In Vitro Evaluation of the Nematicidal Efficacy of Selected Plant Leaf Extracts against Potato Cyst Nematodes *(Globodera* spp.*)*

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ABSTRACT

Potato cyst nematodes (*Globodera* spp.) are among the most destructive pests affecting potato production, causing significant yield losses worldwide. The increasing concerns over the environmental and health impacts of synthetic nematicides have prompted the search for sustainable and eco-friendly alternatives. This study aimed to evaluate the nematicidal efficacy of selected plant leaf extracts under in vitro conditions, focusing on their effects on egg hatching, cyst count, and second-stage juvenile (J2) mortality. Aqueous leaf extracts of neem (*Azadirachta indica*), madre de cacao (*Gliricidia sepium*), mahogany (*Swietenia macrophylla*), hagonoy (*Chromolaena odorata*), and papaya (*Carica papaya*) were prepared and tested using a completely randomized design with three replications.

Results showed that all plant extracts exhibited varying degrees of nematicidal activity. Among the treatments, Treatment 1 demonstrated the highest efficacy, significantly reducing egg hatching compared to the control, indicating strong ovicidal properties. Moderate effects were observed in other treatments, while one treatment showed minimal inhibitory activity. In contrast, the impact of the extracts on juvenile mortality was less pronounced, with only slight variations in juvenile counts across treatments. This suggests that the plant extracts are more effective in inhibiting egg development than in killing already emerged juveniles.

Overall, the findings confirm that selected plant leaf extracts possess stage-specific nematicidal activity, with greater effectiveness at the egg stage. These results highlight the potential of plant-based extracts as eco-friendly and sustainable alternatives to chemical nematicides. However, further research is recommended to evaluate their performance under field conditions, determine optimal concentrations, and identify the bioactive compounds responsible for their nematicidal effects.

Keywords: Potato Cyst Nematodes, Nematicides, Juvenile stage, plant leaf extract

INTRODUCTION

Potato (*Solanum tuberosum L.)* is the most important non-cereal food crop worldwide and is popularly called the king of vegetables because of its nutritional attributes. The potato cyst nematodes (PCN) (*Globodera* spp.) are major pests of potato crops worldwide, which comprise two species, *Globodera rostochiensis* (Woll) and *G. pallida* (Stone), and eight pathotypes (Ro 1 to Ro 5 of *G. rostochiensis* and Pa 1 to Pa 3 of *G. pallida*). They cause significant yield reductions and severely impact the movement of potatoes around the globe through quarantine restrictions. Emergence of juveniles from the cysts is stimulated by host root diffusates; second-stage juveniles (J2) of PCN invade the root tip in the zone of elongation and migrate intracellularly to the cortex surrounding the vascular tissue. Mature cysts get detached from the roots and can remain viable in the soil for several years (Grenier and Benjamin 2017).

The potato cyst nematode *Globodera rostochiensis* (Woll.) is the major pest for the potato cultivars, causing up to 80% loss of yield (Trifonova, 1995; 2000). Soil treatment with nematicides has been an established practice for the control of cyst-forming nematodes of the genus *Globodera*, though it is very expensive for the farming community. In recent years, we have been observing an increasing trend to use alternative methods of pest control based on replacing chemical pesticides with natural compounds.

Plant parasitic nematodes (PPN), which cause significant crop damage and poor yields, are a big issue for farmers all over the world. Cyst nematodes are among the most economically significant and prevalent PPN pests, affecting a wide range of crops around the world. Cyst nematodes are sedentary endoparasites that feed on plant roots, forming galls and cysts, which affect nutrient and water intake and impede plant growth and development (Jones et al., 2013). These nematodes can cause considerable yield losses and reduced crop quality, with annual losses estimated to be in the billions of dollars.

