FOR BETTER USE OF ZEBU HORN POWDERS AS FERTILIZER IN FERRALITIC SOILS

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ABSTRACT

Soil fertilization is essential for maintaining agricultural productivity while providing necessary nutrients to crops. Several fertilizers are used by farmers to improve agricultural production and amend the soil, including zebu horn powder which is one of the potential fertilizers. How can exploit zebu horn powders in agricultural production to increase yield in ferralitic soils? Faced with this problem, a study was conducted in the Haute Matsiatra region, aiming to describe a type of use of zebu horn powders for improving agricultural yields. The experimental design is placed on a flat plot and is composed of Fisher blocks with five replicates. This experiment allowed to compare the effects of zebu horn powders to a "garbage compost" control. Five types of fertilizer were applied: T0 for garbage composts (CO), T1 for raw zebu horn powders (PCZ), T2 for a mixture of equal parts of PCZ CO, i.e. 2PCZ+2CO, T3 for 1PCZ+3CO, and T4 for 1PCZ+4CO. Traditional production techniques used by local farmers were adopted for the experiment. The results obtained show positive effects of burying zebu horn powder on the yields of Cucurbita pepo L. or zucchini crops, particularly in relatively poor soils. Using a mixture of CO and PCZ significantly increases zucchini yield. Furthermore, applying PCZ improved plant growth in terms of leaf number and height. PCZ must be mixed with other fertilizers. T4 for 1 PCZ + 4 CO is the most recommended for zucchini production.

Keywords: *Amendment, fertilization, agriculture, production, yield, type, increase.*

1. INTRODUCTION

Agriculture is one of the main sectors contributing to the socio-economic development of populations. It employs more than 40% of the working population in the world, including more than 52% in Africa and Asia (Momagri, 2016). In this sector, market gardening plays an important role in food security (FAO, 2012).These crops are key to nutrution and poverty reducyion programs and contribute significantly to family income (Yarou &al. 2017).

Like other vegetable-producing countries, Algeria attaches great importance to this type of crop. Over the last few decades, an agricultural policy has been implemented which has encouraged the use of new means of production, including the development of plasticulture, the use of high-yield hybrid seeds, drip irrigation and so on. The aim of this policy is to encourage farmers to increase production and thereby reduce the foreign currency import bill, particularly during periods of international economic crisis (Bessaoud & al. 2019).

In Madagascar, agriculture generates around 24.7% of the overall Gross Domestic Product (Garruchet, 2023) and almost 75% of the working population is engaged in subsistence farming (INSTAT, 2020). All of the island's regions have their own potential, and the Haute Matsiatra region in particular attracts attention as it is favourable to food crops, cash crops, industrial crops and market gardening (VPEI, 2010). The need to increase food production in the Haute Matsiatra Region to feed a rapidly expanding population has led to the expansion of market gardening. Cucurbita pepo, also know as zucchini or « Vanga fotsy » is a commonly grown vegetable, ranking 11th among the most purchased market garden products by urban households (Andriandralambo, 2017).

Demographic pressure has led to a shortening of the fallow cycle, and even to the practice of continuous cropping on poor soils ill-suited to it. However, market gardeners have limited access to organic matter for soil amendment, mainly due to the scarcity of manure, as livestock farming in the region is underdeveloped and livestock numbers are low. To improve the fertility of their soil, market gardeners use garbage compost (CO) in fresh form with a high carbon/nitrogen C/N ratio, having undergone neither fermentation nor mechanical treatment. This practice carries risks, including nitrogen deficiency in plants and the pontential for highly reductive soil conditions (Matondo & al. 1990). Market gardeners also add other fertilizers to their OC, such as zebu horn powder (PCZ) which results from the processing of zebu horns. PCZ has agronomic value as a fertilizer or source of organic matter, but is under-exploited by farmers. In light of this paradox, the following research question was posed: "How can PCZ be used in agricultural production to increase yields in ferralitic soils? The overall aim of the research is to identify the most effective way to utilize PCZ.

The specific objectives are to study the plant parameters affected by the various treatments, identifying the most appropriate dosage for farmers, and to determine the best treatment method to use to obtain the best yield. Two research questions were raised: what is the best use of PCZ in agricultural production, and what yields are obtained by the different treatments. Two hypotheses are put forward: the combination of zebu horn powders and garbage composts promotes plant growth, and the use of zebu horn powder mixtures increases production yields.

