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EFFECTS OF AGRICULTURAL INPUTS ON GERMINATION CAPACITY AND ROOT GALL FORMATION IN OKRA (*Abelmoschus esculentus*)

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ABSTRACT--
*Agriculture in West Africa, particularly in Senegal, plays a crucial role in economic and social development, but it faces numerous challenges, including increasing pressure from pests such as root-knot nematodes. Okra (*Abelmoschus esculentus*), a highly valued local vegetable, is particularly affected by these nematodes, which cause root gall formation and significantly reduce crop productivity. This study evaluates the effects of different agricultural inputs fermented solution of* Calotropis procera*, cactus digestate, and chemical fertilizer (NPK) on the germination potential of okra seeds and the formation of root galls caused by* Meloidogyne *spp. The results show that the fermented solution of* Calotropis procera *(T1) significantly improves seed germination and completely prevents root gall formation. The cactus digestate (T2) moderately reduces gall formation and promotes germination. In contrast, the chemical fertilizer (T3) and the untreated control (T0) show severe infestation, although plant growth is not directly compromised in the T3 treatment. These findings highlight the potential of organic and bioactive inputs to enhance crop resistance to nematodes while stimulating germination, unlike chemical fertilizers whose long-term effectiveness remains limited.*---

INTRODUCTION

African agriculture, particularly in West Africa, is a vital sector for the continent's economic and social development (FAO, 2015). It provides livelihoods for over 60% of the population and contributes significantly to the gross domestic product (GDP) of many countries (OECD/FAO, 2016). In Senegal, the agricultural sector is considered a cornerstone of the national economy (ANSD, 2014). It drives the primary sector, accounting for 9.4% of the national GDP and 62.8% of the nominal added value in the primary sector (ANSD, 2020). Despite its importance, agriculture faces numerous challenges, including low soil fertility, climate variability, limited access to quality inputs, and increasing pressure from diseases and pests (Ndour-Badiane, 2021).

Among vegetable crops, okra (*Abelmoschus esculentus*) holds a prominent place, as it is considered an essential ingredient in local cuisine (FAO, 2012). It is a valuable crop used for its edible leaves and immature fruits, commonly prepared in soups and sauces (Khomsug et *al*., 2010). Okra is highly sought after in local markets and represents a key source of income for small-scale producers, particularly women. However, its production is affected by several biotic and abiotic factors that compromise yield and quality (Amadu et *al*., 2023).

Among biotic threats, plant-parasitic nematodes especially those of the *Meloidogyne* genus are particularly feared for their ability to cause root-knot formation. These galls disrupt water and nutrient absorption, weaken plants, and reduce productivity (Jones et *al*., 2023). Such root galls, a typical symptom of nematode infection, are increasingly observed in vegetable-growing areas of Senegal, particularly in the Niayes region where okra is widely cultivated (Diop, 1994). A study conducted in Nigeria showed that nematode infestation significantly reduces okra growth and yield (Hassan, 2024).

To address these challenges, farmers increasingly turn to agricultural inputs designed to enhance crop performance. These include chemical fertilizers, organic amendments, biostimulants, and occasionally biological control agents. While these inputs may stimulate seed germination and support vegetative growth, their

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effectiveness in reducing root-knot formation remains under-documented, especially under Senegalese agroecological conditions. It is therefore essential to evaluate their impact not only on seed germination and early plant development but also on the suppression of nematode-induced damage to root systems.

This study aims to contribute to the sustainable improvement of okra (*Abelmoschus esculentus*) productivity in Senegal by analyzing the effects of various inputs on germination rates and root-knot nematode infestation levels. Specifically, it seeks to:

- Assess the effect of different inputs (cactus digestate, fermented solution of *Calotropis procera*, and NPK chemical fertilizer) on the germination potential of okra seeds.
- Analyze the incidence of these inputs on the formation of root galls induced by root-knot nematodes (*Meloidogyne* spp.) in okra.