In recent years, significant studies have focused on the complex interactions between PPN and their host plants, as well as the role of soil microorganisms in mediating these interactions (Jones et al., 2013). These advancements have opened up new options for developing natural and ecologically friendly PPN control solutions, such as the use of organic materials and beneficial bacteria. Different strategies for suppressing this kind of pest were slow, hence farmers rely on the use of chemicals. However, chemicals have the potential to cause harm to the environment, human health, and entomopathogens. Nowadays, there are plant extracts that contain derivatives which are non-toxic to the environment and human health that can be utilized as an alternative control management for plant parasitic nematode infestation. According to Peiris *et al*. (2020) and Waisen *et al*. (2020), a plant extract has a natural compound which found to have nematicidal activity is one promising strategy.

Potato cyst nematodes (PCNs) pose a great challenge for potato cultivation throughout the world. Being a rather difficult parasite due to a number of its physiological features, specifically the long-term viability of the eggs, PCNs cause drastic damage to worldwide agriculture. There are several approaches to prevent the spread of these pests, primarily using synthetic nematicides as well as biological products on a bacterial and fungal basis, and the application of agrophytocenotic methods. However, each of these conventional approaches has its considerable disadvantages. As a result, given the high yield losses caused by PCNs and the limited efficacy of conventional approaches to deal with this problem, a new means of pest control needs to be sought and researched. Development of long-acting preparations deposited with nematicidal ingredients could be a novel prospective approach for PCNs management. The indiscriminate use of synthetic pesticides to control nematodes was likely to give rise to phytotoxicity, environmental pollution, and resistance to nematodes, in addition to their very high cost (*Adegbite et al*., 2005). The growing concern for the environment and the recent ban on many nematicides have required a reduction in the amount of chemical nematicides and the development of non-chemical options (Odeyemi *et al*., 2013).In addition, the search for effective, environmentally sound, and safe alternative control methods has been intensified. Nematode control is necessary in order to reduce crop losses and ensure self-sufficiency in the requirement for food and industrial raw materials.

The control practices have become more challenging because of the banishment of the most commonly applied nematicides and the lack of resistant plant material. Antagonistic plants have largely been incorporated into the crop management of root-knot nematodes and potato cyst nematodes populations (Silver, 2018; Carboni *et al*., 2015; Oka, 2010). Plant-derived extracts have long been a subject of research in an effort to develop alternatives to conventional nematicides, usually safer and with minimal residual effects (Ntalli, 2010). Plants have the ability to synthesize a wide variety of biochemical substances that are used to perform important biological functions (Okechalu, 2020). These include the use of synthetic chemicals (Adegbite and Agbaje,2007), crop rotation (Adesiyan et al, 2000), use of resistant varieties (Odihirin, 1981), intercrop (Agu, 2008), organic manure (Ogaraku et al.,2007), biological agents (Kumare et al., 2011), and botanicals (Adegbite and Adesiyan, 2005). The use of biological materials for the synthesis of nanoparticles includes plant extracts.

One of the possible alternatives is the utilization of biopesticides of plant origin, known as botanical pesticides (Javed *et al*., 2007). These biopesticides are generally considered to be non-persistent under field conditions as they are readily transformed by light, oxygen, and microorganisms into less toxic products (Wiratno *et al*., 2009). Plant extract against PCN as an alternative tool for PCN infestation. Plants having nematicidal properties have been used as bio-pesticides (Pagi and Pate, 2017). e use of botanicals appears the most feasible, especially for low-income farmers who constitute about98% of the farming population (Odinakachi et al., 2015). Applications of these botanicals do not constitute a threat to the environment; they are easily affordable, require less skill, and above all, increase soil fertility (Enyiukwu *et al.,* 2014).

Among the numerous ingredients of plant studies during the last 20 years, extracts and compounds from the neem tree (*Azadirachta indica*) have attracted the special interest of entomologists all over the world. In recent years, some marketable, neem-based products have been developed. Investigations on extracts from neem and neem products have revealed that some of them are effective against insects and nematodes (Kumar and Khanna, 2006; Mojumder, 1995; Sharma, 2000).