2. MATERIALS AND METHODS

2.1. Study areas, soil characteristics and zebu horn powder

2.1.1. Study areas

The study was conducted in Ambatolahy V- Fokontany Andrainjato Nord, in the urban commune of Fianarantsoa. The Haute Matsiatra Region is part of Madagascar's central highlans, located in the following geographical coordinates: 45°51 and 47°41 East; 20°68 and 22°21 South (Andriamarolahy, 2023). The region has a tropical, high-altitude climate with two distinct seasons: November to April, a hot, rainy period that accounts for 90% of rainfall (1,000 to 1,200 mm/year) (CREAM, 2013).
The trial area is located on highly denatured ferralitic soils. The main physico-chemical characteristics of the soils of the Haute-Matsiatra Region used for market gardening are presented in Table 1.

Table -1: Soil types in the Haute-Matsiatra Region (Lahanomenjanahary, 2012)

Eastern Highlands	Central Highlands	Western and southern parts
North & South: Association of red ferralitic soils + yellow/red	Ferralitic soil association red + yellow/red	North & South: Association red ferralitic soils + weakly ferralitic and ferrisols
Center: Undeveloped soils and rankers	Complex lithosols and less evolved soils	
South: Complex lithosols and less evolved soils		Grand Ouest: Association Tropical ferraginous soils + poorly developed soils

2.1.2. Characteristics of the soils

The soil in the Haute Matsiatra Region, similar to other ferralitic soils in the Malagasy highlands, has the following physico-chemical characteristics. According to Matondo & al. (1990), at a sampling site characterized by cleared soil, uncultivated for over 25 years, physico-chemical analyses from previous studies showed N and P deficiencies (total N = 1.6 g/kg and total P = 1.31 g/kg) with a relatively acidic pH (water pH= 4.7). Carbon levels were also low (total C = 29.2 g/kg). Particle size analyses indicated a high proportion of clay and fine silt, characteristic of heavy clay soils rich in gibbsite. Iron and aluminum oxide content is also very high (31.4% Fe_2O_3 and 28.2% Al_2O_3), while silica content is low (10% SiO_2). Experiments carried out on this soil showed deficiencies in plant biomass in the order P>Ca>Mg>N.

2.1.3. Zebus horn powders

The Atsimo Andrefana and Haute Matsiatra regions supply zebu horns to the Ambositra district of the Amoron'i Mania region. Ambositra craftsmen transform zebu horns into combs, dice and earrings. The by-products are the powders used (PCZ) for the experimental trials. These powders are obtained during the scraping and polishing phase of the manufactured items. For the basis of the experiment, 1bag of raw PCZ (50 kg) contains 40 kg of PCZ (80%) and 10 kg of bran ash (20%).

2.2. Common verification approach for hypotheses

2.2.1. Analysis of the Physico-Chemical Characteristics of Zebu Horn Powder

A sample of PCZ was analyzed by the RADIOISOTOPES laboratory to determine its physico-chemical properties. PH was measured using a PH meter. Carbon was determined by the Walkley and Black method, and nitrogen by the Kjeldahl method. Exchangeable bases (Ca^{++} and Mg^{++} and K^{+}) were determined by first extracting with ammonium acetate at PH 6. Ca^{++} and Mg^{++} were determined by flame spectrophotometry. Mg^{++} was determined by EDTA complexometry at PH 10.5. Assimilable phosphorus was determined by the Olsen method (Matondo & al., 1990).

2.2.2. Experimental set-up and different fertilizer treatment methods

The experiment was carried out over a total area of 1,117m^2. The experimental set-up consisted of 25 elementary plots in 5 randomized Fisher blocks, with one block corresponding to the 5 treatment replicates (Figure 1). This block comprises 5 elementary plots with 5 types of treatment for zucchini cultivation. The size of each plot is 10mx4m, i.e. 40 m^2 (Figure 1).

