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RESEARCH ARTICLE

COMBINED EFFECTS OF PIG SLURRY AND MINERAL FERTILIZERS ON MAIZE YIELD PARAMETERS AND PHYSICO-CHEMICAL PROPERTIES OF TROPICAL FERRUGINOUS SOIL

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ABSTRACT

Agriculture in Burkina Faso faces a number of difficulties, including climatic constraints and poor soil conditions. Added to this is the high cost of chemical fertilizers. However, effluents such as pig slurry are multiple sources of plant nutrients, and would enable more eco-responsible management of these dejecta. The study was conducted over two consecutive years at the FarakoBâ experimental station in Burkina Faso. The experimental set-up is a completely randomized fisher block. Four treatments of pig slurry was applied in varying doses, and four other treatments in which, in addition to pig slurry, mineral fertilizer was applied at differents doses. The results of the study revealed inter-annual variation in grain and dry matter yields. Grain yield varied from 4.4t.h^{-1} in the first year of study to 2.82 4t.h^{-1} in the second year of experimentation. The results of the study showed an improvement in grain and dry matter yields in treatments combining 5 ton of pig slurry with 100% of the recommended dose of chemical fertilizer. Yields reached 5.49 t.h^{-1}. Concerning soil physico-chemical parameters, C/N values were around 10.89 in treatments with slurry inputs. On the other hand, this ratio was reached in the soil samples taken before the crop was planted. Assimilable phosphorus values improved with the addition of slurry.

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INTRODUCTION

Agriculture in Burkina Faso, dominated by cereal crops, will contribute an average of 21.58% to the country's GDP in 2023, and is the main source of income for around 63% of the working population (FAO, 2024). Among cereals, maize is the third most important field crop after sorghum and millet (Sanou, 1996). In the western part of the country, where rainfall and soil conditions are more favorable, maize takes pride of place in crop rotation (Bacyé, 2011). Today, maize has become part of culinary habits and, above all, a raw material for breweries. It is mainly used for self-consumption, with cash income varying from farm to farm (Sarr, 2011). Maize residues are also an important source of animal feed. From a food crop, maize has gradually become a cash crop, with greater receptivity to technical improvements (Sarr, 2011). However, its cultivation encounters enormous constraints. Maize is a water-demanding plant. It is also more sensitive to drought (Sarr, 1999) than other dry cereals such as millet and sorghum. In addition to these agro-climatic constraints, the often unfavorable socio-economic and political context explains why production levels remain low (Traoré, 2010). Furthermore, sub-Saharan Africa, in this case Burkina Faso, has the lowest consumption of mineral fertilizers, around 10kg of nutrients (N, P_2O_5, K_2O) per hectare per year, compared with an average of 90kg worldwide, 60kg in the Near East and 130kg in Asia (FAO, 200 3). This low consumption of fertilizers is undoubtedly linked to their price and, above all, to producers' low incomes. As a result, maize production suffers from insufficient fertilizer inputs (mineral or organic fertilizers).

Adding organic manures to mineral fertilizers, while reducing their quantity, could help boost maize production in Burkina Faso. This is the rationale behind the present study, whose theme is: "Combined effects of pig slurry and mineral fertilizers on maize yield parameters and physico-chemical properties of tropical ferruginous soil". The general objective of the present study is to contribute to the valorization of livestock manure in maize productivity in Burkina Faso agro-systems in this context of soaring mineral fertilizer prices. Specifically, the study aims to:(1) assess the effect of increasing quantities of pig manure on maize productivity;(2) assess the combined effect of increasing quantities of pig slurry and increasing doses of mineral manure on maize productivity;(3) determine the effect of pig slurry input on the improvement of soil physico-chemical parameters.