Aqueous extract of *Carica papaya* contains biologically active components such as alkaloids, saponins, tannins, flavonoids, carbohydrates, steroids/terpenes, anthraquinones, and cardiac glycosides. These bioactive compounds are reported to have nematicidal properties (Iiker, 2016). These bioactive substances may have been responsible for the nematicidal activities of the seed and leaf extracts in the present study. The bioactive substances obtained in this research from the seed and leaf extracts of *Carica papaya* were found to be present in various quantities. According to Chin *et al.* (2018), some of these phytochemicals contributed to the chemotactic, repellent, or attractant properties of nematodes. However, Rocha *et al.* (2017) noted that phytochemical compounds such as serpentine, saponins, phenols, alkaloids, tannins, flavonoids, steroids, and cysteine proteinases have an anti-helminthic effect against plant parasites and are more active and eco-friendlier, particularly those screened from medicinal and aromatic plants. This could likely be the case with the nematicidal effect of phytochemical screens of plant extracts as observed in the present research. Additionally, Thoden *et al*. (2007) showed pyrrolizidine alkaloids of *C. odorata* that exhibited nematicidal effects on the root-knot nematode Meloidogyne incognita Kofoid and White *(Meloidogynidae*) in West Africa.

Different parts of the neem plant have a nematicidal effect on several plant parasitic nematode species such as *Meloidogyne spp., Rotylenchulus reniformis* Linford and Oliveira, 1940, *Pratylenchus brachyurus* Godfrey, 1929, Filipjev & Schuurmans-Stekhoven, 1941, *Hoplolaimus indicus* Sher, 1963 (Akhtar, 200), *Globodera rostochiensis* Wollenweber, 1923, Skarbilovich, 1959 (Trifonova and Atanasov, 2011), and *Heterodera glycines* Ichinohe, 1952 (Silva et. al.,2008). Neem leaves and neem oil cake can cause immobility and mortality in the case of the second-stage juveniles of *Meloidogyne javanica* (Treub, 1885) Chitwood, 1949, but 0.1% azadirachtin did not influence hatching (Javed *et. al*., 2008).

On the other hand, Neem Azal-U (17% azadirachtin) could decrease hatching and viability of Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949 (Mayer *et.al*., 2007). Neem leaf extract reduced root galling caused by *M. incognita* (Saravanapriya et. al., 2005). As a side-effect, azadirachtin (0.03% Achook) can reduce the number of free-living, non-target nematodes as well (Langat *et.a*l., 2008). In order to protect non-target and beneficial organisms (Barzman *et.al*., 2015), it is a cornerstone to know sub-lethal and low-lethal concentrations of pesticides.

This is in line with the previous results on the use of plant extracts in the control of *Meloidogyne* spp. (Fatoki and Fawole, 1999; Adegbite, 2011; Fabiyi *et al*., 2016). Also, this study supported the findings of (Nakatani *et al*., 2001, 2002) that the chemical constituents of mahogany bark powder have nematicidal properties, and in agreement with findings of Khan(1990), who reported that many wild and cultivated medicinal plants have been shown to possess nematicidal properties against several plant parasitic nematodes.

Therefore, the objective of this experiment is to determine the efficacy of aqueous leaf extracts against potato cyst nematode (PCN) in an i*n vitro* setup. The activity aims to investigate the nematicidal activity of these extracts by assessing their effects on egg hatching, number of eggs, and mortality rate, and to compare their efficacy to a synthetic nematicide.

Objectives

To evaluate the nematicidal efficacy of selected plant leaf extracts against potato cyst nematodes (*Globodera spp.*) under in vitro conditions.

Specific Objectives

1. To determine the effect of selected plant leaf extracts on egg hatching of potato cyst nematodes (*Globodera spp.*).

2. To assess the mortality rate of second-stage juveniles (J2) exposed to different plant leaf extracts.
3. To quantify the number of cysts, eggs, and hatched juveniles under each treatment.
4. To compare the nematicidal efficacy of different plant leaf extracts with control treatments.
5. To identify the most effective plant leaf extract based on egg hatch inhibition and juvenile mortality.
6. To evaluate the stage-specific effects of plant leaf extracts on egg and juvenile stages of potato cyst nematodes.

