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Fertilizing and protective potential of castor oil cake on soil and morphological parameters of eggplant (*Solanuma melongena*)

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Abstract

Vegetable crops are the backbone of agriculture. However, low soil fertility, pest spreading, high cost of chemical fertilizers and effects of pesticides have prompted the search for sustainable alternatives. This study investigated the action of castor oil cake doses on soil properties, rooty nematodes and eggplant parameters. The experiment was conducted on a Fisher block design (4x5). The treatments applied included the negative control, Triple 15 and different doses of castor oil cake (1; 1.9 and 2.8 t/ha). The incorporation of the oil cake changed the texture from clayey-sandy to loamy-sandy. The soil pH changed from 3.9 to 4.6. The saturation rate, the sum of exchangeable bases and the cation exchange capacity also increased by 30 to 41% respectively; 0.94 to 1.36% and 3.1 to 3.29%. Nitrogen content increased from 0.048 to 0.084%, phosphorus and potassium contents did not change. Organic matter rate increased from 0.84 to 2.92%. Analysis of variance showed a significant effect ($p < 0.05$). Plant mortality rates due to nematode were 25.25% for the negative control, 19.12% for the positive control (triple 15), 13% for D1 (1 t/ha of castor cake) and 0.00% for D2 (1.9 t/ha of castor cake) and D3 (2.8 t/ha of castor cake). Yields varied (from 3.58 to 6.80 t/ha) depending on the treatments.

Keywords: agromorphological, castor cake, eggplant, soil fertiprotection

Introduction

In sub-Saharan Africa, population growth has generated an increase in food demand that can only be met by an intensification of agricultural production (Pierre & Serpantie, 1994). As a result, this part of the world must increase its agricultural production by 4% each year to meet demand (Nabhan et *al*., 2003). In addition, population growth is accompanied by a decrease in arable land in favor of human habitats, leading to increased pressure on agricultural land. This results in a decrease in the fertility of agricultural soils with increasingly low crop yields (Zro et al., 2018). According to Annabi *et al.*, (2009) , Organic matter rate, total organic carbon and total nitrogen and organic matter rate are indicators of soil fertility. Total organic carbon and total nitrogen are indicators closely related to the type of land use. Uncultivated soils contain about 1.4% total organic carbon and 0.14% total nitrogen (Coulibaly et al., 2012). In poor soils, the average content of organic matter, total organic carbon, total nitrogen and potassium are 1.92%, 1.12%, 0.09% and 0.714% respectively. The application of mineral fertilizers leads to soil acidification of 0.6 to 0.7 units (Kpéra and *al*., 2017), (Biaou et al., 2018), (Diallo et al., 2011; Igue et al., 2016; Kumah-Amenudzi, et al., 2024; Larounga et al., 2020).

Eggplant is an essential vegetable crop for rural, peri-urban and urban populations. Eggplant production is limited today due to poor soils and attacks by pests (Zakari et al., 2019)(Gürbüz et al., 2018). In Guinea, poor soils and the proliferation of crop enemies constitute the main abiotic and biotic constraints for eggplant cultivation (Issoufou et al., 2017). Although chemical fertiprotection is commonly used to solve these constraints, it leaves undesirable effects such as the resistance of pests to chemical pesticides, pollution and intoxication of water and environment. These harmful effects require the

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search for a sustainable alternative (Badiane et al., 2023). According to the study by Theodore et al., (2018) The use of local resources leads to a quantitative development of eggplant plants (0.96 m to 1.42 m) high and provides fruits with a diameter of between 16.48 mm and 21.45 mm. Under these conditions, eggplant yield can vary from 1.14 to 18.4 t/ha (Brader, 1979; Cissé et al., 1998; Etienne et al., n.d.).

Castor oil cake, derived from the solid residue after the extraction of oil from castor seeds, is a natural fertilizer rich in organic matter (85%). It contains 5.5% nitrogen, 2% phosphorus and 1.5% potassium. The incorporation of castor oil can increase crop yields by 5%. Then, it reduces the number of insects and nematodes in the soil by up to 47% (El Gharras et al., 2011; Mariame et al., 2023a; Mirana, 2011). We therefore wonder about the ability of castor oil cake to fertilize the soil while playing a role as a biopesticide in eggplant cultivation? Our article on castor oil cake doses on soil properties, pest and morphological parameters of eggplant, with the aim of proposing a sustainable strategy for soil fertility management and pest control in eggplant cultivation.