MATERIALS AND METHODS

Study Area Description

The study was conducted in Senegal, a country located between latitudes 12° and 17° North, and longitudes 11° and 18° West. More specifically, the experiments took place in Bambey, at the Application and Production Center (CAP) of the Institut Supérieur de Formation Agricole et Rurale (ISFAR) (Figure 1). The geographic coordinates of the site are 14°57'56'' N and 16°40'82'' W. This site, situated in the north-central part of the country in the Diourbel region, lies at an altitude of 17 meters above sea level. Bambey is characterized by a tropical climate with a dry tendency, marked by two distinct seasons: a dry season from November to May, and a rainy season from June to October.

In terms of relative humidity, September is the most humid month with an average of 96.87%, while June records the lowest humidity with 34.17%. Minimum humidity values range from 34.17% to 67.35%, and maximum values from 89.43% to 96.87% (Meteorological Station of the CNRA in Bambey, 2024).

The soil at the experimental site has the following physical and chemical characteristics: sandy texture composed of 86% sand, 6% silt, and 8% clay. The pH is slightly acidic (6.7), with an organic matter content of 5.9 g·kg^{-1} and a cation exchange capacity (CEC) of 5.3 cmolc·kg^{-1} (Trail et *al.*, 2016).

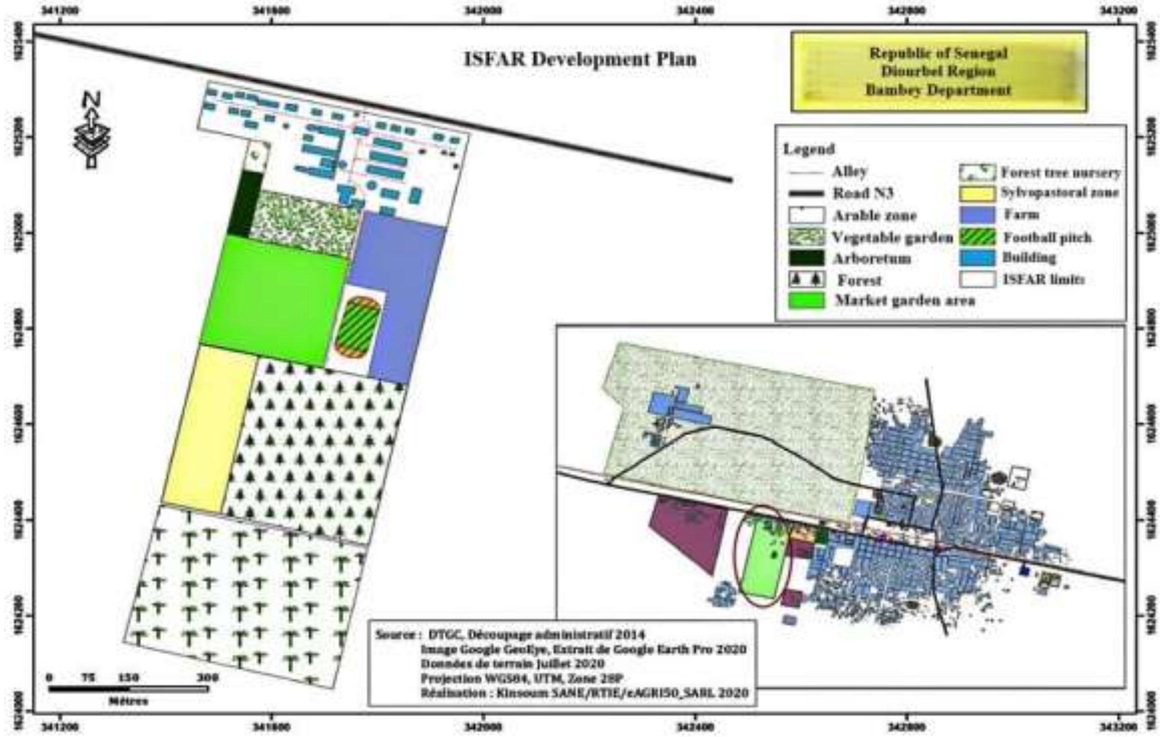

Figure 1 : Location of the experimental zone (Sané, 2020)

Materials

Plant Material

The plant material used in this study is okra (*Abelmoschus esculentus*), a species belonging to the Malvaceae family. The variety used is Indiana, an okra well adapted to the cool dry season. This variety was selected for its ease of use, resistance to YVMV (Yellow Vein Mosaic Virus), and its suitability for export.