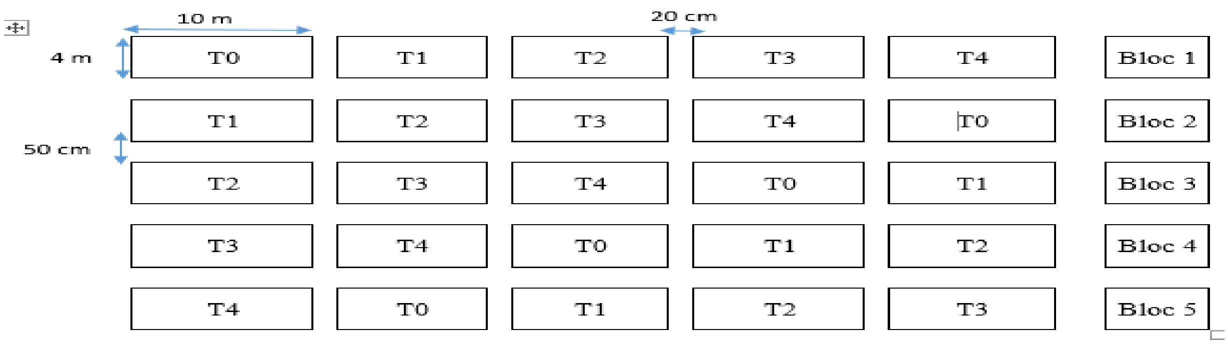

Figure -1: Experimental setup

Five types of treatment on the 5 blocks were compared: T0 for garbage composts (CO), T1 for raw zebu horn powder (PCZ), T2 for an equal mixture of PCZ CO, i.e. 2PCZ+2CO, T3 for 1PCZ+3CO, and T4 for 1PCZ+4CO (Table 2). During experimentation, each type of mixture must be prepared before use.

Table -2: Treatments and dosages

Treatments	Annotation	Types of fertilizer used and composition	Dosage
T0 (sample)	CO	Garbage Compost	9 000 kg/ha
T1	PCZ (1/2kp)	PCZ of 0.5 cups or goblets per hole	117 kg/ha
T2	PCZCO (2+2)	Mix of 2 UM PCZ + 2 UM CO	351kg/ha of PCZ + 16.875t/ha of CO
T3	PCZCO (1+3)	Mix of 1 UM PCZ + 3 UM CO	175,5kg/ha of PCZ +25,3125t/ha of CO
T4	PCZCO (1+4)	Mix of 1 UM PCZ + 4 UM CO	143kg/ha of PCZ +27.5t/ha of CO

UM: Unit of Measure (bag or bucket)
T0: Garbage compost only
T1: PCZ (1/2kp): ½ cup of PCZ to run into a hole
T2: PCZCO (2+2): 3 cups of mix to be poured per hole
T3: PCZCO (1+3): 3 cups of mix to be poured per hole
T4: PCZCO (1+4): 3 cups of mix to be poured per hole

2.2.3. Conducting the culture and method of using the mixture of zebu horn powder with garbage compost

Local farming practices used by the farmers were adopted. Ploughing was carried out with a spade (angady) to a depth of around 25 cm. This deep ploughing helps loosen the soil and improve humus content.The non-fertile soil was prepared two weeks prior to sowing. The variety of zucchini (Cucurbita pepo L) tested was the locally grown *Vanga fotsy*, which produces white fruits with longitudinal green mottling.

For fertilization, three cups (1 cup based on 1 can of Nestlé milk) of the PCZ+CO mixture were poured per hole, depending on the treatment type. Zucchini seeds were sown with 2 seeds in each 60-cm spacing, i.e. 72 seeds for 36 bunches in a 40-m² elementary plot. Sowing was done manually.

After sowing, plant growth and zucchini production were assessed for each plot, and average values were calculated for each treatment.

2.2.4. Analysis of Plant Growth and Production Yield

The data collected were entered into an Excel spreadsheet and processed using XL STAT 2014 software. Plant development was evaluated using emergence rate, main stem height, leaf count, and leaf width.The p-value was calculated to determine the degree of significance of the variables studied, and the mean and standard deviation of the variables studied as references. For yield analysis, the variables studied were number of fruits per plant, fruit weight (g), total fruit weight per plant (g).

2.3. Approach to Verifying Hypothesis 1: "The Combination of Zebu Horn Powder and Garbage Compost Promotes Plant Growth"

During the experiment, manual measurements and weekly monitoring of plant growth were carried out. Parameters studied included emergence rate, height of main stem, number of leaves, width of each leaf, and flowering period.