METHODOLOGY

Study site: The study was carried out at the Farako-Bâ station. The soils are ferralitic and have low clay and organic matter contents, resulting in a lower cation exchange capacity due to the low presence of exchangeable bases [8]. These soils are very sandy, slightly acidic and low in nitrogen and phosphorus. They have a denatured absorbent complex and are highly sensitive to leaching and erosion. The area is characterized by two strongly contrasting seasons, including a relatively short rainy season lasting 5 to 6 months and a dry season lasting 6 to 7 months. The dry season comprises a cool dry season from December to February and a hot dry season from March to

April. Rainfall is relatively high, fluctuating between 800 and 1100 mm depending on the year. The two blocks are separated by a distance of 4 m, and the plots within the same block are 2 m apart.

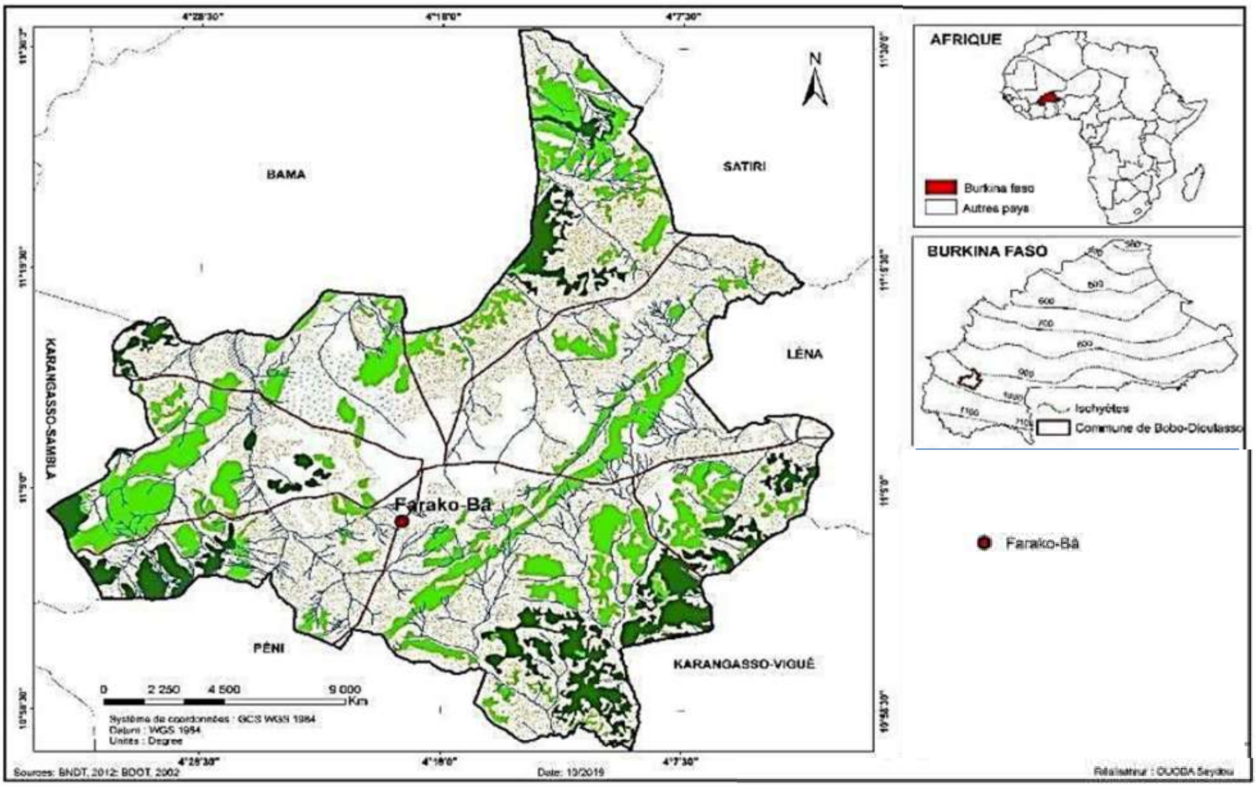

Figure 1. Study site (Farako-Bâ research station in Bobo Dioulasso, Burkina Faso)