Scope and Limitation

This study focused on the in vitro evaluation of the nematicidal efficacy of selected plant leaf extracts against potato cyst nematodes *(Globodera spp.),* specifically assessing their effects on egg hatching, cyst count, and mortality of second-stage juveniles (J2) using aqueous extracts of neem, madre de cacao, mahogany, hagonoy, and papaya under controlled laboratory conditions. It also compared the effectiveness of these plant extracts with a control treatment to determine their potential as eco-friendly alternatives to synthetic nematicides.

However, the study was limited to laboratory conditions, which may not fully represent field environments where factors such as soil properties, climate, and microbial interactions can influence outcomes. Additionally, only a single extract concentration (1:10 dilution) and a fixed exposure period (14 days) were used, and the study did not explore varying concentrations, long-term effects, or field applications. The research also focused on selected plant species and did not identify the specific bioactive compounds responsible for the observed nematicidal activity, which may limit the generalization and application of the results.

METHODOLOGY

Research Design

This study employed an experimental in vitro design to evaluate the nematicidal efficacy of selected plant leaf extracts against potato cyst nematodes *(Globodera spp.)*. The experiment followed a completely randomized design (CRD) with multiple treatments and replications to ensure statistical reliability.

Collection and Preparation of Plant Materials

Fresh, healthy leaves of neem (*Azadirachta indica*), madre de cacao (*Gliricidia sepium*), mahogany (*Swietenia macrophylla*), hagonoy (*Chromolaena odorata*), and papaya (*Carica papaya*) were collected early in the morning from a pesticide-free area at the citrus production of the College of Agriculture, Abra State Institute of Science and Technology. The samples were washed thoroughly with distilled water to remove remains and air-dried at room temperature. Each sample was weighted at 200 grams and was homogenized using a blender, and the crude extract was obtained by squeezing through sterile cheese cloth. The filtrates were diluted with distilled water at a 1:10 (w/v) ratio to prepare aqueous extracts, following standard procedures for botanical extraction (Ntalli & Caboni, 2012; Okechalu et al., 2020).

Collection and Extraction of Potato Cyst Nematodes

Infested soil samples containing potato cyst nematodes were collected and processed using the flotation method to isolate cysts (Fenwick, 1940). The cysts were manually picked using a fine brush or bamboo stick under a stereomicroscope and transferred into Petri dishes lined with moist tissue.

To release eggs, cysts were surface sterilized using 20% sodium hypochlorite (NaClO), placed in an Erlenmeyer flask with a rubber stopper, shaken rapidly, and gently crushed. The suspension was sieved and rinsed thoroughly with distilled water to remove residual chemicals, following established nematode extraction protocols (Hussey & Barker, 1973).

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Preparation of Treatments and Controls

Each treatment consisted of 2 mL of plant extract placed in sterile test tubes. The treatments included:

T0 = Positive Control (vinegar)

T1 = Neem aqueous leaf extract

T2 = Madre de cacao aqueous leaf extract

T3 = Mahogany aqueous leaf extract

T4 = Hagonoy aqueous leaf extract

T5 = Papaya aqueous leaf extract

A positive control (vinegar diluted 1:1 with distilled water). Each treatment was replicated three times with three samples per replicate.

In Vitro Egg Hatch Inhibition Assay

Ten cysts were introduced into each test tube containing the respective treatment solution. The setups were maintained at room temperature (25–28°C) for 14 days. After incubation, the number of hatched second-stage juveniles (J2) was counted under a microscope. The percentage inhibition of egg hatching was calculated using the formula adapted from Khan et al. (2019):

$$\% Inhibition = \frac{(H_t)}{H_c} \times 100$$

where:
H_c= number of juveniles hatched in control
H_t= number of juveniles hatched in treatment

Juvenile Mortality Assay

The hatched juveniles (J2) were observed for mortality and mobility after exposure to treatments. Nematodes showing active movement were considered alive, while immobile and straight-bodied nematodes were considered dead.