The plant is well-branched and compact, allowing for high planting density. It produces long, slender, and straight fruits; medium to dark green in color; with pentagonal cross-sections and slightly ribbed surfaces. Depending on the climatic conditions and the growing region, it reaches maturity 45 to 55 days after sowing, with a total growth cycle of 110 to 120 days.

Figure 2 : Okra plant (Indiana variety)

Technical Equipment

The equipment used in the field included a measuring tape, which was used to demarcate the plots. Stakes with labels were used to mark the different experimental blocks. To identify the plots corresponding to each treatment, labels were attached using stakes. A notebook was used for manual data collection. An electronic scale was used to weigh the harvests. Finally, a mask and gloves were used to comply with health and safety measures during the application of phytosanitary treatments.

Inputs Used

The experiment required the use of different fertilizers. The applied fertilizers were:

- Cactus digestate, whose chemical composition is presented in Table 1,
- NPK 10-10-20 chemical fertilizer,
- Fermented solution of *Calotropis procera*, with its chemical composition shown in Table 2.

Table 1 : Chemical Composition of Cactus Digestate (SenAgriTech, 2022

Chemical Elements	Concentration in g/l
Azote (N)	159
Phosphore (P)	204
Potassium (K)	503

Table 2 : Chemical Constituents Isolated from the Leaves of Calotropis procera (Niang, 2022)

Plant Parts	Groups of Compounds	Isolated Substances	References
Leaves	Cardenolides	Calotropin (0.165%), Calotropagenin (0.087%)	Hesse & Reicheneder (1936)
		Uscharin, Uscharidin, Calotropin, Calotoxin, Uzarigenin, Acide-19-calotropin	Brüschweiler (1969)
		Proceroside	Qudrat-I-KHuda & Amir (1969)
	Polysaccharide	D-glucose + D-arabinose + D-glucosamin + L-rhamnose	

Methods

Experimental Design

The experimental design used was a Randomized Complete Block Design (RCBD), also known as Fisher's blocks. The principle involved randomly assigning treatments to experimental units block by block through a full random draw without replacement. The trial considered the input type as the factor under study, with three (3) replications,

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each constituting a block. Each block contained four (4) treatments: T0 (control), T1 (fermented solution of *Calotropis procera*), T2 (cactus digestate), and T3 (NPK), corresponding to different types of fertilization. The experiment was conducted on an area of 86.25 m² (10.5 m × 6.5 m), consisting of 3 rows of 10.5 m in length per block. The blocks were spaced 1 meter apart and each contained four (4) elementary plots measuring 1.8 m in length and 1.5 m in width, making a total of twelve (12) elementary plots (Figure 3).