2.4. Approach to Verifying Hypothesis 2: "The Use of Zebu Horn Powder and Garbage Compost Mixtures Increases Production Yield"

Yield was calculated at harvest. The variables studied included the number of fruits per plant, the weight of one fruit, the weight of fruits per plant per m^2 and per 40 m^2 (Table 3).

Table -3: Yield Components

Yield components per $40m^2$ plot	Method of determination
Average Number of Fruits per Plant	Manual counting
Weight of a Fruit	Comparison with normal weight
Average Number of Fruits per $40m^2$	Manual counting

The yields (R in $g/40m^2$) and (R in g/m^2) of zucchini crops can be estimated as follows:

Yield (R)= Nbr P*Nbr F*P , with
Nbr P = Number of plants per $40m^2$
Nbr F = Number of fruits per plant
P = Average weight of a fruit

3. RESULTS

3.1. Zebu Horn Powders and Plant Growt

3.1.1. Physico-Chemical Characteristics of Zebu Horn Powder

Table 4 presents the physico-chemical characteristics of Zebu Horn Powder (PCZ). According to the results from the Radioisotope Laboratory at the University of Antananarivo, PCZ has a high nitrogen (N) content, a moderate potassium (K) concentration, but very low levels of phosphorus (P), calcium (Ca), and magnesium (Mg).

Table -4: Main Physico-Chemical Characteristics of PCZ

N	44,14g/kg	Total nitrogen (N): Acid mineralization, measured using a continuous flow autoanalyzer Total phosphorus (P total): Calcination at 550°C, measured by colorimetry Total K, Ca Mg: Calcination at 550°C, measured using an atomic absorption spectrometer
P	1,12g/kg	
K	3,83g/kg	
Ca	0,17g/kg	
Mg	0,48g/kg	

3.1.2. Growth Parameters

3.1.2.1. Emergence Rate

The emergence rates (100%) are identical for all treatments. There is no significant difference (p value <0.0001) (Figure 2).

Figure -2: Graphical Representation of the Emergence Rate

T0: Compost of Garbage only
T1: PCZ (1/2kp): ½ cups of PCZ to hide in a hole
T2: PCZCO (2+2): 3 cups of mix to be poured per hole
T3: PCZCO (1+3): 3 cups of mix to be poured per hole
T4: PCZCO (1+4): 3 cups of mix to be poured per hole

3.1.2.2. Height of the Main Stem

Throughout the weeks of monitoring, a significant difference in the height of the main stem of the zucchini was observed across the different treatment types (Figure 3). The zucchini in Treatment (T4) exhibited faster elongation compared to the others, despite receiving the same care and being exposed to the same climate conditions.

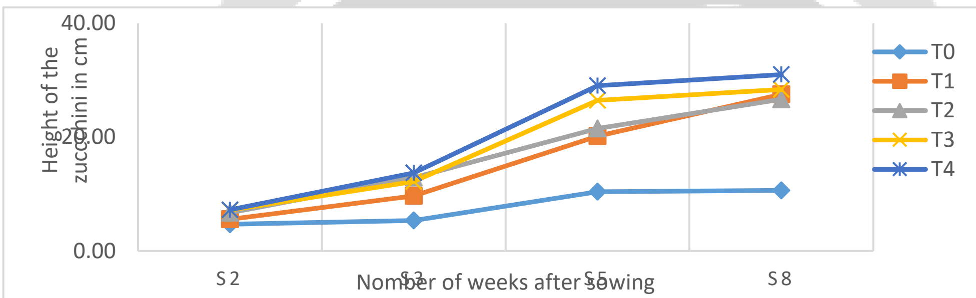

Figure -3: Evolution of Zucchini Plant Heights

T0: Compost of Garbage only
T1: PCZ (1/2kp): ½ cups of PCZ to hide in a hole
T2: PCZCO (2+2): 3 cups of mix to be poured per hole
T3: PCZCO (1+3): 3 cups of mix to be poured per hole
T4: PCZCO (1+4): 3 cups of mix to be poured per hole

3.1.2.3. Number of Leaves

Regarding the number of leaves, the zucchini plants exhibit a growing trend. It is noteworthy that the number of leaves in Treatment T4 is higher than in the other treatments (Figure 4).