Materials and Methods

Presentation of the study sites

The experiment was carried out in the experimental station of the Agriculture Department of the Agronomic Institute of Faranah, in the Republic of Guinea. The climate of the experimental area is characterized by a rainy season from May to October, followed by a cold dry season from November to January, then a hot dry season from February to March. The month of March records the highest maximum temperature, reaching 28.76 °C. The months of December and January are cold, with a minimum of 8 °C. During the year of the test, the total rainfall recorded was 1944 mm allocated over 91 rainy days, i.e. a monthly average of 162 mm. The test was conducted on ferralitic soil. Soil analyses followed the protocol established by Petard, (1993).

Presentation of plant material

Eggplant (Solanum melongena) is a vegetable plant of the Solanaceae family, cultivated for its fruit generally purple color. In order to obtain robust and uniform plants, a 2m x 1m nursery was installed. The quantity of seed sown in the nursery was 5.2g. The nursery lasted 21 days, corresponding to the development stage of 2 to 3 leaves. Transplanting was done on the 21st day. The planting spacing was 0.6 m between the lines and 0.6 m in the lines. The Barbentane variety was used as experimental material for the study.

Obtaining of castor Cake

The castor oil meal used in this study comes from the urban area of Faranah. The cake was obtained after the extraction of oil from castor seeds using the cold press machine as described by Mariame et al., (2023). It was reduced to powder by manual crushing. A total of 12 kg of castor oil cake was collected. According to Caset (2021), castor oil cake is a natural and pure organic fertilizer. It is rich in major fertilizing elements and micronutruments ; it releases nitrogen very gradually into the soil and ensures better flowering and fruiting. It also provides organic matter and stimulates soil microbial life. In soil fertilization, it is applied at a dose of 1 to 3 tons per hectare.

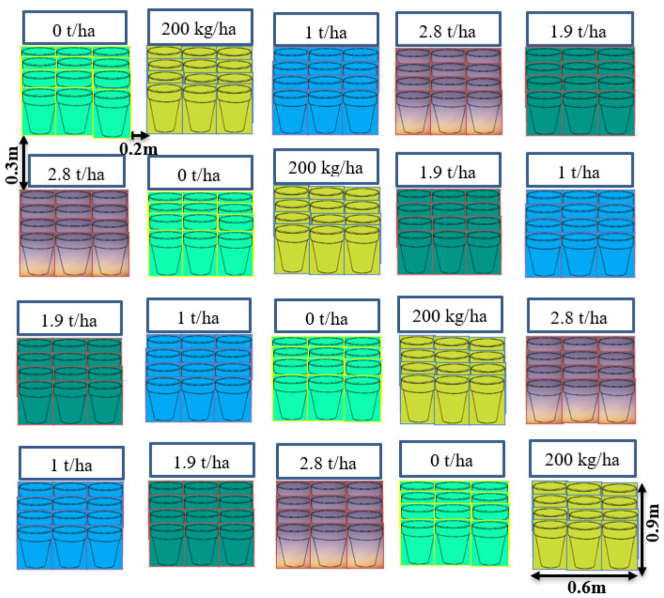
Experimental device

The diagram of the experimental device of the test

The experiment was conducted on a completely randomized 4x5 Ficher block. The treatments applied were as follows: negative control (no fertilization treatment), positive control (triple 15 fertilizer at a dose of 200 kg/ha), D1 = 1 t/ha of castor oil cake; D2 = 1.9 t/ha of castor oil cake and D3 = 2.8 t/ha of castor oil cake.

The doses during application were: (0; 7.2; 36; 68.4; 100.8 g/hole) respectively for the negative control, the positive control, D1, D2 and D3.

A total of 192 eggplant plants were transplanted on plots of 3 m in length and 1.8 m in width.



Soil sampling and analysis

Before the test, a composite soil sample was collected from undisturbed soil and analyzed to determine the physicochemical properties of the test soil before the incorporation of castor oil cake doses. After the test, a composite sample of disturbed soil was collected and analyzed to assess the effect of the incorporation of the oil cake on the physicochemical properties of the soil. For these samples, the protocol described by Blaise (2020) was followed.