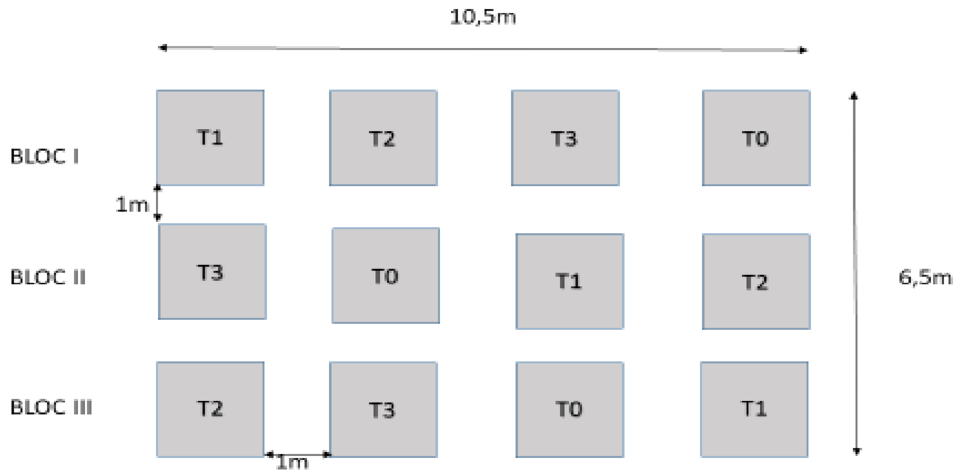

Figure 3 : Experimental design

In these elementary plots, spaced 1 meter apart, okra seeds were sown in four (4) rows. The spacing between rows was 0.5 meters, and between planting holes (hill pockets) was 0.6 meters. Four (4) okra plants were randomly selected in each elementary plot to serve as the useful sample plot.

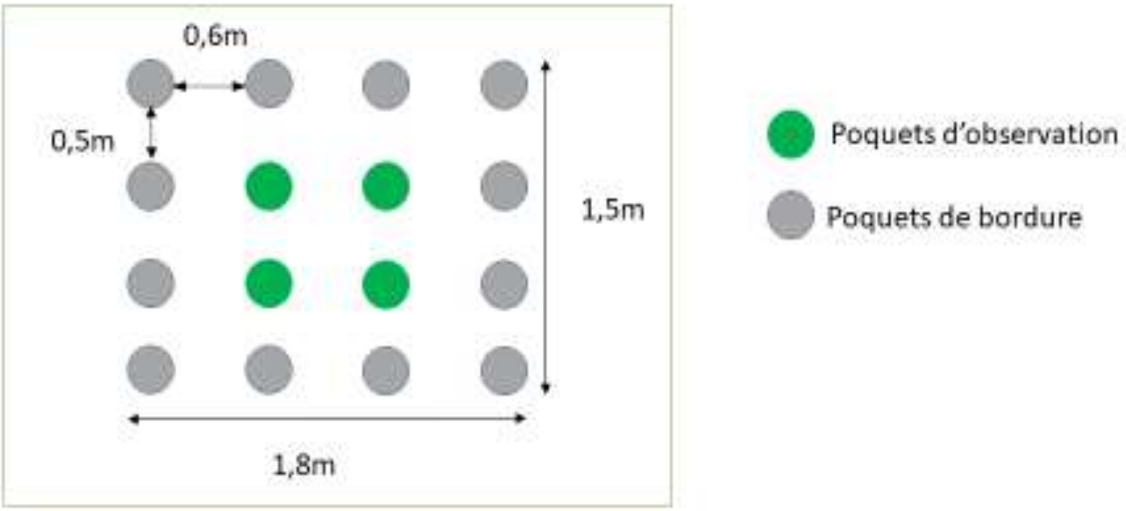

Figure 4 : Experimental Unit

Trial Management

The trial began with superficial tillage (15–20 cm deep) using a traditional "sine" hoe, followed by leveling with a rake and soil treatment using the fungicide Ivo Plus 80 WP (Mancozeb 800g/kg) to protect against pests. The plots were demarcated using the 3-4-5 method. Direct sowing was carried out on August 14, 2024, with three seeds per hill. Irrigation was done manually with a watering can, according to the crop's water needs. Thinning to one plant per hill was done on the 15th day after sowing (DAS), followed by four manual weedings using a hoe.

