel}$
T0	15,58	20,58	17,88	18,01a	1,00
T1	21,01	15,62	30,45	22,36a	1,24
T2	19,96	18,65	16,15	18,25a	1,01
T3	18,09	12,25	23,31	17,88a	0,99
$\bar{X}_{bloc}$	18,66	16,78	21,95		

Caption:

T0: Control (No amendment), T1: pig manure, T2: wood sawdust, T3: NPK mineral fertilizer; X: Mean; Xtreatment: Treatment mean; Xblocks: Block mean; Xrel: Relative mean (Treatment/Control). Means per treatment followed by different letters within a column are significantly different at $p < 0.05$.

The examination of this table shows that the average leaf area obtained varied slightly from one treatment to another. Under T0, it averaged 18.01 cm², while under T1, T2, and T3 it was 22.36 cm², 18.25 cm², and 17.88 cm², respectively. This indicates a leaf area increase of 24% and 1% for T1 and T2, respectively, compared to the control (T0), whereas T3 resulted in a 1% reduction in leaf area compared to the control (T0).

One-way ANOVA at the end of the experiment (Appendix 3) shows that there are significant differences ($p < 0.05$) among the different treatments applied. However, multiple comparison tests of means indicate that there are no statistically significant differences between treatments. This contradiction suggests the use of other multiple comparison tests such as Newman-Keuls, LSD, etc., which are less conservative than the one used (Tukey) in this study.

3.4.Number of fruits per plant

Table 4. Number of fruits per plant

Blocs Traitements	Bloc I	Bloc II	Bloc III	$\bar{X}_{trait}$	$\bar{X}_{rel}$
T0	9,40	11,20	11,50	10,70	1,00
T1	11,60	13,30	9,30	11,40	1,07
T2	10,50	9,70	10,90	10,37	0,97
T3	9,60	12,50	11,80	11,30	1,06
$\bar{X}_{bloc}$	10,28	11,68	10,88	-	-

Caption:

T0: Control (No amendment), T1: pig manure, T2: wood sawdust, T3: NPK mineral fertilizer; X: Mean; Xtreatment: Treatment mean; Xblocks: Block mean; Xrel: Relative mean (Treatment/Control).

From the reading of this table, it appears that under T0, the average number of fruits obtained per plant is 10.70, while under T1, T2, and T3 it is 11.40, 10.37, and 11.30, respectively. This indicates that T1 and T3 show increases of 7% and 6%, respectively, compared to T0, whereas T2 shows a decrease of 3% compared to the control (T0). Analysis of variance shows that, although these values are numerically different, there is no statistically significant difference in the number of fruits per plant among the different treatments studied.

3.5.Fruitquality

a)Fruitdiameter

Table 5. Fruit diameter (mm).

Blocs Traitements	Bloc I	Bloc II	Bloc III	$\bar{X}_{trait}$	$\bar{X}_{rel}$
T0	38,33	46,6	43,16	42,70 a	1,00
T1	68,5	44,78	48,66	53,98 b	1,26
T2	54,8	39,7	41,5	45,33a	1,06
T3	63,6	74,4	50,7	62,90c	1,47
$\bar{X}_{bloc}$	56,31	51,37	46, 01		

Caption:

T0: Control (No amendment), T1: pig manure, T2: wood sawdust, T3: NPK mineral fertilizer; X: Mean; Xtreatment: Treatment mean; Xblocks: Block mean; Xrel: Relative mean (Treatment/Control). Means per treatment followed by different letters within a column are significantly different at $p < 0.05$.

Reading this table shows that the average fruit diameter is 42.70 mm under T0, 53.98 mm under T1, 45.33 mm under T2, and 62.90 mm under T3. This corresponds to increases of 26%, 6%, and 47% for T1, T2, and T3, respectively, compared to T0.

One-way ANOVA at the end of the experiment (Appendix 4) shows that there are highly significant differences ($p < 0.001$) among the treatments considered with respect to their effects on pepper fruit diameter. The mean comparison test highlights the superiority of treatments T1 and T3 over the others.

b)Fruitlength

Table 7. Fruit length obtained (mm).

Blocs Traitements	Bloc I	Bloc II	Bloc III	$\bar{X}_{trait}$	$\bar{X}_{rel}$
T0	33,00	60,00	62,50	51,83a	1,00
T1	80,00	81,14	58,66	73,27b	1,41
T2	64,70	47,30	67,10	59,70c	1,15
T3	69,73	80,25	63,50	71,16b	1,37
$\bar{X}_{bloc}$	61,86	67,17	62, 94		

Caption:

T0: Control (No amendment), T1: pig manure, T2: wood sawdust, T3: NPK mineral fertilizer; X: Mean; Xtreatment: Treatment mean; Xblocks: Block mean; Xrel: Relative mean (Treatment/Control). Means per treatment followed by different letters within a column are significantly different at $p < 0.05$.

Reading this table shows that numerically, the average fruit length varied depending on the treatments. It was 51.8 mm under T0; 73.27 mm under T1; 59.7 mm under T2; and 71.16 mm under T3. This corresponds to fruit length increases of 41%, 15%, and 37% for T1, T2, and T3, respectively, compared to T0.

Analysis of variance (ANOVA) (Appendix 5) shows that there is a highly significant difference ($p < 0.001$) among the treatments applied on fruit length. The mean comparison test again highlights the superiority of treatments T1 and T3 over the others.

c)Fruitshape

Table 8: Ratio of fruit length to diameter obtained under the different treatments.

