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Response of Maize (*Zea mays* L.) to Poultry Dung Compost on Sandy Soil in Toumodi, Central Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The increase in maize harvests among farmers in the Toumodi locality (6°25'4.8˝N and 5°4'19.2˝w), in Côte d'Ivoire, required a study during the June cropping season in 2023. 4 increasing doses of compost: T0 (0 t/ha), T1 (10 t/ha), T2 (15 t/ha) and T3 (20 t/ha), were applied to the soil (0 - 20 cm) in a Fischer-type set-up with 4 replications. The mean values of the yield components of the various treatments were compared with each other and with those of the blank control using analyses of variance for a critical threshold, α = 0.05. Flowering was observed in male and female plants after 50 days following sowing in all the amended plots, whereas it appeared 10 to 15 days later in the plots without application. The highest grain yields were noted in the plots receiving the 15 t/ha dose, with average harvests of around 5 t/ha compared with 1.9 t/ha for the treatment without application. In addition, the 15 t/ha dose produced more seeds than the other treatments. In addition to its

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availability, the compost tested is rich in nutrients. An application of at least 10 t/ha is enough to increase yields, which are estimated to be almost twice as high as those in soils without compost. To this end, spreading this material on farmers' fields is highly desirable. However, the use of compost requires pre-treatment of the raw organic material, which could be a constraint on its use.

Keywords: Food security; organic fertilization; sandy soil; maize Ivory coast.

1. INTRODUCTION

In Côte d'Ivoire, maize is a subsistence crop. It is a socio-cultural crop [1]. It is grown in all rural areas. It is produced mainly for human and animal consumption [2]. It is also an important source of commercial revenue. Its production is estimated at around 170,000 tonnes of grain, whereas its consumption is estimated at 250,000 tonnes [3]. This shortfall in agricultural yields is probably partly due to the low productivity of the country's soils. Ancient climates and vegetation types have allowed the fertilisation process to develop with varying degrees of intensity [4,5]. Most of the soils encountered are characterised by a low cation exchange capacity (CEC) and a variable saturation rate in exchangeable bases, which is generally low, especially in the B horizons [6]. In the case of the present study, in the locality of Toumodi (central Côte d'Ivoire), acidic Ferralsols (5 < pH < 6) with medium to low desaturation (V: 20 - 50%) and low cation exchange capacity (CEC: 2 - 5 cmol.kg-1) are much more common [7], resulting in low yields of crops such as maize among farmers in the area. To improve crop yields, experiments based on traditional know-how [8] have been carried out and yields have been obtained with little satisfaction [9]. On the other hand, the use of improved varieties with high production potential and commercial chemical fertilisers has increased yields [10]. But this practice is more difficult for farmers to apply. Furthermore, in addition to the exorbitant and ever-increasing prices of mineral fertilisers and farmers' low incomes, which limit their use of fertilisers [5], the use of mineral fertilisers has also contributed to acidification, lowering organic matter levels and the cation exchange capacity of soils [11,12]. Restoring soil productivity has thus become a vital issue for farmers in the Toumodi area, where cropping systems are marked by increasingly declining productivity levels. Faced with this situation, there is an urgent need to find other sources of soil nutrients to increase crop yields. Organic fertilisers could provide such an alternative. Numerous studies have shown that organic amendments play an important role in various soil properties, which justifies their use [13-15]. It should also be noted that the decomposition of plant residues significantly improves the level of nutrients [16] and organic matter in soils [17]. Azontonde [18], by burying green manure from a legume grown for 12 months and composted maize residues, restored the productivity of bar land in Togo. From a biochemical point of view, organic matter, whether composted or not, represents a source of energy for micro-organisms [19]. They decompose it, transforming it into a mineral form that can be assimilated by plants [20]. In Toumodi, poultry droppings are available in large quantities as compost. It is rich in soil nutrients [21]. This study is testing different doses of poultry dung compost on sandy soil in maize crops in order to improve yields. The ultimate aim is to find a dose of this material that can help local farmers increase maize production.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

This study was conducted at the station of the Swiss Centre for Scientific Research in Côte d'Ivoire (CSRS, Toumodi, 6°25'4.8″N and 5°4'19.2″w) [Fig. 1] in the June cropping season of 2023. This is a forest/savanna transition zone with two rainy seasons that accumulate an average of 1,250 mm of water over 5 to 6 months of the year [22]. The average annual temperature and relative humidity recorded are 26°C and 77% respectively. The soils encountered are essentially deep Ferrasols (≥ 120 cm) characterised by high sand contents (≥ 40%) and low humus thicknesses (≤ 10 cm). High levels of clay (≥ 20%) accumulate at the bottom of the soil profiles [23,24].