Four treatments were applied as shown in Table 3:

- T0: Control
- T1: Fermented solution of *Calotropis procera* (20 ml per hill before sowing and then weekly)
- T2: Cactus digestate (same application method as T1)
- T3: NPK 10-10-20 chemical fertilizer (4 g per hill before sowing and 10 g per hill weekly)

Plant protection included several targeted applications:

- Mancozeb (10 days before sowing, and on the 38th and 50th day after sowing)

- Neem oil (18th day after sowing)
- Abamectin (28th day after sowing)
- PASCHA 25 EC (47th day after sowing)
- Copper (53rd day after sowing)

These treatments were aimed at controlling insect pests (aphids, whiteflies, caterpillars, termites) and fungal diseases.

Table 3 : Number of applications, quantity per application, and application dates

Treatment	Type of Fertilizer	Basal Fertilization	Top Dressing	Application Dose
T0	No fertilizer applied	0	0	0
T1	Fermented solution of *Calotropis procera*	Once	Three times	300 L/ha
T2	Cactus digestate	Once	Three times	300 L/ha
T3	NPK 10-10-20	Once	Three times	300 Kg/ha

Measurements and Analyses

The average number of seedlings emerged was evaluated over a period of 10 days. A seed was considered germinated when the radicle reached 2 mm. The average number of seedlings emerged was calculated for each treatment using the formula:

$$\text{Average number of seedlings emerged} = \frac{\text{Sum of seedlings emerged for all treatments}}{\text{Total number of treatments}} \times 100$$

Root extraction was performed for each elementary plot studied. Three root subsamples were taken from each plot and used to determine the gall index. After harvest, sampling of three plants per elementary plot was carried out. The roots of these plants were carefully washed with clean water to remove soil and facilitate observation. The nematode infestation assessment was carried out using the Zeck scale (1971), which rates the severity of root galls on a scale from 0 to 8. This method is recommended for evaluating *Meloidogyne* spp. in tropical vegetable crops (Luc et *al*., 2005). The scale classifies roots based on gall intensity, ranging from 0 (no galls) to 8 (very severe infestation), allowing for a more precise evaluation of nematode attack severity. The mean index was calculated for each treatment using the formula:

$$\text{Mean infestation index} = \frac{\sum(ni \times vi)}{N}$$

Where:

- n_i is the number of plants rated at level i,
- v_i is the value of the rating i on the Zeck scale (from 0 to 8),
- N is the total number of plants observed.

The collected data were entered into Excel, which was also used to perform certain calculations and create graphs. Statistical analysis was conducted using XLSTAT 2023 software. An analysis of variance (ANOVA) was applied to quantitative data following a normal distribution. In the case of a significant treatment effect, a multiple comparison test (HSD or Newman-Keuls) was performed to identify differences between means.

RESULTS

Effect of treatments on the number of seed germinations

Treatment T1 (fermented solution of *Calotropis procera*) induced the highest average number of germinations (44.33) and is statistically distinguished by belonging to group A. Treatments T2 (cactus digestate) and T3 (chemical fertilizer) fall into an intermediate group (A B), suggesting that they are not significantly different from T1 nor from T0 but tend to promote germination compared to the control. Treatment T0 (no treatment) recorded the lowest average (37.00) and belongs solely to group B, meaning it is statistically lower than T1 but not significantly different from T2 and T3 (Figure 5).