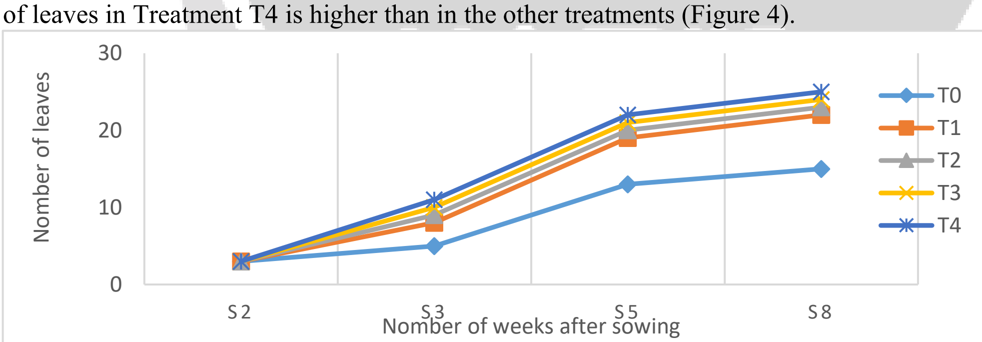

Figure -4 : Evolution of Zucchini Plant Leaves

T0: Compost of Garbage only
T1: PCZ (1/2kp): ½ cups of PCZ to hide in a hole
T2: PCZCO (2+2): 3 cups of mix to be poured per hole
T3: PCZCO (1+3): 3 cups of mix to be poured per hole
T4: PCZCO (1+4): 3 cups of mix to be poured per hole

3.1.2.4. Leaf Width

As with the other variables, the effects of T4 dominate the other treatments (Table 5).

Table -5: Evolution of Zucchini Plant Leaf Widths

Treatment	Fertilizer	**Leaf Width (cm)***
T0 (sample)	CO	11,75±1,08
T1	PCZ (1/2kp)	18,22±1,64

T2	PCZCO (2+2)	16,14±2,51
T3	PCZCO (1+3)	22,22±2,46
T4	PCZCO (1+4)	24,64±1,58

* Mean ± Standard Deviation

T0: Compost of Garbage only
T1: PCZ (1/2kp): ½ cups of PCZ to hide in a hole
T2: PCZCO (2+2): 3 cups of mix to be poured per hole
T3: PCZCO (1+3): 3 cups of mix to be poured per hole
T4: PCZCO (1+4): 3 cups of mix to be poured per hole

3.1.2.5. Flowering

This section covers the flowering period of the plants for each treatment. The appearance and maturity of male and female zucchini flowers occur at different times. The flowering date of zucchini plants in Treatment T0 is significantly later than that of plants in the other treatments (T1, T2, T3, T4). The plants in Treatment T0 flower after 52 days (±3 days), whereas the plants in the other treatments take 28 days (±3 days) after sowing to flower.

3.2. Zebu Horn Powders and Yields

3.2.1. Number of fruits per plant

It is observed that the zucchini plants in treatment T0 have a zero fruiting rate five weeks after sowing, as the plants in plots amended with waste composts begin to flower starting from 45 days after sowing. All the plants in treatments T1, T2, T3, and T4 have a 100% fruiting rate, which is significantly higher than that of the plants in treatment T0, which is zero in week 5 and 31% in week 8 (Table 6).

3.2.2. Average Fruit Weight

Ripe fruits were harvested 90 to 100 days after sowing. Fruits from Treatment T1 were the largest on average compared to those from other treatments.
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3.2.3. Total weight of fruit per plant

Decreasing doses of PCZ mixed with CO led progressively higher fruit production. Several parameters were used to compare yield performance accross treatments (Table 6). Treatment T4 produced the best results based on mean and standard deviation analyses. Fruits from Treatment T1 were larger than those from the other treatments. For the treatment in which the plots are amended with PCZ, the number of fruits is not only the highest but also significantly different from those treated solely with garbage compost. Depending on the applied treatment, the average yields vary from one treatment to another (Table 6).

