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EFFECT OF COMPOST DOSES WITH BIOINSECTICIDE APPLICATION ON OKRA (*Abelmoschus esculentus*) TO PESTS IN THE SUDANO-SAHELIAN ZONES OF MALI

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ABSTRACT
The widespread decline in soil fertility in Mali, combined with the effects of climate change, represents a major challenge for the development of national agriculture. It is in this context that this study was conducted, the objective of which is to contribute to food and nutritional security in Mali, through the promotion of agroecological production of okra (Abelmoschus esculentus). Two contrasting agroecological zones were selected for the study: Bougouni (South) and Bankass (Center-East). The effect of two types of compost (pit compost and heap compost), applied at two doses (7.5 t/ha and 15 t/ha), plus two controls (mineral fertilization and a control without input) was evaluated with the application of a bio-insecticide, on the resistance of okra to pests. The experimental design used is a randomized Fisher block with three replications, implemented over three consecutive years in the two localities. The results showed that compost, whatever its form, had a significant effect on the resistance of okra to pests in both study areas. Our results revealed that organic fertilization through compost has a significant effect on the level of resistance of okra in both study areas. The doses of 15 tonnes and 7.5 tonnes of compost in pits and piles induced the best levels of resistance and also the best fruit yields ranging from 7601 kg/ha to 6944 kg/ha compared to an average of 6617.5 kg/ha for simple mineral fertilization and 4385.5 kg/ha for the control without input. The use of compost has many advantages for producers: it is locally available, inexpensive, improves soil fertility and contributes to increasing okra yield while strengthening its resistance to pests.

Keywords: Okra, Compost, Bio-insecticide, Bioaggressors, Bougouni, Bankass.

1. INTRODUCTION
The vegetable sector plays a leading role in providing fresh and nutritious food to consumers around the world, in expanding urban areas as well as rural areas (FAO, 2021). Vegetable products constitute an important component of the Malian agricultural economy, with high economic value and strong growth potential.
Like other vegetables, okra is grown for its fruits, which are rich in protein, vitamins, and minerals. It is widely used in African cuisine, and its fruits are appreciated for their viscosity.

However, okra is subject to numerous hazards that seriously limit its cultivation, the most well-known of which are insects and diseases (Asare-Bediako *et al*., 2014; El Hociene, 2021; Zidi, 2022). These enemies of okra include viruses (virosis), fungi, bacteria, nematodes and insect pests (Fondio & Djidji, 2007). The use of insecticides creates many problems such as the elimination of natural enemies and environmental risks (air pollution, groundwater and soil). These practices are harmful to human health and cause the development of resistance to chemical insecticides by harmful insects (Kadri *et al*., 2013; Hénault-Ethier, 2015).

Agroecological crop protection seeks to maintain pest populations at acceptable levels, without causing significant damage to crops, human health, or the environment. Hence the use of compost combined with a biopesticide based on plant extracts such as neem, chili, and garlic.

Compost has been shown to induce systemic resistance and suppress various pathogens by acting on microbial communities and plant defenses (Rowen and Tooker, 2020; Yatoo et al., 2021; Bouchtaoui et al., 2024; Ma et al., 2024). Indeed, organic fertilizers meet the nutritional needs of plants and also reduce plant pest populations (Yanar et al., 2011). A plant well supplied with minerals is capable of producing defense compounds such as phenolic compounds or alkaloids. These compounds make the plant less palatable to pests and can even repel them. Studies have shown that rationalized fertilization promotes the reduction of certain insect pests and crop diseases (Bationo *et al.*, 2002; Owolade *et al.*, 2006; Asiwe , 2009). A well-nourished plant can regenerate more quickly after a pest attack, thus minimizing damage (Datnoff et al., 2007).

On the other hand, several authors (Gueye *et al*., 2011; Tano *et al*., 2019; Mondedji *et al*., 2014; Ossey *et al*., 2018) have highlighted the effectiveness of plant extract-based biopesticides on crop pest management. Generally, according to Youdeowei (2004) neem leaves and neem seeds contain a substance (azadirachtin) which is effective on soft-bodied insects such as young caterpillars, aphids and whiteflies. The work of Koffi et al., (2014) has shown fungicidal effects of chili pepper extracts against several fungal phytopathogenic organisms (*Alternaria sp., Penicillium sp., Fusarium sp., Apergillus flavus*).