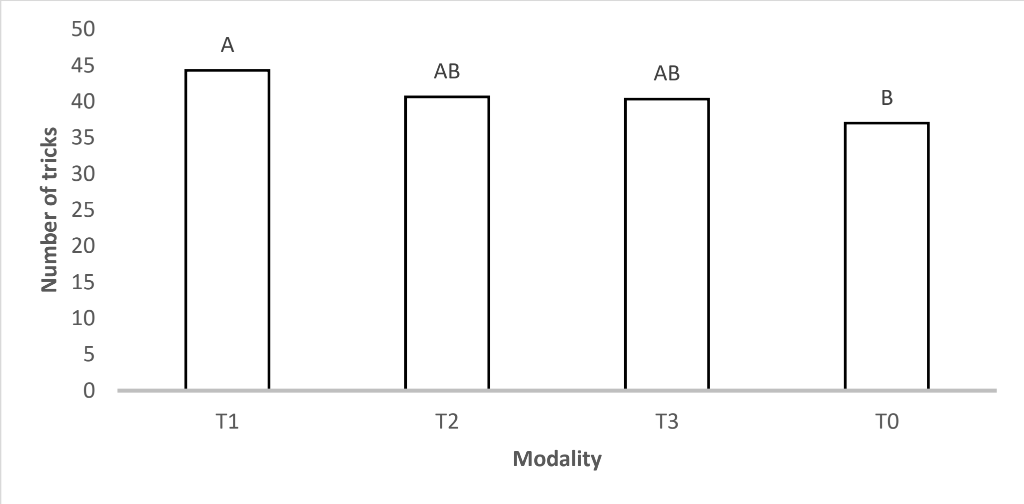

Figure 5 : Effect of treatments on the number of plant germinations.

Effect of treatments on root gall profiling

The assessment of nematode gall infestation levels across the different treatments was carried out using the Zeck scale. At 67 days after sowing (DAS), results showed that treatment T1 (fermented solution of *Calotropis procera*) exhibited a completely healthy root system, with a gall index of 0. Treatment T2 (cactus digestate) displayed an index of 1, corresponding to approximately 5% of the root volume affected. In contrast, treatments T3 and T0 showed indices of 6 and 7 respectively, indicating severe infestation, with between 50% and 75% of the root volume affected by galls (Figure 6).

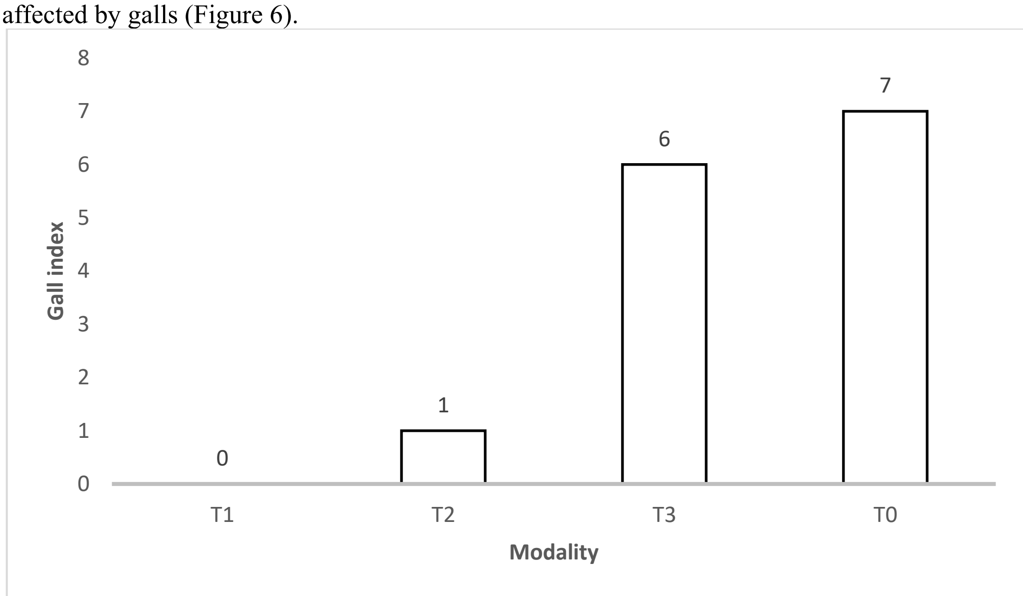

Figure 6 : Effect of treatments on plant gall index

DISCUSSION

Effect of treatments on the number of seedlings emerged

The results obtained show that the different treatments applied variably influenced the number of seedlings emerged, reflecting a differential effect on seed germination and initial seedling development. The fermented solution of *Calotropis procera* (T1) proved to be the most effective, with a significantly higher average emergence (44.33) compared to the control. This result suggests that the bioactive compounds present in the fermented solution, such as alkaloids, flavonoids, saponins, and other secondary metabolites, may have stimulated germination by acting as natural biostimulants or by improving substrate conditions, notably microbial activity and nutrient availability (Unitec, 2021). These findings corroborate the work of Mathur et *al*. (2022), who showed that certain plant extracts improve seed behavior under field conditions.