Table 6: Mean and standard deviations of the parameters studied

Treatment	Treatment	Parameters studied		
		Number of fruits per plant *	**Fruit weight (g)***	**Total fruit weight per plant (g)***
T0 (Témoin)	CO	1,64±0,49	384±209,46	654±411,88
T1	PCZ (1/2kp)	2,83±0,38	**758**±287,39	2198±955,16
T2	PCZCO (2+2)	4,67±1,12	481±96,95	2229±676,96
T3	PCZCO (1+3)	5,44±0,77	450±102,80	2434±637,08
T4	PCZCO (1+4)	5,89±0,32	455±123,68	2663±680,06

Mean ± Standard deviation , UM: Unit of Measurement (bag, bucket)

T0: Compost of Garbage only
T1: PCZ (1/2kp): ½ cups of PCZ to hide in a hole
T2: PCZCO (2+2): 3 cups of mix to be poured per hole
T3: PCZCO (1+3): 3 cups of mix to be poured per hole
T4: PCZCO (1+4): 3 cups of mix to be poured per hole

Table 7 shows that there is no very significant difference between treatment T0 and T1 because the p-values are less than 0.0001 for each parameter studied.

Table -7: Summary of p-values of parameters

Variables \ Treatment	T0/T1	T1/T2	T2/T3	T3/T4
Final plant height (cm)	<0,0001	0,889	0,005	<0,0001
Number of leaves per plant	<0,0001	1	<0,0001	<0,0001

Leaf width	<0,0001	1	<0,0001	<0,0001
Number of fruits per plant	<0,0001	<0,000 1	0,001	0,001
Fruit weight (g)	<0,0001	1	0,906	0,422
Total fruit weight per plant (g)	<0,0001	0,436	0,095	0,073

The p-value is very significant when referring to the threshold of 0.05 and comparing the average fruit weight and the total fruit weight per plant of the T3 and T4 treatments. For these two parameters, the p-values are 0.422 and 0.073 respectively; so it is good to use the mixture of PCZ and garbage composts respecting the best composition (1+4) to have a better use of PCZ in agricultural production.

Treatment T4 resulted in the highest yield, with an average total fruit weight of 2,663g per plant. Although fruits from T1 were larger on average up to 758g, the number of fruits per plant was lower (3 in T1 vs 6 in T4).

Table 8 sumarizes the total weight of fruit per plant per treatment.

Table -8: Yield by treatment type

	T0	T1	T2	T3	T4
Average number of fruits per plant	2	3	5	5	**6**
Average fruit weight (g)	399	758	478	447	472
Average weight per plant (g)	654	2 198	2 229	2 434	**2 663**
Total fruit weight (kg/ha)	4,08	19,77	20,06	21,91	**23,97**

4. DISCUSSION

4.1. Improving plant growth

4.1.1. Lifting rate

Overall, the results obtained showed that the types of treatment have the same effects on the germination rate. All five treatments reached the germination stage (Figure 1). However, according to Tayeb (1995), «germination is linked to extrinsic factors such as humidity, temperature, oxygen, and light ». Regardless of the type of treatment, it is the environmental factors that influence the germination of young plants. The combined influence of these various extrinsic factors makes germination possible. Although a hot and dry period was observed during the experiment, regular watering twice a day helped maintain soil moisture and promote seed germination. Additionally, germination starts at 12°C, with the optimal germination temperature being 20°C (Hallouin, 2012).

4.1.2. Rapid plant growth

The results obtained 8 weeks after sowing show that the plants on the plots amen%ded with PCZ has a longer main stem length than the plant on the plots fertilized with CO (Figure 2). The number of leaves deployed by the different zucchini cultivation treatments is not identical. Indeed, the average number of leaves differs according to the type of treatment at the final stage: CO (12), PCZ1/2 (16), PCZCO 2+2 (14), PCZCO1+3 (26), PCZCO1+4 (29) (Figure 3).

These numbers are high compared to those mentioned by CAM (2007), who recorded four leaves at seven days after sowing. The high temperatures and the rainfall deficit observed during the experiment were responsible for the slowed growth of zucchini plants. According to Abatzian & al. (2003), zucchini has high organic matter requirements, and water stress affects the vegetative growth of the plant. The elements present in the ferralitic soil, which is acidic, are insufficient to ensure proper plant growth, even when PCZ was applied. Indeed, the mineralization of organic fertilizers is slow, causing nutrients to become progressively available (Fanjaniaina, 2009).