2.2 Trial Site

The trial was set up on a 500 m^2 hand-cleaned plot. The experimental design adopted was a Fisher block with 4 replicates. Each block was subdivided into 4 microplots (4.8 m x 3.2 m), each corresponding to a dose of compost: 0 t/ha; 10 t/ha; 15 t/ha and 20 t/ha. The microplots were spaced 1.5 m apart. Each microplot consisted of

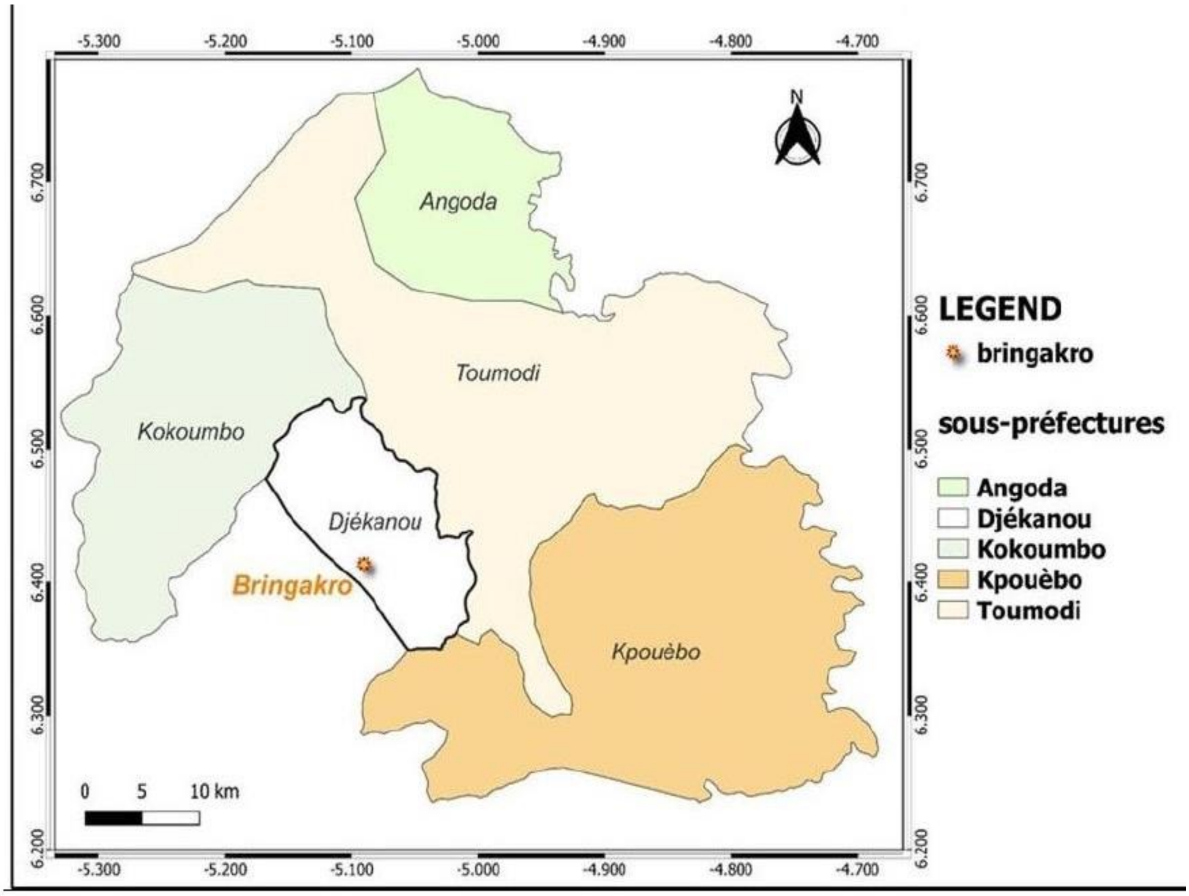

Fig. 1. Map of Toumodi department: Bringakro, study site

7 rows of seed, 10 cm deep, planted manually using a hoe. The rows were separated by gaps of 0.8 m. On each row, stacks 0.4 m apart were planted. Two maize grains (≤ 5 cm) were sown in each poquet the day after the compost was applied as a bottom dressing.

2.3 Maize Tested

Local maize seed, yellow in colour, obtained from producers in the area was chosen for the study. The yields obtained (2 to 3 t/ha) and the taste when cooked partly justify its predominance in farmers' fields. This variety is harvested between 95 and 100 days after sowing.