The cactus digestate (T2) and the chemical fertilizer NPK 10-10-20 (T3) also favored emergence, although their effects were less marked than those of T1. These two treatments, belonging to an intermediate statistical group (AB), indicate an improvement in emergence conditions but without significant difference compared to the control (T0). The digestate may have acted by progressively enriching the soil with organic matter and nutrients, thus promoting better rooting. As for the chemical fertilizer, although quickly available, its rapid mineralization could lead to losses by leaching or volatilization, reducing its long-term effectiveness.The T0 treatment (control), without any amendment, recorded the lowest emergence rate (37.00). This result confirms that the absence of nutrient input limits the availability of essential nutrients, hindering germination and seedling vigor. These observations align with those of Pannacci et *al*. (2022), who noted that certain plant extracts may have inhibitory or stimulatory effects depending on dose, plant species, and the plant organ used. These results confirm the importance of adequate nutrient input to stimulate germination.

Effect of treatments on root gall profiling

The results obtained using the Zeck scale indicate that fertilization with cactus and *Calotropis procera* digestates has a positive effect on reducing root galls caused by nematodes. Treatment T3 (mineral fertilizer 10-10-20) showed a relatively severe attack, with about 50% of the root system affected by galls. However, this infestation did not hinder the growth, development, or production of the plants. Conversely, the T0 treatment (unfertilized control) showed the lowest agronomic performance, with 75% of the root system infested.

These results can be interpreted in light of findings that exclusive use of mineral fertilizers does not sustainably maintain soil fertility due to leaching, acidification, and progressive degradation of their physico-chemical properties. Indeed, according to FAO (1998), the use of mineral fertilizers without organic matter return inevitably leads to a decline in soil fertility and yields. Studies also highlight that the rapid mineralization of chemical fertilizers can cause nutrient leaching into deep soil layers, making them inaccessible to roots, and weaken crops' resistance to diseases and pests. For example, a study conducted in the Democratic Republic of Congo showed that exclusive use of chemical fertilizers affects soil fertility and makes plants more vulnerable to pest attacks (Kazadi et *al*., 2023).

These observations are corroborated by the work of Mochiah et *al*. (2011), who reported a significant reduction in pests of okra and eggplant following application of *Allium* spp. extracts (30 g/L) and *Carica papaya* (92 g/L). Additionally, Adegbite and Agbaje (2011) demonstrated that extracts from various plants such as *Azadirachta indica*, *Nicotiana tabacum*, *Carica papaya*, *Cannabis sativa*, *Cassia alata*, and *Vernonia amygdalina* can inhibit egg hatching of the root-knot nematode *Meloidogyne incognita*. Similar findings were reported in a literature review led by Yarou et *al*. (2017), which highlights that the nematicidal effect of plant extracts on *Meloidogyne* species varies depending on the plant and the organ extracted. However, these results differ from those obtained by Gnago et *al*. (2010), who showed that under field conditions, the efficacy of plant extracts is often assessed by pest population abundance or severity of observed damage, without always noting a significant reduction.

CONCLUSION

This study demonstrates that the use of organic and natural inputs, particularly the fermented solution of *Calotropis procera*, is an effective approach to improve okra seed germination and significantly reduce root gall formation induced by phytoparasitic nematodes. Conversely, the exclusive use of chemical fertilizers shows limitations in controlling nematodes and sustainably maintaining soil fertility. These results encourage the adoption of agroecological practices that integrate organic amendments and natural biostimulants for sustainable management of vegetable crops in Senegal. Such strategies can contribute to improving productivity and resilience of agricultural systems against pests while preserving soil health.

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