Similarly, Dauda & al. (2009) in Nigeria demonstrated that the application of increasing doses of poultry manure led to a proportional increase in the number of fruits per plant in watermelon (Citrullus lanatus). This growth is explained by the fact that PCZ contains a significant amount of nitrogen and phosphorus, which are essential for plant growth and development. These elements act immediately on foliage development and enhance plant production in cultivation.

PCZ can provide the necessary nutrients for plant nourishment and growth, thereby increasing the yield of cultivated plants. Ezzo & al. (2012) found that zucchini had a reduced fruit weight when fertilized with 100%

poultry manure compared to other organic fertilizers. This suggests that the synchronization of nutrient release in PCZCO during decomposition and its assimilation by the plant was effective. Indeed, Mulaji (2011) demonstrated that the rate of organic matter decomposition and plant growth is closely linked to the synchronization between nutrient release and its uptake by the plant.

4.1.3. Early flowering

The flowering date of zucchini plants for treatment T0 is significantly later than that of the plants in the other treatments (T1, T2, T3, T4). The plants flower after 52 days (±3 days) for treatment T0, whereas the plants in plots amended with PCZ take 28 days (±3 days) after sowing to flower. This result does not conform to the study by Andriamanantsoa (2017); the introduced zucchini variety « Non-coureuse d'Italie » flowers earlier than the « Vanga fotsy » variety. It flowers 1.5 months after sowing, while the local variety takes 2 months.

The result is also not consistent with the study by Abatzian & al. (2003), which indicates that flowers appear approximately 40 days after sowing (1.3 months). The first flowers observed during the experiment on TO were male flowers. However, according to Abatzian & al. (2003), under normal conditions, female flowers appear first. This contradiction is explained by Gry (2010), who states that zucchini produces more male flowers under difficult conditions, such as climatic stress. Indeed, the high temperatures and low rainfall recorded during the experiment disrupted the flowering of the zucchini plants.

Considering the studied growth parameters, the results related to plant growth partially confirm Hypothesis No. 1: « The combination of powdered zebu horns and garbage compost promotes plant growth ». Indeed, the different treatments led to the same results regarding germination rates.

4.1.4. Vegetative growth limited by climatic conditions

In this experiment, zucchini showed a dominant germination rate. The plants in plots amended with PCZ exhibited a remarkable germination rate. According to Fuchs (2009), compost amendments create better growth conditions for plants in vegetable farming. The average temperature in December was around 25.29°C, which corresponds to the optimal germination temperature for zucchini seeds, ranging from 25 to 30°C, according to Espagnacq (2008). Additionally, watering facilitated seed germination. Moreover, according to Tayeb and Etienne (1994), germination is influenced by extrinsic factors such as humidity, temperature, oxygen, and light. However, high temperatures slow down plant growth, both in terms of stem length and biomass production. Indeed, the optimal temperature for vegetative growth is between 20 and 22°C (Garcia, 2008). This temperature is significantly lower than the average recorded in the study area during the zucchini growth period, which was 25.35°C in September. Furthermore, according to Terrentroy (2000) and Ramiaranjatovo (2017), recorded precipitation levels were among the lowest, and daily temperatures exceeded 30°C for several days. Beyond 30-35°C, and depending on water supply conditions, the plant may wilt more or less irreversibly. Prolonged high temperatures accompanied by water deficit led to the death of several zucchini plants during this period. The vegetative phase is the most critical, as early stress impacts root development, vegetation uniformity, and the number of fruits per plant (Abatzian & al., 2003). Moreover, scale insects attach themselves to the roots, attack young zucchini plants, slow growth, and ultimately cause plant deterioration (Abatzian & al., 2003).

4.2. Yield improvement

Under normal growth conditions, male zucchini flowers appear before female flowers, which is a typical characteristic of this species' development (University of New Hampshire Extension, 2018). In the experiment, male flowers appeared first, and zucchini plants produced more male flowers. This result aligns with the study by Bodnar and Fitts (2000), which states that high temperatures affect the formation of female flowers and the quality of pollen in male flowers. Additionally, according to Gry (2010), zucchini produces more male flowers under difficult conditions, such as climatic stress. At this physiological stage, climatic conditions remain favorable for plants, with an average annual temperature below 22°C (Andriamarolahy, 2023). However, the optimal temperature for zucchini fruiting generally ranges between 20°C and 25°C (MAEP, 2009). Thus, the use of a mixture of powdered zebu horns (PCZ) and garbage compost (CO) in production offers several advantages, including increased agricultural yield and improved production quality.