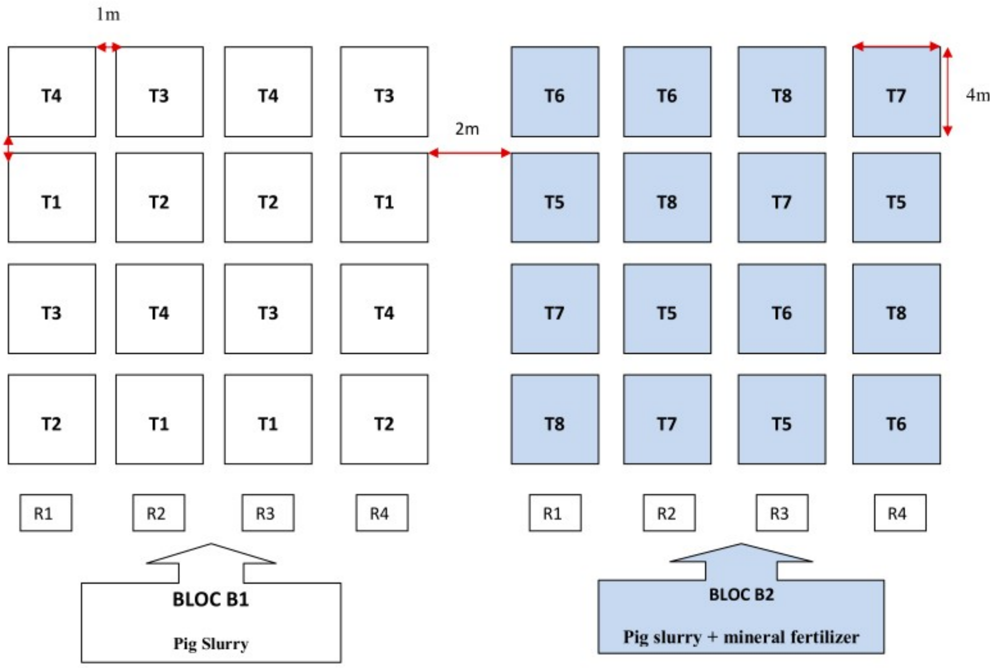

Figure 2. Experimental design

Experimental Design: The trial was conducted in a semi-controlled environment over two years (2021-2022) and on the same experimental plot. The experimental set-up is a completely randomized Fisher block with 4 treatments organized into 2 blocks (Figure 2). The first block comprises treatments T1, T2, T3 and T4, in which pig slurry is applied in varying doses. The quantities of slurry applied varied from 5t/ha to 20t/ha from T1 to T4. In treatments T5 to T8 of the second block, in addition to pig slurry, mineral fertilizers ranging from 25 to 100% of the recommended dose for maize were applied.

In total, each block consists of four (4) treatments with four (4) replicates. The plots are 16 m^2 each (4 m x 4 m) and the experiment was conducted over two consecutive years. The different treatments are as follows:

- T1: maize + pig slurry at 5 t/ha
- T2: maize + pig slurryat 10t/ha
- T3: maize + pig slurry at 15t/ha
- T4: corn + pig slurryat 20t/ha

- T5: maize + pig slurryat 5 t/ha+100% recommended dose of NPK and urea
- T6: maize + pig slurryat 10t/ha+75% recommended dose of NPK and Urea
- T7: maize + pig slurry at 15t/ha+50% recommended dose of NPK and Urea
- T8: maize + pig slurryat 20t/ha+25% recommended dose of NPK and Urea

In addition to these slurry-based treatments, four treatments were added and received only 5t.h^{-1} compost as an amendment.