The mortality rate was computed using the formula adapted from Khan et al. (2019):

$$Mortality\ Rate = \frac{(L_t)}{L_c} \times 100$$

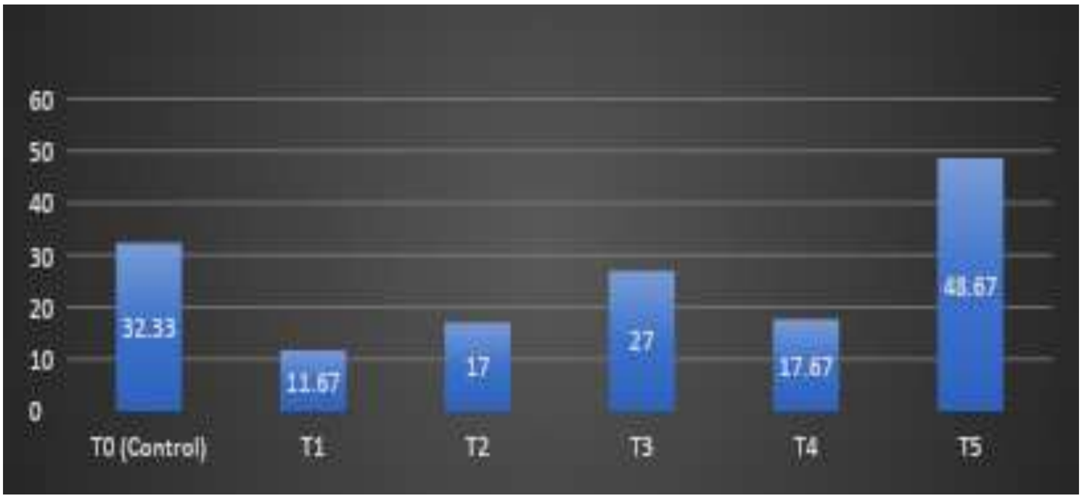
where:
L_c= number of live nematodes in control
L_t= number of live nematodes in treatment

Data Analysis

Data on egg hatch inhibition, juvenile mortality, and number of hatched juveniles were subjected to descriptive statistics (mean values). Differences among treatments were compared to determine the most effective plant extract. If applicable, analysis of variance (ANOVA) was used to test for significant differences at a 5% level of significance.

RESULTS AND DISCUSSIONS

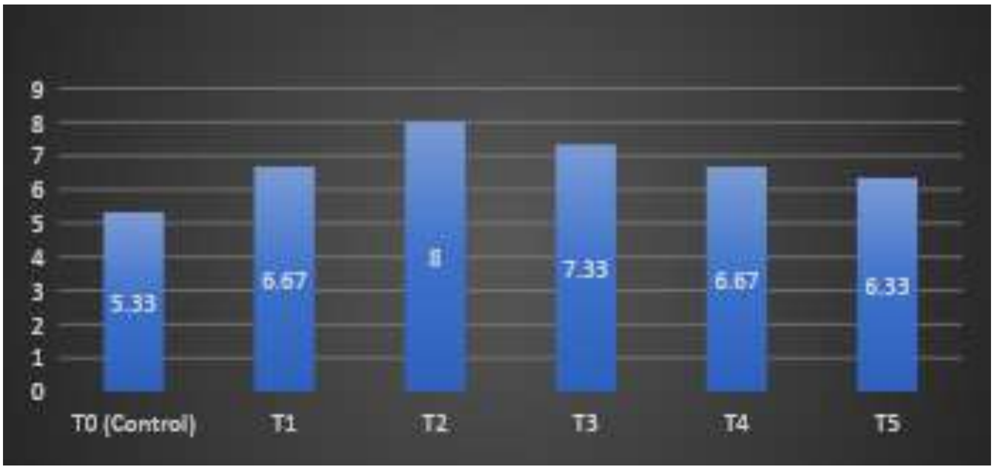
Graph 1. Mean Number of Eggs per Treatment