In the Sudano-Sahelian zones of Mali, okra cultivation is highly threatened by pests (jassids, whiteflies, aphids, etc.), whose pressure is exacerbated by agro-climatic conditions and low soil fertility. Producers in Bougouni in the south and Bankass in the north of Mali are increasingly resorting to agroecological practices, but the combined effectiveness of compost and bio-insecticides remains poorly documented. The lack of optimal compost dosage limits the resilience of plants to attacks, compromising yields and the sustainability of production systems. Furthermore, the interactions between organic fertilization and biological control require rigorous evaluation to guide technical recommendations. This context justifies a targeted study on the effect of compost doses associated with bio-insecticide, in order to improve okra resistance to pests in these two strategic agricultural zones.

2. MATERIALS AND METHODS

2.1 Material

2.1.1 Study sites

The experiments were carried out in the towns of Bougouni and Bankass (Figure 1). These two sites were chosen because of their contrast in terms of agronomic, pedological and climatic characteristics. These agropedoclimatic differences between Bougouni and Bankass provide a diverse framework for the study, allowing the impact of organic composting methods on okra cultivation in varied environments to be examined.

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In Bankass , the test was installed in the experimental plots of the Bankass Vocational Training Institute with geographical coordinates 14°04'57.7" North and 3°30'17.2" West.

In Bougouni, a portion of a pilot producer's plot on the outskirts of the town of Bougouni was used. The geographical coordinates of the site are 11°25'38.5" North and 7°30'20.3" West.

- **Bougouni**

The town of Bougouni is located in the south of Mali with geographical coordinates of 11.425° North and -7.449° West. The climate is pre-Guinean, with an average annual rainfall of 1199 mm (±165 mm) over the period 2000-2020. This region experiences a prolonged dry season of 6 to 7 months, extending from November to May, followed by a rainy season of 5 to 6 months, from May to October. Maximum and minimum temperatures reach 34°C and 21°C respectively, with an annual average of 27°C (Coulibaly, 2024). The soils of Bougouni are of the hydromorphic tropical ferruginous type, adapted to the climatic conditions of this area.

- **Bankass**

Bankass is located in the center-east of the country with geographical coordinates 14.055° North and -3.494° West. It has a Sahelian climate, with annual rainfall ranging from 500 mm to 700 mm for an average of 652 mm over the period from 2000 to 2020 (Mali-météo, 2024). This region is marked by a long dry season, which lasts 8 to 9 months, from October to June, and a short rainy season of 3 to 4 months, from June to September. Annual rainfall in Bankass is relatively low at the beginning of the year, reaching its peak in August. The soils of this region are sandy-loam, reflecting Sahelian climatic conditions. Most of the circle is occupied by a sandy plain called the Séno, occupying more than half of its territory.