Experimental conduct: The trial was conducted with the same maize variety over two rainy seasons. Cultivation operations included soil preparation, manual weeding, tractor ploughing, harrowing, levelling, manure spreading, sowing, weeding, ridging and harvesting. The improved variety SR 21 is a composite "white" maize variety with a 95-day cycle, and is resistant to disease and drought. Pig slurry was used in all treatments. The maize kernels were sown in rows. The rows were 80 cm apart and the bunches 40 cm apart. Manual weeding was carried out two weeks after sowing. A second manual weeding was carried out on the 40th day. Ridging was carried out on the 45th day after sowing. Mineral fertilizers NPK (14-23-14) and UREE (46%) were used in some treatments (from T5 to T8). Organic fertilizer, consisting solely of pig slurry, was applied in all treatments at doses ranging from 5t to 20t/ha, depending on the treatment. Mineral fertilizers NPK (14-23-14) and urea (46%) were applied at doses ranging from 25% to 100% of the recommended dose. The recommended mineral fertilization rates for maize are 200kg/ha NPK and 150kg/ha Urea.

Data collection

Data collection on yield components: Two yield components were selected and monitored during the two experimentation campaigns. These were grain and stalk yields. To assess these yields, yield squares (1x1m) were laid out on the diagonal in each elementary plot. In each yield square, all ears were harvested and shelled. The grains and stalks were then dried and weighed.

Soil sample collection: Manure and soil samples were taken. Soil samples were taken from the 0-20 cm horizon before the plot was developed. A second sample was taken after harvesting, as well as on another plot that had been left fallow for at least 5 years. Soil samples were also taken in treatments that had received compost only. In general, soil samples were taken per treatment and per repeat for chemical analysis in the laboratory.

Analysis of soil samples

For the parameters studied, the analysis methodologies were as follows:

- pH: was evaluated as [9]
- Total nitrogen was assessed using the modified Kjeldahl method
- Organic carbon was determined using the Walkley and Black method [10].
- Total phosphorus and available potassium were determined using the Bray 1 method [11];
- Cation Exchange Capacity (CEC) according to the analytical method of [12].

Data analysis: Analyses of variance were performed using SPSS22.0 (statistical package for social sciences). The Tukey test was used to separate and compare means at the 5% threshold.

RESULTS

Yield parameters

Inter-annual variation in yield parameters: The results showed an inter-annual variation in dry matter and grain weight (t.ha-1) (Table 1). Grain and dry matter weights ranged from 4.43 to 2.82 t.ha^{-1} from 2021 to 2022. Dry matter weights reached 9.01 t.ha^{-1} in 2021 and only 6.16 t.ha^{-1} in 2022. Low grain and biomass weights were observed in 2022. Statistical analyses are significant for dry matter weight ($p<0.002$) but also for grain weight ($p<0.001$).

Table 1. Inter-annual variation in grain weight and dry matter

	Year-2021	Year-2022	Probability
Dry matter weight (t.ha^{-1})	$9.01^a \pm 4.16$	$6.16^b \pm 3.35$	0.002
Grain weight (t.ha^{-1})	$4.43^a \pm 2.5$	$2.82^b \pm 1.05$	0.001

Variation in grain and dry matter yields according to treatment : Grain and dry matter weights varied significantly ($p<0.0001$) from 1.64 t.ha^{-1} to 5.49 t.ha^{-1} according to treatment (Table 2). The lowest grain and dry matter weights were observed in the T-Compost treatment, with values of 1.64 t.ha^{-1}in grain and 4.94 t.ha^{-1}in dry matters. Grain and dry matter weights were significantly ($p<0.001$) higher in the (5T+DR) and (15T+50DR) treatments.