The soil samples collected were air-dried under cover for 10 days, then crushed, sieved at 2 mm and stored in a cool place. Soil analysis was carried out according to the method described by Kumah-Amenudziet *al*. (2024). The parameters determined were particle size, organic carbon (C), total nitrogen (N), hydrogen potential (pH), exchangeable bases (Ca^{2+}, Na^{+}, Mg^{2+}, K^{+}) and cation exchange capacity (CEC). The pH measurement was carried out from soil suspensions with soil/water ratios of 1/2.5 and 1/10, respectively.

The particle size was determined according to the method (Robinson, 1922) based on the use of the Robinson pipette. Exchangeable bases were determined by the ammonium acetate extraction method (pH < 7), the cation exchange capacity (CEC) by the NH_4^+ saturation method. Organic carbon was determined by the method of Gürbüz et al., (2018) and nitrogen by the method of Kumah-Amenudzi, et al., (2024). The C content was determined using the C.H.N Microanalyzer by total combustion of the analytical soil sample at 1050°C under oxygen flow. Sodium (Na^+) and potassium (K^+) were determined by atomic absorption spectrophotometry. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) were determined by volumetry with EDTA as chelator.

Monitoring of Nematofauna in the Roots of Eggplant Plants

Samples were taken from eggplant plants at the fruiting stage. The objective was to assess the impact of castor oil cake on root-knot nematodes. Four eggplant plants were systematically collected in each treatment according to the device, then sent to the laboratory. To determine the presence of nematodes and confirm or refute the plant mortality rate linked to these parasites, extraction, identification and counting of nematodes were carried out. Nematodes were extracted from the roots using the grinding method described by Johnson et al., (2018). The extracted nematodes were observed and counted using the Dino-Lite 2.0 microscope (Boers, 2009). The percentage of nematode attack per plant sample was calculated by the formula of Tchegueni et al. (2022).

$$\text{Attack rate} = \frac{\text{Number of plants dead due to nematode attack}}{\text{Total number of plants observed}} \times 100$$

Measurement of agromorphological parameters of eggplant

Phenological parameters

Phenological observations focused on recovery, branching, flowering, fruiting and maturation. For phenophase times, they were noted until at least 50% of the plants in the elementary plot had completed the phenological phases (Yeo et al., 2022b). Observations were made according to the treatments on each eggplant plant.

Morphological parameters

The height of the main stem of the plants was used to determine the average growth rate of the plants. They were measured at the 28th and 43rd days using a graduated tape measure that was placed on the collar to the end of the last apical leaf (Ignassou Alain et al., 2023). The values obtained were used to calculate the associated growth rate (AGR). It consisted of taking the difference between the consecutive measurements reported to the number of days between these measurements:

$$AGR = \frac{dl}{dt} \text{ où } AGR = \frac{\Delta H}{t}$$ (Ignassou Alain et al., 2023)

Harvests were carried out every week when the first fruits reached maturity and continued until the plant senescence.

Measurement of height (HAU) and diameter (Diam) of eggplant plants

The height and diameter of the plants were collected in a yield square placed in each elementary plot and containing four eggplant plants. The height was measured using a tape measure from the collar to the end of the terminal bud; The diameter at the collar was determined at 2 cm from the top of the soil using an electronic caliper (BT114900 150 mm). All measurements were carried out manually at transplanting, at 67 days after transplanting

Measurement of fruit length and diameter

The length was measured on five (05) fruits randomly selected in each treatment after harvest. The measurement was made longitudinally using a tape measure.

The diameter of the fruits was measured transversely using a caliper.

Yield

The yield per hectare was determined by extrapolation of the production of each elementary plot considered as a yield square according to the formula of Tchegueni et al. (2022) and Yeo et al. (2022b)

$$Yield\ \left(t/ha\right) = \frac{Weight\ of\ fruits\ harvested\ \ from\ useful\ plants\ (kg)}{Surface\ area\ occupied\ by\ these\ plants\ (m2)}\ x\ \frac{10\ 000\ m^2}{1000}$$

Yield gain

Yield gain (YG) corresponds to the additional gain in yields due to a fertilizer compared to the absolute control. It was determined by the formula of Sawadogo et al., (2021):

$$YG = \frac{X2 - X1}{X1} \times 100$$

where X1 = Yield of the control plot; X2 = Yield of the plot treated with the castor oil cake dose.