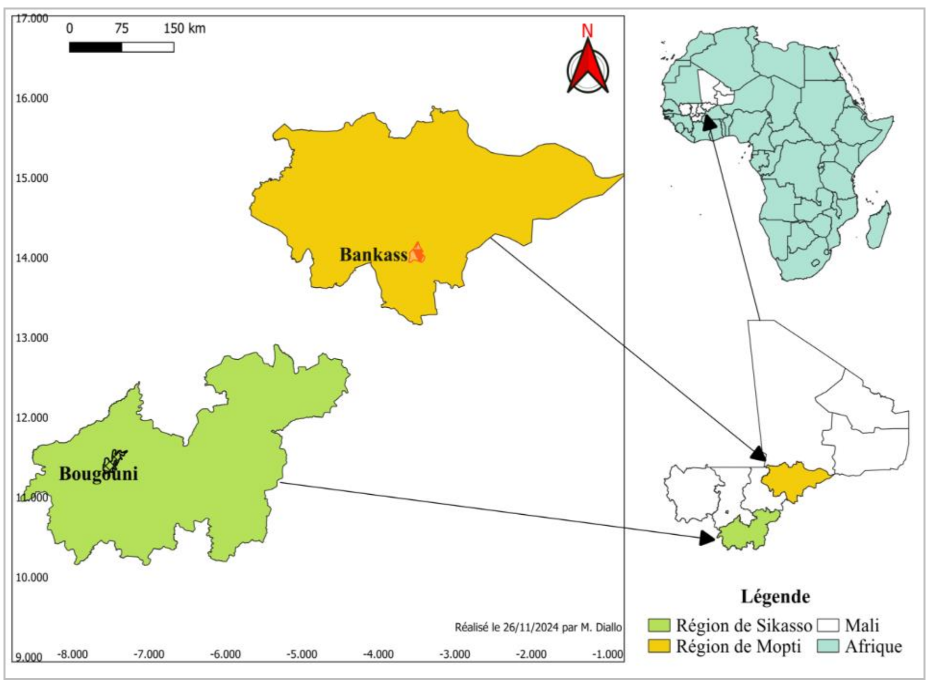

Figure 1: Map of the study’s experimental sites (Oyahitt, 2023)

2.1.2 Technical equipment and inputs

- **Plant material**

Okra (*Abelmoschus esculentus), the Clemson* Spineless variety

- **Technical equipment**
  - A scale for weighing;
  - A mortar and pestle, for grinding neem leaves, garlic bulbs and chili fruits;
  - Buckets, for transporting water and preparing the bio-insecticide;
  - A T15 sprayer with a capacity of 16 liters.
- **Inputs**
  - Compost in pits and piles
  - Neem leaves;
  - Garlic bulbs;
  - Dried chili pepper fruits.
  -

2.2. Method

2.2.1 Factor studied and treatments put into competition

The object of study was compost-based fertilization taken at seven levels of variation. The variations were, 5 levels of compost including two types taken at 2 doses, 1 at a single dose and 2 controls, namely the mineral fertilization popularized for okra and 1 absolute control without contribution (Table 1).

Table 1: Different treatments put into competition

Culture	**Postman**	**Type of fertilizers**	**Doses (kg** /ha)	**Line No.**
Okra	Fertilization	Compost prepared in a pit	15000	T1
		Compost prepared in a pile on the surface	15000	T2
		Compost prepared in a pit	7500	T3
		Compost prepared in a pile on the surface	7500	T4
		Compost mix prepared in a pit and piled	15000	T5
		Mineral fertilizers (NPK and Urea)	500	T6
		Without contribution	0	T7

2.2.2 Experimental device

The Fisher randomized block experimental design with three repetitions was used (Figure 2). The design consisted of 3 blocks or repetitions with a dimension of 13.7 m in length and 4 m in width, an area of 54.8 m². The blocks were separated from each other by a 1 m aisle. Each block consisted of 7 elementary plots (4 m x 1.5 m). The overall plot dedicated to the test had a total dimension of 205.5 m², including 15 m in length and 13.7 m in width.

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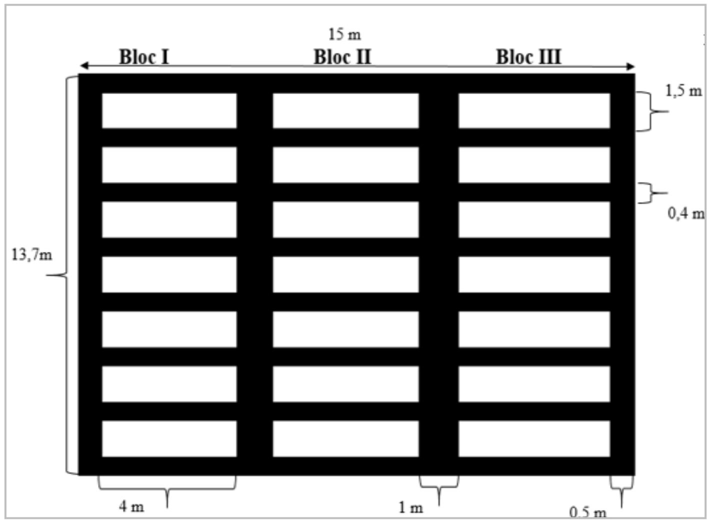

Figure 2: Ground plan of the experiment (Oyahitt, 2021)

2.2.3 Preparation of the bio-insecticide

- **Extraction of concentrated juice from neem leaves**

Fresh neem leaves were harvested. A total of 900 g of leaves were carefully pounded to facilitate the extraction of the active ingredient (azadirachtin). The pounded leaves were placed in a bucket containing 4.5 liters of water, where they were left for three days to allow the active ingredient to be fully released into the water. They were then macerated to recover the liquid, which was then filtered to remove impurities (Figure 3).