Traitements	Longueur (en mm)	Diamètre (en mm)	L/D
T0	51,83	42,7	1,21
T1	73,27	53,98	1,36
T2	59,7	45,33	1,32
T3	71,16	62,9	1,13

Caption:

T0: Control (No amendment), T1: pig manure, T2: wood sawdust, T3: mineral fertilizer.

The reading of this table reveals that fruit length was greater than its diameter. This indicates that the fruits were less elongated regardless of the treatments applied. This suggests that fruit shape remains an independent trait from the level of soil amendment.

Regarding fruit color, it was observed that it remained green from the beginning of its development until physiological maturity. It turned dark red when the fruits ripened about ten days after physiological maturity. This also shows that this parameter is not influenced by the different treatments applied.

3.6.Fruityield

Table 9. Fruit yield

Blocs Traitements	Bloc I	Bloc II	Bloc III	$\bar{X}_{trait}$	$\bar{X}_{rel}$
T0	88,00	74,00	84,00	82,00a	1,00
T1	145,00	127,50	136,50	136,33b	1,66
T2	94,00	106,00	118,00	106,00c	1,20
T3	147,00	152,00	159,00	152,67 d	1,86s
$\bar{X}_{bloc}$	118,50	118,38	124, 38		

Caption:
T0: Control (No amendment), T1: pig manure, T2: wood sawdust, T3: NPK mineral fertilizer; X: Mean; Xtreatment: Treatment mean; Xblocks: Block mean; Xrel: Relative mean (Treatment/Control). Means per treatment followed by different letters within a column are significantly different at $p < 0.05$.

The analysis of this table shows that the average fruit yield obtained is 82 kg/are under T0. It is 136.33 kg/are under T1, 106.00 kg/are under T2, and 152.67 kg/are under T3. This corresponds to yield increases of 66%, 20%, and 86% for T1, T2, and T3, respectively, compared to the control (T0).

One-way ANOVA (Appendix 6) shows that there is a highly significant difference ($p < 0.001$) among the treatments applied regarding their effect on pepper yield under the conditions of Yangambi. The mean comparison test again highlights the superiority of treatments T1 and T3 over the others.

The results obtained show that both compost and NPK mineral fertilizers positively influenced the fruit yield of the test plant. Among treatments, pepper yield followed the order T3 > T1 > T2 > T0. Therefore, in order to maintain or increase soil productivity, it is necessary to apply organic matter, preferably in large quantities, or otherwise in smaller amounts combined with mineral fertilizers. The sole use of mineral fertilizers cannot maintain long-term soil productivity due to leaching and degradation of soil properties (Alvares, 2005; Deblay, 2006; Mbonigaba, 2007 in Mulaji, 2010).

The fruit yields obtained in this trial are higher than those reported for the same test variety by FAVREAU and BERGERON (2010), at 112 kg/are, except for T0, which produced less. The relative superiority of T3 can be explained by the fact that mineral fertilizers directly supply nutrients to the plant, and the soil had a good level of organic matter, resulting in a highly beneficial effect on yield. However, this effect remains temporary once the organic matter is depleted if it is not replenished.

Pig manure, being rich in fertilizing elements—particularly nitrogen contained in pig urine—promotes active microbial life, ensuring good decomposition of organic matter and the formation of more stable humus, thereby improving soil productivity. In contrast, wood sawdust, being rich in cellulose (high C:N ratio), promotes a higher fungal population that slows down the decomposition of soil organic matter, resulting in slow nutrient release. Short-cycle crops do not benefit sufficiently from these slowly released nutrients.

Finally, the lower yields in the control plot can be explained by the absence of organic inputs, which leads to a loss of organic matter and nutrients, soil acidification, reduced biomass and microbial activity, and phosphorus immobilization, all of which contribute to a significant reduction in crop yield (Deblay, 2006).

V. CONCLUSION AND SUGGESTIONS

The present study aimed to evaluate the influence of pig manure, wood sawdust, and NPK mineral fertilizer on the performance of pepper (Capsicum annuum) in cultivation at Yangambi.

The results obtained showed that:

- ✓ Plant height varied depending on treatments. Mean comparison shows that T3 and T2 resulted in height gains of 32% and 7%, respectively, compared to T1 and T0.
- ✓ Collar diameter also varied with treatments. T1 and T3 resulted in collar diameter increases of 35% and 30%, respectively, compared to T0, while T2 had a similar effect to T0.
- ✓ Treatments influenced leaf area. Only T1 produced a significant increase (24% compared to T0), while T2 and T3 had almost no effect compared to T0.
- ✓ Only T1 and T3 had a positive effect on the number of fruits per plant, with increases of 7% (T1) and 6% (T3) compared to T0, whereas T2 caused a 3% reduction compared to T0.
- ✓ Average fruit diameter varied with treatments. T1, T2, and T3 resulted in increases of 26%, 6%, and 47%, respectively, compared to T0. The same trend was observed for fruit length, with increases of 41%, 15%, and 37%, respectively.
- ✓ Average fruit yield, like most studied parameters, varied with treatments. T1, T2, and T3 resulted in yield increases of 66%, 20%, and 86%, respectively, compared to the control (T0).

Thus, under the conditions of Yangambi, the application of pig manure, wood sawdust, and NPK mineral fertilizer to pepper cultivation has a positive effect on fruit yield (Capsicum annuum), as statistical analysis revealed highly significant differences among treatments.

In light of the above, we suggest the following:

- ✓ That this experiment be repeated over time and space in order to assess crop production responses to organic inputs across seasons and to evaluate the agronomic efficiency of the amendments applied;
- ✓ That a study be conducted to determine the optimal timing for the application of these organic manures so that their effects are more beneficial to pepper cultivation.

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