Economic profitability

For the evaluation of economic profitability (ER), the following expenses were taken into consideration: plowing, purchase of seeds, purchase of seed, spreading labor, maintenance labor, labor harvesting eggplant fruits, transport of cake. The average price of kg of eggplant in the Faranah market.

The net profit was obtained by taking into account a loss margin of 25%(Ignassou Alain et al., 2023)

A value-cost ratio (VCR) was calculated to identify the best treatment that could be easily adopted by producers. The ratio was determined by comparing the gross monetary gain to the total fertilizer costs calculated using the following formula:

$$VCR = (X-Y)/Z$$

where X: Net benefit of the treatment ($/ha); Y: Net benefit of the absolute control ($/ha) and Z = Total variable costs. Thus, a technology can only be easily adopted if the VCR value is equal to or greater than 2. Adoption is reluctant if this value is between 1.5 and 2 and below 1.5 there is rejection (Sawadogo et al., 2021).

Data Analysis

Data was collected and entered using Microsoft Excel 2021 spreadsheet. SPSS 22 software on Windows was used for statistical analysis of data. Origin Pro 9.0 software was used to generate graphs.

Results and discussion

Chemical characteristics of the castor cake used

Table 1 presents the agrochemical characteristics of the castor cake applied. The results of the analysis of the cake show that it contains 53.96% of total organic carbon, 92.81% of organic matter; 3.91% of total nitrogen; 3.19% of total phosphorus; 1.26 ppm of total potassium; 0.23% of Sulfur; 7551 mg/kg of calcium; 2470 mg/kg of magnesium and 320 mg/kg of iron. The water pH was approximately alkaline (pH = 6.70). The pH KCl, was 6.10. The C/N ratio was 13.814 indicating that the cake had a good level of mineralization.

Table 1: Agrochemical analysis of the cake

Parameter	Unit	Castor oil cake results
Total carbon	%	53.96
Organic matter	%	92.81
C/N ratio	-	13.81
Total nitrogen	%	3.91
Total phosphorus (P_2O_5)	%	3.19
Total potassium	ppm	1.26
Calcium	mg/kg	7551.00
Magnesium	mg/kg	2470.00
Sulfur	%	0.23
Iron	mg/kg	320.00
pH water (P/V: 1/2.5)	–	6.70
pH KCl (P/V: 1/2.5)	-	6.10

Meteorological data recorded during the test period

The results of the meteorological data recorded during the test are shown in ***Table 2***. The average temperature was 25.44 °C, the total rainfall was 1333.21 mm, the average relative humidity was 86.28% and the average wind speed was 1.39 $m.s^{-1}$.

Table 2 : Meteorological data recorded during the test (June – September 2023)

Meteorological parameter	Unit	Value	Methods
Average temperature	°C	25.44	According to the method described by Vanlande (1955)
Relative humidity	%	86.28	
Total rainfall	mm	1333.21	
Wind speed	$m\ s^{-1}$	1.39	

Source: ISAV Agro-meteorological Station (2023)

Phenological observations

The results of the phenological observations obtained during the vegetative cycle show that the duration of recovery was uniform for all treatments 1 day after sowing. On the other hand, branching, flowering, fruiting and maturation were not uniform (**Table 3**). At the branching level, D2 and D3 were uniform with a duration of one day against 11 and 5 days respectively for negative control, positive control and D1. For flowering, the durations are 15, 14, 9 and 7 days respectively for negative control, positive control, D1, D2 and D3. The duration of fruiting was uniform for the negative control, the positive control and D1 with a duration of 8 days while D2 and D3 lasted 6 and 7 days respectively. Furthermore, maturation lasted one (1) day for the negative control and 2 days for D1, D2 and D3. Therefore, negative control achieved a vegetative cycle of 88 days compared to 86 days for D2 and 87 days for positive control, D1 and D3. The demarcation in branching, flowering, fruiting and maturation can be explained by the effect of castor oil cake applied at different doses (Table 3).