Figure 3: Extraction of Neem leaf juice (Oyahitt , 2023)

- **Extraction of concentrated garlic juice**

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A quantity of 1300 g of garlic was purchased for the bio-insecticide. The garlic was first peeled, then soaked in 4.5 liters of water for three days, and then the concentrated juice was collected, following the same process as the previous one.

- **Extraction of concentrated chili juice**

A quantity of 900g of dried chilies was purchased. It was ground before being added to 4.5 liters of water. As with the other two ingredients, after 3 days, the concentrated chili juice was collected.

- **Preparation of the final solution**

The concentrated juices of neem, garlic, and chili, free of all impurities, were mixed in a basin. This homogeneous mixture of approximately 13.5 liters of these three species constituted the bio-insecticide.

This preparation was carried out over the 3 years of the experiment in the two study sites.

2.2.4 Treatment of okra plants with bio-insecticide.

As okra is highly prized by insects, treatments began on the 20th ^{day} after sowing. In total, 3 treatments were carried out, namely on the 20th, 40th and 60th days after sowing. The bio-insecticide solution used was a dose of 3 liters diluted in 7 liters of water for a total volume of 10 liters used evenly over the entire trial plot.

2.2.3 **Data collection and analysis**

- **Data collection**

To determine the sensitivity level of okra plants in each treatment to pest attacks, careful observation was carried out throughout the vegetative and productive phases. This assessment involved regular monitoring of the treated plots to note the incidence and intensity of attacks. Attacks were quantified using a rating scale ranging from 0 to 3, defined as follows:

- 0 = No symptoms: No signs of insect attack or disease were noted on the plants, indicating a complete absence of symptoms on the treatment.
- 1 = Very low damage: Insect or disease attacks were low, causing low damage, affecting less than 20% of the plants in the plot. This category represents a situation where symptoms are present but their impact is minimal.
- 2 = Medium damage: Damage caused by insect or disease attack is moderate, with 20% to 40% of the plants in the plot affected. In this case, symptoms are more widespread and visible, but have not yet reached a critical threshold.
- 3 = Severe damage: The attacks caused significant damage, affecting between 40% and 60% of the plants in the plot. This situation indicates a high incidence of insects or disease, with widespread symptoms and a considerable impact on plant health.

Observations were made regularly following the phenological stages of the plant until maturity. Data on the fruit weight per plot were also taken to determine the yield.

- ✓ **Data analysis**

The collected data were entered into an Excel spreadsheet and then analyzed using R software (Version 4.4.1). A frequency analysis was first performed on the qualitative data, then the chi-square test was performed to determine the level of significance of the differences between the modalities studied. Descriptive analysis, followed by analysis of variance (ANOVA) was performed on the performance data.

3. RESULTS

3.1 Overall level of damage caused by insect attack

Statistical analysis using the Chi-square test (P = 0.318) showed no significant difference between the different levels of damage observed in the experiment. However, it emerged that the level of damage was generally average in both sites over the 3 years with 43% of the plots. Then, 33% of the plots suffered significant damage from pests and only 24% of the plots suffered low damage (Figure 4).