Table 2. Variation in grain weight and dry matter by treatment

	Dry matter weight (t.ha^{-1})	Grain weight (t.ha^{-1})
T-Compost	$4.94^a \pm 1.50$	$1.64^a \pm 0.6$
5T	$4.62^a \pm 1.85$	$2.48^{ab} \pm 0.44$
10T	$5.11^a \pm 1.6$	$2.47^{ab} \pm 0.44$
15T	$8.84^{ab} \pm 3.54$	$3.18^{bc} \pm 1.58$
20T	$7.38^{ab} \pm 3.6$	$3.23^{bc} \pm 1.58$
5T+DR	$10.96^c \pm 4.47$	$5.49^e \pm 2.16$
10T+75DR	$6.94^{ab} \pm 3.37$	$4.48^{de} \pm 1.35$
15T+50DR	$10.26^{ab} \pm 5.01$	$5.23^e \pm 2.35$
20T+25DR	$9.5^{ab} \pm 4.7$	$4.08^{bc} \pm 3.2$
Probability	P<0.0001	P<0.001

Legend : *T-compost: treatment having received compost; 5T: 5tonof pig slurry; 10T: 10 ton of pig slurry; 15T: 15 ton of pig slurry; 20T:20 ton of pig slurry; 5T+DR: 5ton of pig slurry+recommended doses of mineral fertilizer; 10T+75DR: 10 ton of pig slurry+75% recommended doses of mineral fertilizer; 15T+50DR: 15 tonpig slurry+50% recommended doses of mineral fertilizer; 20T+25%DR: 20 ton*pig slurry *+25% recommended doses of mineral fertilizer.*

Variation in basic soil parameters between treatments: The results showed statistically similar values for pH, organic carbon, total nitrogen and available potassium in all treatments, although C/N was significantly higher ($p<0.0001$) in the 5-year fallow than in T-before the trial was set up. C/N values ranged from 10.89 to 13.95. Assimilable phosphorus values ranged from 3.17 to 3.95mg/kg respectively in the fallow and in the soil samples taken before the trial was set up. In these treatments, P-assimilble represented statistically ($p<0.0001$) the lowest values. Furthermore, the highest amounts of P-assimilblewere observed in the 20T treatment, with values reaching 44.7mg/kg. Overall, the addition of slurry and compost significantly increased P-assimilable values.

Effect of pig slurry on grain and dry matter yields: The results showed inter-annual variation in grain and dry matter weights (t.ha^{-1}). The first year of the eperiement in 2021 gave significantly higher yields than the following year 2022. These results could be explained by seasonal variations in rainfall. However, maize is sensitive to climatic hazards (Baize, 2000). This can have a negative impact on crops, reducing yields. The results also showed that manure alone was insufficient to generate high yields. The addition of chemical fertilizers was also necessary to induce significant increases in grain and dry matter yields. The combination of slurry with mineral fertilizer appears to be more effective. In fact, improving soil chemical characteristics through applications of pig manure can stimulate growth in a larger volume of soil, intensifying water and nutrient uptake (Abossolo, 2015). This translates into yield increases for crops such as maize (*Zea mays* L.) and common bean (*Phaseolus vulgaris* L.) and increases in the above-ground dry matter of cover crop species [14]. In addition, the usefulness of pig slurry as a crop fertilizer has been demonstrated in various studies (Abossolo, 2015 and Payet, 2009). In some contexts, farmers who spread pig slurry are reducing their doses of commercial fertilizers (Bergeron, 2016).