Table 3: Duration of the different phenophases in days after recovery (DAR)

Castor oil solution	Resumption			Branching			Bloom			Fructification			Maturation			Vegetative cycle
	B	E	d	B	E	d	B	E	d	B	E	d	B	E	d	
TN	24	25	1	51	61	11	60	74	15	77	84	8	88	88	1	88
Tp	24	25	1	51	51	1	56	64	9	66	71	6	85	86	2	86
D1	24	25	1	51	55	5	56	69	14	75	82	8	86	87	2	87
D2	24	25	1	51	51	1	56	64	9	66	71	6	85	86	2	86
D3	24	25	1	51	51	1	55	61	7	62	68	7	86	87	2	87

Legend: B = beginning; E = end; d = duration

Analysis of variance of studied parameters

The analysis of variance showed that the treatments had a significant effect on all the studied parameters ($P < 0.05$) (**Table 4**). Comparison of the means of the parameters indicated that the plant growth rate (PGR) was classified into four categories, with the first class occupied by D3 (2.8 t/ha of Castor cake), followed by D2 (1.9 t/ha of cake), the positive control (200 kg/ha of triple 15) and D1 (1 t/ha of Castor cake). The negative control (without fertilizer) occupied the last class. The mean plant height (MPH), the mean fruit length (MFL) and the mean fruit diameter (MFD) were each classified into three categories, with D3 (2.8 t/ha of Castor cake) and the positive control occupying the first class, followed by D2 and D1, which showed no significant difference between them. The negative control occupied the last class. The root nematode (Meloidogyne spp.) attack rate was divided into five categories. The yield was divided into two categories, the first of which was assigned to D3 (2.8 t/ha of Castor cake) and the second to treatments D2, D1, positive control and negative control.

Physicochemical characteristics of the soil

The results of particle size analysis of the test soil are presented in **Table 5**.

The texture of the test soil before castor oil cake incorporation was silty-clayey-sandy. The bulk and true densities were 1.43 g/cm^3 and 2.14 g/cm^3, respectively. The porosity was 33.18%. After castor oil cake incorporation, a dynamic change between soil fractions was observed. The texture of the test soil changed from silty-clayey-sandy to silty-sandy. The bulk density was 1.43 to 1.82 g/cm^3; the true density was 2.14 to 2.50 g/cm^3. The porosity was 33.18 to 27.20%.

The chemical characterization studies carried out show variability in the composition of soils before and after application of castor oil cake (**Table 6**).

The results show that the soil had a silty-clayey-sandy texture before application of castor oil cake with a water pH of 3.9. After use of the castor oil cake, the soil texture became silty-sandy with a water pH of 4.6. The saturation rate, the sum of exchangeable bases and the CEC increased from 30%; 1.36; 3.1 to 41%; 0.94 and 3.29 respectively for the soil after application of castor oil cake. The total nitrogen content increased from 0.048 to 0.084% while the total phosphorus and total potassium content remained constant at 0.0105 and 0.2203% respectively; the organic matter rate increased from 0.84 to 2.92% after castor oil cake application.

The application of castor cake increased the C/N ratio, organic matter rate, total soil nitrogen, exchangeable bases and saturation rate compared to the reference threshold values of (Ballot et al., 2016).

Compared to the fertility level found by Amonmide et al., (2019) the soil in the trial went from a low fertility level (severe limitations) to a medium fertility level (medium limitations).

Table 4: Analysis of variance of the parameters studied

	APGR	*AFD*	*AFL*	*AFH*	*Yield*	*RNAR*
R^2	0.718	0.501	0.482	0.357	0.526	0.853
F	9.577	3.766	3.493	2.086	4.162	21.876
Pr > F	0.000	0.026	0.033	0.133	0.018	<0.0001

Calculated against the model Y=Mean; Significance codes: 0 < *** < 0.001 < ** < 0.01 < * < 0.05 < . < 0.1 < ° < 1
Legend: APGR = Average Plant Growth Rate; AFY: Average Fruit Diameter; AFL: Average Fruit Length; AFH: Average Fruit Height; RNAR: Root Nematode Attack Rate.