2.4 Compost Used

The compost used for the study comes from the farm of the research station of the Swiss Scientific Center of Bringakro. Its characteristics are recorded in Table 1.

Table 1. pH, C/N ratio and average nutrient content (% DM) of the compost used in the study [21]

Chemical elements	Content (% DM)
C	19.9
N	0.12
P	1.19
K^+	0.89
Ca^{2+}	1.23
Mg^{2+}	0.32
PHeau	6.3
C/N	165.42

DM: Dry Matter

2.5 Treatments Applied

4 different doses (0 t/ha; 10 t/ha; 15 t/ha and 20 t/ha) of compost were applied to the soil (0- 20 cm) on the seed rows (Table 2). The application levels were set in relation to the dose of 12 tonnes. This quantity has been recommended [25] for soil improvement using organic matter in Africa.

Table 2. Compost doses tested during the trial

Treatments	Doses (t/ha)
T0	0
T1	10
T2	15
T3	20

2.6 Statistical Processing of Data

The mean values of the yield components collected in the different treatments were compared with each other. And the effect of each treatment was compared with that of the blank control by means of analyses of variance for a critical threshold α = 0.05.

3. RESULTS

3.1 Height and Crown Circumference of Maize Plants at Harvest

At harvest, Table 3 shows the heights (HT) and girths (circf) of the maize plants, with significantly different values (p = 0.0001) between treatments. Three homogeneous groups emerged in terms of heights. Doses T2 and T3 produced the highest heights, with respective averages of 210.6 and 202.2 cm, unlike the control treatment (T0), which produced the lowest heights (117.8 cm). Treatment T1 (10 t/ha) formed the intermediate group, with an average height of 186.1 cm. Plant neck circumference was greatest with treatment T2 (6.6 cm). The smallest circumference was observed under the zero application control (T0).

3.2 Onset of Flowering in Male and Female Maize Plants

Table 4 shows the flowering times for male and female maize plants as a function of the doses applied. There was a significant difference between the treatments applied. Plots treated with 10 t/ha, 15 t/ha and 20 t/ha showed earlier male and female flowering. Flowers were observed after 50 days following sowing. In contrast, flowers appeared in the control plots (0 t/ha) 6 days later (56 or even 60 days after sowing).

3.3 Maize Grain Yield

Grain yields (rdmt), mass of a grain (M1g) and number of grains per line on an ear (nbrg/L) recorded for each treatment are shown in Table 5. The results show significant differences between the amended plots and the plots not treated (Pr = 0.0001). The highest yields were obtained with the 15 t/ha dose (average yield = 4.7 t/ha). The 10 t/ha and 20 t/ha treatments gave similar yields (3 t/ha). In addition, a seed harvested following the application of 10 t/ha, 15 t/ha and 20 t/ha weighed an average of 0.3 g. In contrast, the control soil (0 t/ha) produced a smaller harvest (1.9 t/ha). In terms of number of grains, the T2 dose (15 t/ha) was higher (p = 0.000) than the other treatments.

3.4 Yield Gains for the Different Doses of Compost Applied Compared with the Treatment with no Input (T0)

The yield gains for the different treatments compared with the soil without any input are shown in Table 6. Treatment T2 showed the greatest gain, at over 140% compared with T0. T1 and T3 follow. Applying 15 t/ha of compost to the soil results in maize harvests that are one to two times higher than on control soils (without compost).

Table 3. Average values for the heights (HT) and circumferences (circf) of maize plants at harvest according to treatments

Treatments	HT (cm)	circf (cm)
T0	117.8a	4.9a
T1	186.1b	6.0b
T2	210.6c	6.6c
T3	202.2c	6.5bc
MG	179.2	5.99
SD	38.16	0.76
Pr > F	**< 0.0001**	**< 0.0001**

MG: Overall Mean; SD: Standard Deviation; Pr > f: Probability (in a column, the Yields Assigned by the same letters are statically identical, on the contrary, they are different with a<b<c); 0 t/ha: T0 _10 t/ha: T1 _15 t/ha: T2 _20 t/ha: T3

Table 4. Flowering time (Tf) for male maize (MM) and female maize (MF) as a function of doses

Treatments	TfMM (jours)	TfMF (jours)
T0	56.2b	60.2b
T1	50.2a	53.0a
T2	49.6a	52.4a
T3	49.3a	52.3a
MG	52.45	55.58
CV	6.04	6.7
Pr > F	**< 0.0001**	**< 0.0001**