Legend: T0 = Positive Control (vinegar), T1 = Neem aqueous leaf extract, T2 = Madre de cacao aqueous leaf extract, T3 = Mahogany aqueous leaf extract, T4 = Hagonoy aqueous leaf extract, T5 = Papaya aqueous leaf extract

Graph 1 shows the mean number of eggs per treatment, indicating that the different plant leaf extracts had varying effects on egg hatching of potato cyst nematodes (*Globodera spp.*). The control treatment (T0) recorded a relatively high mean egg count (32.33), while T1 exhibited the lowest mean (11.67), suggesting the strongest inhibition of egg hatching. Treatments T2 (17.00) and T4 (17.67) also demonstrated moderate suppression, whereas T3 (27.00) showed a weaker effect. Notably, T5 had the highest mean egg count (48.67), indicating little to no inhibitory effect and possibly even stimulation of hatching. These results imply that certain plant extracts, particularly T1, possess significant ovicidal or egg hatch–inhibiting properties. This finding is supported by previous studies, which reported that plant-derived compounds such as alkaloids, flavonoids, and tannins can interfere with nematode egg development and hatching processes (Ntalli & Caboni, 2012; Okechalu et al., 2020). Similarly, phytochemicals from plants like neem and papaya exhibit nematicidal activity by affecting egg viability and reducing hatching rates. Therefore, the observed reduction in egg counts in treatments such as T1 confirms the potential of plant leaf extracts as effective, eco-friendly alternatives for managing potato cyst nematodes.

Graph 2. Mean Number of Juveniles per Treatment



Legend: T0 = Positive Control (vinegar), T1 = Neem aqueous leaf extract, T2 = Madre de cacao aqueous leaf extract, T3 = Mahogany aqueous leaf extract, T4 = Hagonoy aqueous leaf extract, T5 = Papaya aqueous leaf extract