Table 5: Agro-physical soil analyses following the Yiel of (Yeo and *al*., 2022)

Characteristics	Unit	Test floor		Reference threshold values (Barry et al., 2019)
		Before use of castor oil cake	after using castor oil cake	
Clay	%	24.00	15.6	15,6
Fine silt	%	5.00	6.0	6,0
Coarse silt	%	8.25	6.0	6,0
Fine sand	%	13.15	28.8	28,8
Coarse sand	%	49.60	43.0	43,0
Da	g cm^{-3}	1.43	1.41	1,41
Dr	g cm^{-3}	2.14	2.5	2,5
Porosity	%	33.18	43.60	43,60

Table 6: Agrochemical analyses of soil following the protocol (Kumah-Amenudzi, D. et al., 2024)

Characteristics	Unit	Test floor		Reference threshold value (Ballot and *al.*, 2016)
		Before use of oil cake	After use of the cake	
Total carbon	%	0.49	0.66	1.6-2.5
C/N ratio	-	10.18	11.63	11-15
Organic matter	%	0.84	1.68	3.6-6.5
Total nitrogen	%	0.05	0.08	1.2-2.2
Total phosphorus	ppm	105.65	105.65	3-8
Total potassium	ppm	2203.33	2203.33	0.15- 0.25
Calcium (Ca2+)	meq/100g	0.66	1.10	5-8
Magnesium (Mg2+)	meq/100g	0.12	0.14	1.5- 3.0
Potassium(K+)	meq/100g	0.09	0.11	0.1 – 0.2
Sodium (Na+)	meq/100g	0.05	0.03	0.3- 0.7
Sum of bases (S)	meq/100g	0.94	1.36	2 ≤ S < 10
Cation exchange capacity (T)	meq/100g	3.10	3.29	10 ≤ CEC ≤2 0
Saturation ratio (S/T)	%	30.00	41.00	60 ≤ S/T < 90
pH water (P/V: 1/2.5)	-	3.90	4.60	5.5-6.5
pH KCl (P/V: 1/2.5)	-	3.90	3.60	6.5-8.2

Effects of castor oil cake on the growth rate and height of plants at harvest

The analysis of **Figure 1** shows that the growth rate and height of plants are a function of the doses of the castor oil cake. The analysis of variance at the 5% threshold showed a significant difference between the growth rate and the height of plants. The Duncan test performed at the 5% threshold ($P < 0.05$) allowed to group the treatments into three distinct classes (a; b and c). According to this discrimination, the plants of the negative control gave the lowest growth (0.26 cm/day) against 0.35; 0.49; 0.52 and 0.70 cm/day for respectively D1; positive control; D2; D3. The height of the plants at harvest was between 0.45 m and 0.70 m. For these parameters, we note D2 (1.9 t/ha of cake) and D3 (2.8 t/ha of castor oil cake) exceed the positive control (200 kg/ha of triple 15).

Effect of castor oil cake on fruit length, diameter and average fruit weight.

Figure 2 shows the effect of castor oil cake on fruit length and diameter. From this graph, we find that the length and average diameter of the fruits each gave 3 classes of which D3 and positive control occupy the best class without significant difference between them. Then, we note that the increase in the length and diameter of the fruits is proportional to the dose of castor oil cake.

For the average diameter of the fruits, the control gave 3 cm against 4; 4; 4 and 5 cm respectively for positive control; D1; D2 and D3. All the same for the average weight of the fruits, the control gave 100 g against 116 g for D1, 123 g for D2 and positive control and 153 g for D3.

Effect of castor oil cake on the root nematofauna and the yield of what?

At the fruiting stage, an extraction of the roots of the eggplant plants was made. After the extraction, only one genus of nematode was identified: the genus Meloïdogyne. The mortality rates of eggplant plants due to this nematode were significant, reaching 25.25% for the negative control, 19.12% for the positive control, 13% for D1, and 0.00% for D2 and D3 (**figure 3**). These attacks caused the outgrowth of some plants of the control and D1.

However the treatment D3 gave a yield of 6.805 t/ha compared to 4.98 t/ha for the positive control; 4.795 t/ha for D2, 4.743 t/ha for D1 and 3.582 t/ha for the control.

Economic profitability of using castor oil cake in eggplant cultivation

Table 7 presents the results of the economic profitability of the study on the effect of castor oil cake doses on eggplant cultivation. The results of the VCR show that the 2.8-ton dose of castor oil cake had a beneficial effect with an VCR of 2.12. These production gains made it possible to cover the production costs of eggplant cultivation. However, in view of the results of the effects of each treatment as illustrated in Table 4, it should be noted that the use of 2.8 tons of castor oil cake alone is advantageous. Thus, the doses of 1.9 t/ha and 2.8 t/ha of castor oil cake can be offered to market gardeners operating in the same or similar ecological conditions with a greater chance of adoption. However, the 2.8 t/ha dose is advantageous because of its higher VCR (2.12).