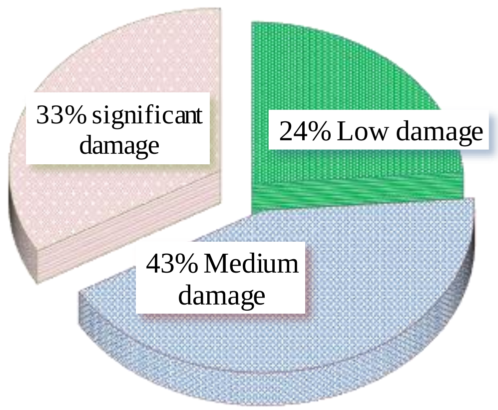

Figure 4: General level of insect damage observed in all experimental plots

3.2 Level of damage caused by insect attack by year

Analysis of the level of damage from insect attacks in the experimental plots showed that the level of damage varied depending on the year. No significant difference (P = 0.124) was observed between the levels of damage depending on the year at the 5% significance level. However, the year 2022 was the one that recorded the highest level of damage from pests with 54% of significant damage in the experimental plots compared to 28% in 2021 and 18% in 2023. The highest average level of damage was observed in 2021 with 58%. The year 2023 recorded the lowest level of pest damage with 39% compared to 17% and 14% respectively in 2022 and 2021 (
Table).

Table 2: Statistical results of the level of damage according to the years

Years	**Low damage (%)**	**Average damage (%)**	**Significant damage (%)**
2021	14	58	28
2022	17	29	54
2023	39	43	18
Average	**23**	**43**	**33**
Chi-square test (P)		**0.1248**	

Legend: P: probability

3.3 Level of damage caused by insect attack depending on the site

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The results of the statistical analysis showed a significant difference between the modalities representing the levels of damage caused by pests and diseases according to the study sites (Table). Overall, the damage was greater in Bougouni compared to Bankass with 43% of significant damage compared to 23% in Bankass . In Bankass the level of damage was generally average with 49%, compared to 38% in Bougouni. The level of low damage was 28% in Bankass compared to 19% in Bougouni.

Table 3: Statistical results of the level of damage according to the sites

Sites	Low damage (%)	Average damage (%)	Significant damage (%)
Bankass	28	49	23
Bougouni	19	38	43
Chi-square test (P)		**0.0412**	

3.4 Level of damage caused by insect attack depending on treatments

The statistical analysis results showed a significant difference (P = 0.0497) between the treatments regarding the level of damage. T7 recorded the highest percentage of the significant damage modality with 28%, followed by T3 (20%) and T6 (17%). The highest average damage level was also observed in T7 with 29%, followed by T5 with 21% and T4 and T6 with 14% each. However, the treatments that recorded the lowest damage were the treatments with 15 tons/ha of compost, namely T1 (28%), followed by T4 (17%) and T3 (14%) (Table).

Table 4: Statistical results of the level of damage according to the treatments

Treatments	Low damage (%)	Average damage (%)	Significant damage (%)
T1 (15 t compost in pit)	28	6	6
T2 (15 t compost in pile)	13	8	14
T3 (7.5 t compost in pit)	14	7	20
T4 (7.5 t compost in pile)	17	14	10
T5 (15 t compost in pit + pile)	11	21	5
T6 (Mineral Fertilizer)	6	14	17
T7 (without contribution)	11	29	28
Chi-square test (P)		**0.0497**	

3.5 Average performance over the 3 years of the study

Looking at the results on the average yield of the 3 years of the experiment, it is clear that the doses of 15 tonnes/ha of the two types of compost induced the best yields in both sites. In Bougouni, T1 was the most efficient in terms of yield with 7601 kg/ha followed by T5 and T2 with respectively 7165 kg/ha and 7146 kg/ha. Similarly, in Bankass the treatments that obtained the best yields were T5 (7553 kg/ha), T2 (7083 kg/ha) and T1 (6944 kg/ha).

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Table 5: Average okra yields over the 3 years of the study at the two sites

Statistical parameters	Yield (kg/ha)	
	Bougouni	**Bankass**
T1	7,601	6,944
T2	7,146	7,083
T3	6,371	6,024
T4	5,819	6,672
T5	7,165	7,553
T6	6,970	6,265
T7	4,548	4,223
Average	6,517	6,395
Standard deviation	2,092	2,344
Coefficient of variation	0.37	0.32
Minimal	3,701.67	3,442
Maximum	13,964.33	12,053
ANOVA (P)	**0.041**	**0.027**

4. DISCUSSION

The level of damage caused by okra pests was generally average for all plots evaluated with 43%. This reveals that the effectiveness of compost doses associated with biopesticide based on neem, chili and garlic extract was average. Biopesticides based on plant extracts are safer alternatives to synthetic pesticides for human health and the environment, however their effectiveness in controlling pests is not total. This result corroborates that of Gnago et al., (2010) who noted that neem leaf extracts at the normal dose have a slight effectiveness on aphids, flea beetles and jassids of okra. For Aggarwal and Brar (2006), plant extracts are a good means of integrated control, they must be associated with other control methods to increase their effectiveness.