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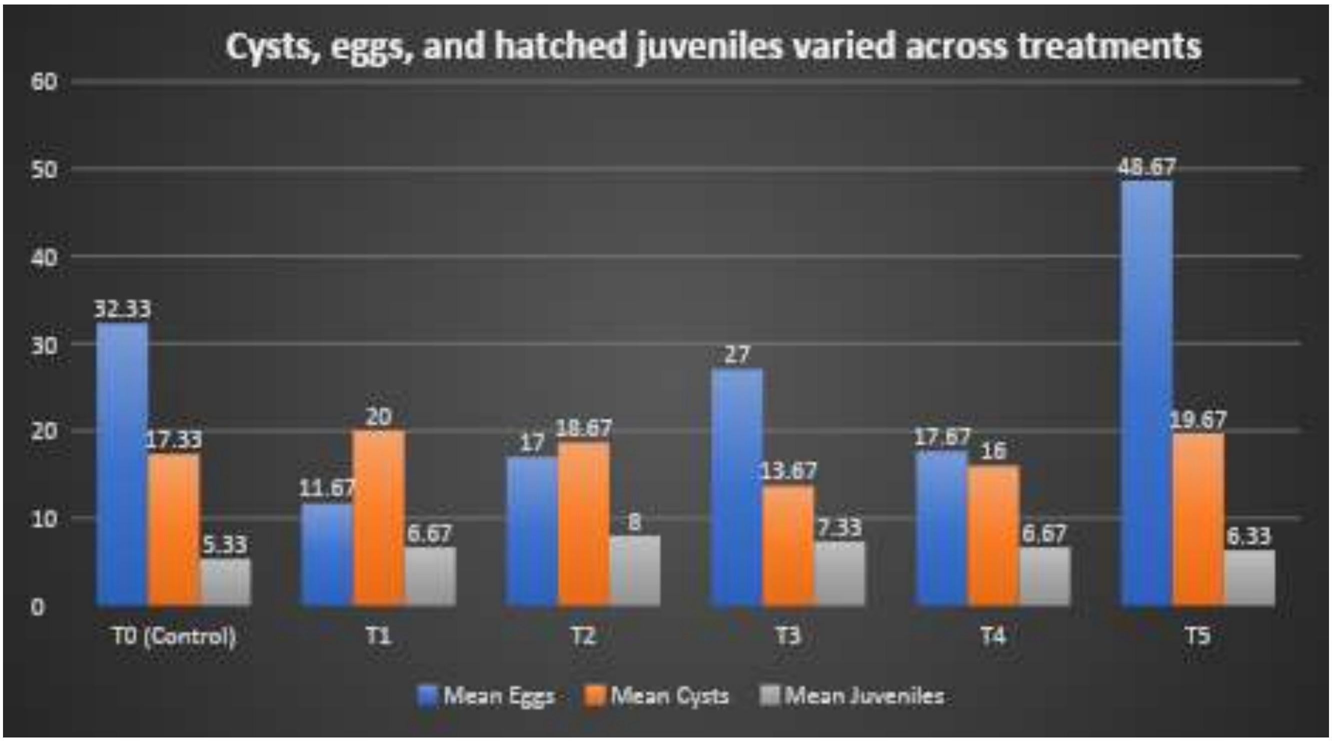
Graph 2 of the mean number of juveniles per treatment shows that the different plant leaf extracts had varying effects on the survival of second-stage juveniles (J2) of potato cyst nematodes (*Globodera spp.*). The control (T0) recorded the lowest mean juvenile count (5.33), while T2 exhibited the highest (8.00), followed by T3 (7.33), indicating lower nematicidal activity in these treatments. Treatments T1 and T4 (both 6.67) and T5 (6.33) showed moderate effects on juvenile survival. In this context, a higher number of juveniles suggests lower mortality, whereas a lower number indicates greater nematicidal effectiveness. The relatively small differences among treatments suggest that the plant extracts had limited larvicidal activity compared to their stronger effects on egg hatching, as observed in the previous results. This pattern is supported by studies showing that plant-derived compounds often exhibit stronger ovicidal (egg-inhibiting) effects than larvicidal activity, since juveniles are more physiologically developed and resilient (Ntalli & Caboni, 2012; Okechalu *et al*., 2020). Furthermore, notes that phytochemicals such as alkaloids, flavonoids, and tannins can disrupt nematode development, but their effectiveness may vary depending on the life stage. Therefore, the results indicate that while the extracts influence juvenile survival, their primary strength lies in preventing egg hatching rather than killing already emerged juveniles.

Graph 3. Cysts, eggs, and hatched juveniles varied across treatments



Legend: T0 = Positive Control (vinegar), T1 = Neem aqueous leaf extract, T2 = Madre de cacao aqueous leaf extract, T3 = Mahogany aqueous leaf extract, T4 = Hagonoy aqueous leaf extract, T5 = Papaya aqueous leaf extract

Graph 3 results show that the number of cysts, eggs, and hatched juveniles varied across treatments, indicating differential effects of the plant leaf extracts on potato cyst nematodes (*Globodera spp.*). The control (T0) recorded a relatively high mean number of eggs (32.33) and moderate juvenile count (5.33), while T1 showed the lowest mean egg count (11.67), indicating strong inhibition of egg development and hatching. Treatments T2 (17.00) and T4 (17.67) also showed reduced egg numbers, whereas T5 recorded the highest egg count (48.67), suggesting minimal effectiveness. In terms of cysts, values were relatively close among treatments, although T3 showed the lowest mean cyst count (13.67), indicating some reduction in cyst presence. For juveniles, T2 had the highest mean (8.00), suggesting lower mortality, while T0 had the lowest. Overall, the data demonstrate that plant extracts significantly influenced the reduction of eggs and, to a lesser extent, juvenile populations, confirming their role in suppressing nematode development. This supports previous findings that botanical extracts can reduce nematode populations by affecting egg viability and development stages (Ntalli & Caboni, 2012; Okechalu et al., 2020).