TfMM: Flowering Time for Male Maize; TfMF: Flowering Time for Female Maize (MF); MG: Overall Mean; CV: Coefficient of Variation; Pr > f: Probability (in a column, the values assigned by the same letters are statically identical, on the contrary, they are different with a<b); 0 t/ha: T0 _10 t/ha: T1 _15 t/ha: T2 _20 t/ha: T3

Table 5. Average values for grain yield (rdmt), mass of a grain (M1g) and number of grains per line on an ear of corn according to compost doses

Doses (t/ha)	rdmt (t/ha)	M1g (g)	nbrg/L
0	2a	0.26a	23.0a
10	3.6b	0.31b	27.0b
15	4.7c	0.33b	34.0c
20	3.3b	0.30b	28.5b
MG	3.4	0.300	28.12
ET	1.12	0.030	4.52
Pr > F	< 0.0001	**0.006**	**0.000**

MG: Overall Mean; SD: Standard Deviation; Pr > F: Probability (in a column, yields assigned the same letters are statically identical, on the contrary, they are different with a<b<c); M1g: Mass of a grain; nbrg/L: Number of Grains Per Line on an Ear; - Rdmt: Grain Yield

Table 6. Yield gain values for compost application rates compared with the control treatment (no application)

Doses (t/ha)	Gains (%)
0	0
10	83
15	143
20	70

4. DISCUSSION

Analysis of the results showed higher yields with plots amended with 15 t/ha of compost, with average harvests close to 5 t/ha. In addition, a maize grain harvested following application of 15 t/ha weighed an average of 0.3 g. Based on the characteristics of the compost tested [21], the application of 15 tonnes of compost per hectare corresponds to the supply of 180 kg of phosphorus (P), 135 kg of potassium (K+), 18 kg of nitrogen (N), 184.5 kg of calcium (Ca2+) and 48 kg of magnesium (Mg2+). This means that adding 15 tonnes of this material to the soil greatly enriched the soil in terms of N, P, K+, Ca2+ and Mg2+. It follows from these findings that the maize grain yields obtained are partly attributable to the nitrogen richness of the compost, because nitrogen is a determining factor in plant growth and yield [26,27]. Amadji and colleagues [28] attributed the increase in cabbage yield on sandy soil to compost enriched with poultry droppings. In the same context, a study on ferralitic soil in Benin by Saïdou [29] found better lettuce harvests after using poultry droppings compost. In the light of the results obtained, and in comparison with the soil without any inputs, the richness in nutrients of the poultry droppings compost studied partly explains the better results obtained for maize yields. From the 10-leaf stage to flowering, maize requires 4 kg of N, 1 kg of P and 10 kg of K+ per day to cover its nutritional needs [30]. Compared with the richness of the compost tested in these nutrients, spreading 15 tonnes of this material on maize can cover P and K requirements over this period. Specifically, maize absorbs between 80 and 90 kg of P per hectare during its physiological cycle

[30]. The compost tested, in addition to allowing phosphorus to feed the maize, creates the conditions for the availability of P and other nutrients (K+, Ca2+, Mg2+) in acid ferralitic soils [31] such as those at the study site ([23], which are naturally poor in these elements. Similarly, the calcium contained in compost could have positive effects on the physical and biological properties of soils [32]. And this can lead to better harvests. The calcium provided by compost can improve the reaction of soil that is already too acidic by creating a favourable environment for the proliferation of soil micro-organisms and the development of maize. Compost has a very high C/N ratio of around 165. When applied to soil, this type of material increases structural stability and improves structure. And a good structure creates the conditions for better harvests. Soil structure complements texture and, together, they govern the physical characteristics of the soil [34]. However, structure has a dominant influence on the physical aspects: porosity, infiltration (runoff), aeration, resistance to erosion and drought, root penetration and resistance to tillage, and is involved in leaching [33-35].

5. CONCLUSION

In an agricultural context marked by falling yields due to soil degradation, and faced with the high cost of commercial chemical fertilisers and their effects on the environment, the profitability of farms and the preservation of the environment depend, in part, on the use of organic matter in agriculture. In this study, in addition to its availability, the compost tested was rich in nutrients. An input of at least 15 t/ha was enough to increase yields, which were estimated to be almost twice as high as in soils without compost. In addition, a maize grain harvested after spreading the compost weighed an average of 0.3g. In the light of these results, the application of this material in farmers' fields is highly desirable, given that tropical soils, most of which are naturally poor, are facing the over-exploitation necessary to feed a rapidly growing population. However, the use of such compost requires pre-treatment of the organic raw material, which can be a constraint on its use.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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