No significant difference was observed between the level of damage caused by pest attacks over the 3 years of the study. However, 2022 was the year that recorded the highest level of damage from pests with 54% of significant damage in the experimental plots compared to 28% in 2021 and 18% in 2023. This could be explained by the high amount of exceptional rainfall recorded during this year leading to a heavy infestation of crops of the Malvaceae family (okra, cotton, etc.) by jassids. According to the report of the Regional Program for Integrated Cotton Production in Africa (PRPICA), (2022), during the 2022-2023 campaign, a massive infestation of jassids occurred earlier in the cycle, with the emergence of a new, more invasive species, Amarasca Bigutula with a negative impact on cotton production with production losses of around 30 to 50% depending on the country (50% in Mali).

The damage was more significant in Bougouni compared to Bankass with 43% significant damage against 23% for Bankass . This result indicates that the level of okra pests varies depending on the agro-climatic zones. The south (Bougouni) being more humid than the Center-East (Bankass) presents a higher level.

From our results, a significant difference emerged between the treatments regarding the level of damage. T7 (absolute control) was the most sensitive with the highest percentage of significant damage. The treatments that induced the best levels of resistance with low damage were T1 with 15 tons of compost in the pit and the treatments with 7.5 tons of compost in the pit and in the pile. This indicates that the supply of organic fertilizer influences the level of sensitivity of okra to pests. Our results are consistent with those of Nitiéma et al., (2019), who noted that the use of organic and mineral fertilizers induces a decrease in the pressure of *M. vitrata pests.* and *C. tomentosicollis on cowpea.* In the same sense, Luong and Heong (2005) pointed out those organic fertilizers positively influenced the growth of rice plants and minimized the pressure of harmful insects and some diseases. These authors, in addition to Datnoff et al., (2007) wrote that the supply of nutrients such as phosphorus, potassium, nitrogen and essential trace elements (zinc, copper, manganese and iron) through fertilizers would induce a resistance capacity in the plant against certain insect vectors. In addition, these nutrients are involved in many metabolic reactions vital for the health of the plant. Regarding fruit yield, the most effective treatments were the 15t/ha doses of compost prepared in pit or pile or both combined, the least effective in terms of yield was the absolute control without input. Results Kouayet et al., (2021), noting that the application of compost in okra promotes the production of fruits with a higher weight with more seeds and a higher rate of normal seeds than those of the fertilizer and non-fertilizer treatments. The effectiveness of the compost was proportional to the dose, reflecting that the high doses induced the best yields higher than that of the mineral fertilization and the control without fertilizer application.

5. CONCLUSION

At the end of this qualitative evaluation study of the effect of compost doses in pits and piles and controls (mineral fertilizer and without input) associated with a biopesticide based on plant extracts on the level of resistance of okra to pests, interesting results were obtained. The effectiveness of biopesticides based on plant extracts including neem, chili and garlic was average on the control of okra pests. The level of pest damage was not significantly influenced in the years, however, years with heavy rainfall are more favorable to the attack of okra pests. The level of damage varied significantly between the two sites. The most significant damage was observed in the South (Bougouni), which is more humid than the Center-East (Bankass). The jassids were the most important in terms of damage caused to okra. Our results revealed that organic fertilization through compost has a significant effect on the resistance level of okra in both study areas. The doses of 15 tons and 7.5 tons of compost in pit and pile induced the best resistance levels and also the best fruit yields ranging from 7601 kg/ha to 6944 kg/ha against an average of 6617.5 kg/ha for the treatment consisting of mineral fertilization and 4385.5 kg/ha for the control without input.

Using compost in pits or piles offers several advantages for producers. They are less expensive and available locally for small producers, they improve soil fertility, increase crop yields, and they also contribute to strengthening the phytosanitary resistance of crops to pests and diseases for healthy and environmentally friendly production.

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