Table 3. Variations in soil physico-chemical parameters according to treatments

	pH-water	C-organic	N-Total	C/N	P-assimilable	K-available
T-Before planting the crop	$6.24^{a}\pm0.2$	$4.93^{a}\pm0.6$	$0.35^{a}\pm0.03$	$13.95^{b}\pm0.99$	$3.95^{a}\pm1.1$	$78.01^{a}\pm10.35$
T-Compost	$6.25^{a}\pm0.13$	$4.2^{a}\pm0.65$	$0.37^{a}\pm0.04$	$11.2^{a}\pm0.52$	$10.08^{ab}\pm2.32$	$70.04^{a}\pm14.54$
5-year fallow	6.25a±0.41	$5.6^{a}\pm1.75$	$0.402^{a}\pm0.09$	$13.7^{b}\pm1.1$	$3.17^{a}\pm0.9$	$66.31^{a}\pm24.24$
5T	$5.91^{a}\pm0.30$	$4.44^{a}\pm1.04$	$0.41^{a}\pm0.06$	$11.8^{a}\pm0.96$	$21.1^{bc}\pm12.7$	$83.85^{a}\pm34.76$
10T	$6.00^{a}\pm0.1$	$5.12^{a}\pm0.6$	$0.45^{a}\pm0.05$	$11.4^{a}\pm1.07$	$31.95^{cd}\pm11.02$	$71.03^{a}\pm17.05$
15T	$5.95^{a}\pm0.1$	$4.97^{a}\pm0.89$	$0.45^{a}\pm0.07$	$10.89^{a}\pm0.1$	$31^{cd}\pm5.3$	$73^{a}\pm18.44$
20T	$6.05^{a}\pm1.85$	$4.77^{a}\pm0.51$	$0.44^{a}\pm0.06$	$10.89^{a}\pm0.81$	$44.7^{d}\pm8.08$	$73.5^{a}\pm16.77$
Probability	$p<0.03$	P=0.495	P=0.218	$p<0.0001$	$p<0.0001$	P=0.928

Legend : *T-compost: treatment having received compost; 5T: 5tonof pig slurry; 10T: 10 ton of pig slurry; 15T: 15 ton of pig slurry; 20T:20 ton of pig slurry; 5T+DR: 5ton of pig slurry+recommended doses of mineral fertilizer; 10T+75DR:10 ton of pig slurry+75% recommended doses of mineral fertilizer; 15T+50DR: 15 tonpig slurry+50% recommended doses of mineral fertilizer; 20T+25%DR: 20 ton*pig slurry *+25% recommended doses of mineral fertilizer.*

Moreover, compared with other types of manure, pig slurry is the closest to commercial fertilizers in terms of nutrient concentration (Lory, 2006). However, pig slurry differs from commercial fertilizers in that it contains a diverse mixture of organic nitrogen compounds (Chantigny, 2014).

Effect of pig slurryon soil physio-chemical parameters: The addition of pig slurry led to a drop in C/N and an increase in soil assimilable phosphorus values. Indeed, previous studies have shown that pig slurry contains over 60% of phosphorus in inorganic form and all potassium in mineral form (Payet, 2009 and Chantigny, 2014). In addition, pig slurry applications can lead to an increase in labile forms of inorganic phosphorus in the soil (Cledimar, 2014). Studies have also shown that the C/N ratio of pig slurry is low, making it very different from that of manure from other animals, which has a higher ratio (Lourenzi, 2014), (Chastain, 2002). However, in terms of available nitrogen and potassium, no significant changes were observed. Concerning nitrogen, the combination of ammoniacal nitrogen and the neutral pH of slurry makes inorganic nitrogen prone to volatilization [21]. Significant quantities of nitrogen are lost in the form of ammonia during the storage period. And these losses generally continue, at even higher rates, when slurry is applied to field surfaces. These potential losses could explain the low levels of nitrogen in the soil. Available potassium is also present (Abossolo, 2015) in pig slurry, but like nitrogen, the risk of loss remains just as high.

CONCLUSION

The study conducted on the effect of pig slurry on maize yield components and soil physico-chemical properties led to positive improvements in maize grain and dry matter yields. At soil level, too, improvements in assimilable phosphorus values and C/N ratios were observed. Of the various combinations tested, the one incorporating 5 ton of slurry at the recommended rate of application of mineral fertilizer for maize enabled the crop to reach its potential yield. Consequently, with the increase in pig farming, the valorization of effluents from these barns could contribute to the development of corn production. However, precautions must also be taken in the management of these effluents (pig slurry), which are particularly rich in the trace metal elements copper and zinc, often added to feed rations for their veterinary properties.

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