Thus, the combination of powdered zebu horns and garbage compost promotes the growth of vegetable plants, confirming Hypothesis No. 2: « The use of mixtures of powdered zebu horns and garbage compost increases production yield ».

4.2.1. Various factors compromising fruiting

The plants in plots amended with the mixture of PCZ and CO flowered earlier than the plants in other plots. The fruiting rates show significant differences. These results can be explained by both environmental conditions and zucchini physiology, particularly pollination issues. Zucchini has high heat requirements (Garcia, 2008). The optimal fruiting temperature ranges between 20 and 25°C (Réseau GAB/FRAB[1], 2009; Ramiaranjatovo, 2017), which is lower than the study area's recorded temperature, reaching over 27°C in December. Locally, high temperatures[2] and a prolonged rainfall deficit were observed for several days before and after zucchini flowering in February and March, whereas the plant is highly sensitive to water scarcity at the beginning of flowering (Abatzian & al., 2003). Moreover, zucchini tends to produce more male flowers when subjected to difficult conditions, such as climatic or water stress (Réseau GAB/FRAB, 2009). However, it is important to note that female flowers are the ones that develop into fruits. Zucchini is a monoecious plant, meaning it has distinct male and female flowers that mature at different times. Abatzian & al. (2003) also state that a zucchini plant will produce a maximum of one to two fruits, depending on the variety and growing conditions.

The results (Table 6) show that the plant gives six (6) zucchini fruits on the use of a good composition of PCZ and CO « 1 quantity of PCZ measure to associate a quantity four times more of garbage composts PCZCO (1+4) ». These results are in the same direction as those of Gascho & al. (2001) and Batamoussi & al. (2016).They are comparable to those reported by Kouakou & al. (2012) who demonstrated in a study on cucumber (Cucumis sativus) that poultry manure promotes its growth. In Nigeria, the application of increasing doses of poultry manure resulted in high fruit weights per plant in watermelon (Citrullus lanatus), according to Dauda & al. (2009). The PCZ dosage applied decreased progressively during the zucchini experiment. The use of mixtures of zebu horn powders increases production yield. Therefore, hypothesis 2 is confirmed.

4.2.2. Cultivation conditions constraining plant physiology

Zucchinis have high nutrient requirements for fruit enlargement (Abatzian & al., 2003). They prefer light, well-drained soils, but also soils rich in organic matter (Masclet, 2017). However, no maintenance amendment was applied to the plots treated with PCZ. In contrast, an application of CO was made one month after sowing, and the lack of maintenance limited fruit development in the To treatment. Moreover, during the ripening phase, zucchini fruits do not require much water. This finding was already noted by Abatzian & al., (2003). A high soil moisture level could lead to fruit rot.

5. CONCLUSION

The use of powdered zebu horns allows for the valorization of this by-product from processing for the benefit of agriculture, particularly vegetable cultivation. The results obtained highlight advantages in both technical and agronomic aspects.

From a technical perspective, the use of processed powdered zebu horns affects yields and vegetable crops. Additionally, mixing PCZ with waste compost leads to very high yields due to the addition of organic matter.
From an agronomic perspective, trials have shown that applying powdered zebu horns improves zucchini crop yields compared to household waste compost applications on relatively poor ferralitic soils in the vegetable belt of Haute-Matsiatra.

Although the yields obtained with chemical fertilizers are higher in the treatments, their use by vegetable farmers in the Haute-Matsiatra region is very limited due to their high purchase price.
Furthermore, it should be noted that the direct burial of powdered zebu horns has detrimental effects, particularly on crops with a short vegetative cycle. Hence, there is an interest in promoting the use of powdered zebu horns in the vegetable belt of the Haute-Matsiatra region.

The two hypotheses of this research are confirmed: the combination of powdered zebu horns and waste compost promotes the development of vegetable plants, and the use of mixtures of powdered zebu horns increases agricultural production yield.

Future work will focus on the use of powdered zebu horns in agriculture. The objective is to determine agricultural profitability based on crop types in the Haute-Matsiatra region.

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