The results of the analysis of the castor cake used as an amendment showed that it is an excellent organic amendment, with a matter content of 92.81% and a C/N ratio of 13.91. The nitrogen (N), phosphorus (P) and potassium (K) contents of the tested oil cake are slightly lower than those obtained by Mirana (2011), who states that the castor oil cake contains 5.5% nitrogen and 1.5% potassium. On the other hand, the organic matter content of the cake is higher than that reported by Mirana (2011), who found that the castor oil cake contains 85%

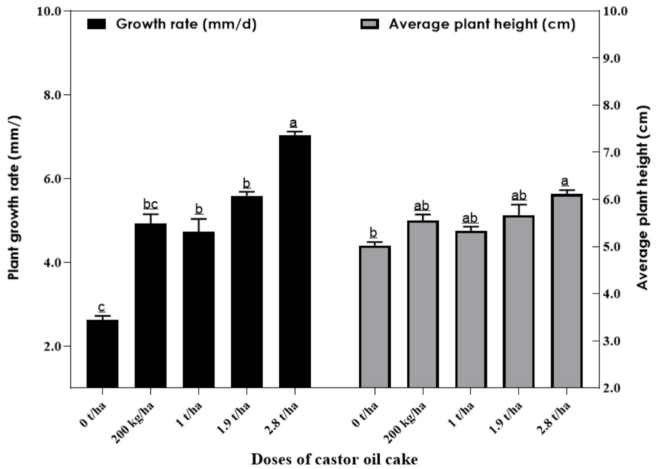


Figure 1: Effect of castor oil cake on growth rate and average height of plants

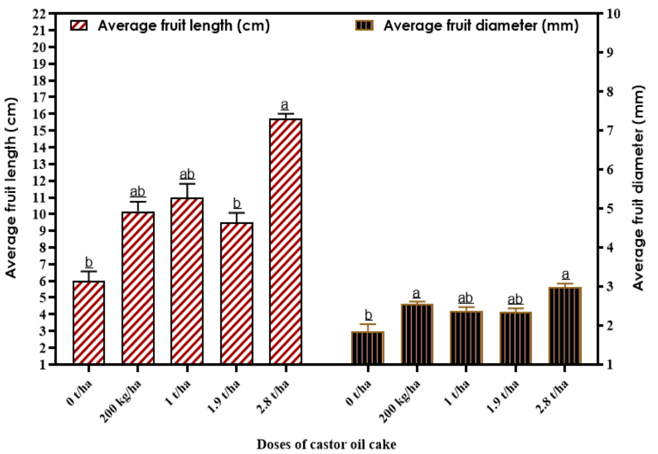


Figure 2: Effect of castor oil cake on fruit length, diameter and average weight

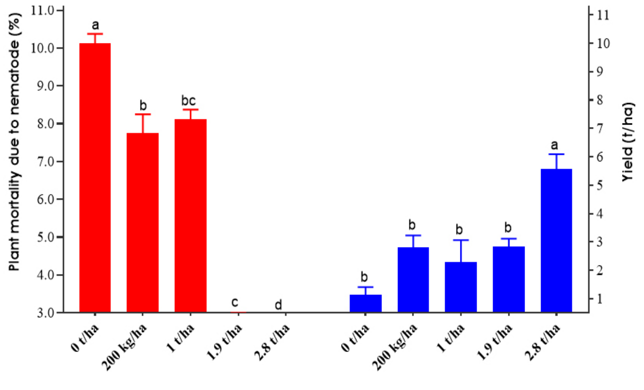


Figure 3: Effect of castor oil cake on yield and root nematode attack

organic matter. Our results revealed the presence of calcium, magnesium, sulfur and iron in considerable proportions. The soil characteristics of the trial improved by 18% after the incorporation of the cake, compared to the negative control. The soil texture changed from a clayey-silty-sandy texture to a silty-sandy texture (a soft, porous soil when dry and easy to work), with a decrease in the percentage of clay of 41.66% in favor of fine silt (50%). Similarly, the porosity was reduced to 27.20%. These changes were more ameliorative than those obtained by Barry et al., 2019) when they used different digestates of bovine origin. The pH of the soil, which was extremely acidic before the incorporation of the cake (pH = 3.9), became slightly acidic (pH = 4.6), after the incorporation of the castor oil cake. This observation corroborates the findings made by Diallo et al., 2011; Igue et al., 2016; Kumah-Amenudzi, D. et al., 2024; Larounga et al., 2020) according to which the incorporation of organic fertilizer made it possible to obtain a pH close to neutrality, which is an asset for better root absorption of nutrients. On the other hand, the sum of exchangeable bases decreased by 30.88%. These values are close to those reported by (Ballot et al., 2016), who found a sum of exchangeable bases between 2 and 10 after the incorporation of four types of organic fertilizers. Compared to the fertility level given by (Amonmide et al., 2019), the soil in the trial went from a low fertility level (severe limitations) to an average fertility level (average limitations).

In this study, the average height of the plants varied between 0.45 m and 0.56 m. For the average diameter, it varied from 3 to 5 mm. Similarly, the average length of the fruits was between 6 and 15 cm. These results are lower than the values given by (Allan et al., 2008) which stipulate that the use of banana peel by-products made it possible to obtain eggplant plants of size between 0.96 and 1.42 m with fruits of diameter ranging from 16.48 to 21.45 mm.

Studies on crop nematofauna (El Gharras et al., 2011; Mirana, 2011) have demonstrated that the use of the castor oil cake reduces plant mortality caused by nematodes by up to 43%. In contrast, our research shows that the incorporation of castor oil cake at doses of 1.9 and 2.8 t/ha reduced eggplant plant mortality due to nematodes to 0%.

In terms of yield, the negative control produced 3.58 t/ha compared to 4.98 t/ha for the positive control, while doses D1, D2 and D3 gave 4.743, 4.795 and 6.805 t/ha, respectively. These figures are close to those reported by Brader (1979b), Cissé et al. (1998) and Etienne et al. (2020), who showed that by controlling the pressures on eggplant plants, the yield can vary from 1.14 to 18.4 t/ha.

From an economic point of view, no losses were economic at the level of the experimental variants recorded. However, the best profitability was obtained with the treatment of 2.8 tonnes of castor cake per hectare, which gave an VCR of 2.12 and a profit margin of $4565. Although all treatments were profitable.

Table 7: Economic analysis of the trial reported on 1 ha of eggplant according to the doses of castor oil cake

Treatments	Total variable costs ($/ha)	Yield (kg/ha)	Gross Revenue ($/ha)	Gross Profit ($/ha)	Net profit ($/ha)	VCR
Negative control	745	3,582	3,976	3,231	2,237	0.00
Positive control	926	4,981	5,529	4,603	3,221	1.06
1.0 t/ha (D1)	872	4,743	5,265	4,393	3,076	0.96
1.9 t/ha (D2)	986	4,795	5,322	4,336	3,005	0.78
2.8 t/ha (D3)	1,100	6,805	7,554	6,453	4,565	2.12

Profitability is greatly improved with the use of castor oil cake, due to its concentration of fertilizing elements and the heterogeneity of the soil. These results are similar to those of Savadogo et al. (2019), who showed that the lower the cost of production factors, the more profitable the treatments are.

The doses of 1.9 and 2.8 t/ha of castor oil cake completely eliminated nematodes in the soil of the trial, reaching a presence rate of 0%. This result largely exceeds that reported by El Gharras et al. (2011), who observed a nematode presence rate of 47% after the incorporation of castor oil cake.

Conclusion

The results of the analysis of castor oil cake have several important implications for agriculture, it has a high organic matter content of 92.81% and a good level of composition with a C/N ratio of 13.91. Castor oil cake can be used as an alternative to chemical base fertilizers and synthetic chemical amendments.

Incorporating castor oil cake into the soil significantly improves the physicochemical properties by up to 18%. This cake is an effective alternative to chemical fertilizers and amendments.

The doses of 1.9 and 2.8 t/ha of castor oil cake eliminate soil nematodes, reducing eggplant plant mortality to 0%.

The addition of castor oil cake increases the yield of eggplant: 32.40% for 1 ton, 32.96% for 1.9 tons, and 89.94% for 2.8 tons per hectare.

This study shows that castor oil cake, used as an organic amendment, offers significant benefits for soil fertility and crop growth. A dose of 2.8 t/ha allows a yield of 6.80 tons of eggplant and a rooty nematode index of 0%, which is particularly beneficial for farmers aiming for sustainable productivity.

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Competing interests

The authors have declared no conflicts of interest.

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