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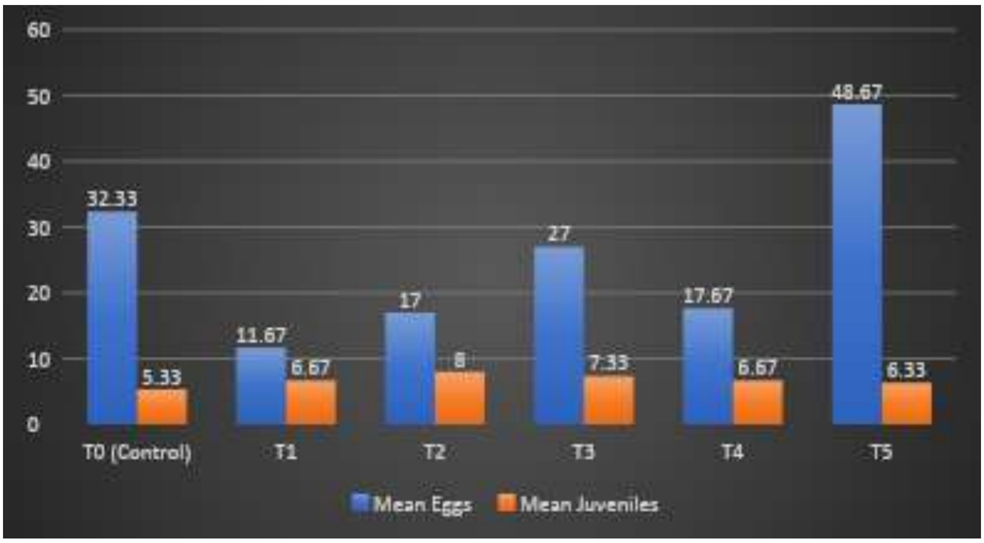
Table 1. Comparison between the plant leaf extracts and the control

Treatment	Mean Eggs	Mean Cysts	Mean Juveniles
T0 (Control)	32.33	17.33	5.33
T1	11.67	20	6.67
T2	17	18.67	8
T3	27	13.67	7.33
T4	17.67	16	6.67
T5	48.67	19.67	6.33

Legend: T0 = Positive Control (vinegar), T1 = Neem aqueous leaf extract, T2 = Madre de cacao aqueous leaf extract, T3 = Mahogany aqueous leaf extract, T4 = Hagonoy aqueous leaf extract, T5 = Papaya aqueous leaf extract

Table 1 shows the comparison between the plant leaf extracts and the control (T0), demonstrating that several treatments exhibited notable nematicidal efficacy against potato cyst nematodes (*Globodera spp.*). The control showed a relatively high mean egg count (32.33), indicating normal hatching conditions without treatment. In contrast, T1 (11.67), T2 (17.00), and T4 (17.67) significantly reduced egg numbers, suggesting stronger nematicidal activity, particularly in inhibiting egg hatching. Among these, T1 emerged as the most effective treatment, showing the lowest egg count and thus the highest inhibitory effect. However, some treatments, such as T5 (48.67), recorded higher egg counts than the control, indicating poor or negligible efficacy. In terms of juvenile counts, differences among treatments were less pronounced, suggesting that while the extracts have some effect on juvenile survival, their primary action is more evident at the egg stage. Overall, the results confirm that selected plant leaf extracts are more effective than the untreated control in suppressing nematode development, supporting their potential as eco-friendly alternatives to chemical nematicides. This aligns with previous studies reporting that plant-based extracts can significantly reduce nematode populations compared to untreated controls due to their bioactive compounds (Ntalli & Caboni, 2012; Okechalu et al., 2020).

Graph 4. Most effective plant leaf extract based on egg hatch inhibition and juvenile mortality



Legend: T0 = Positive Control (vinegar), T1 = Neem aqueous leaf extract, T2 = Madre de cacao aqueous leaf extract, T3 = Mahogany aqueous leaf extract, T4 = Hagonoy aqueous leaf extract, T5 = Papaya aqueous leaf extract

Based on the results, Treatment 1 (T1) was identified as the most effective plant leaf extract against potato cyst nematodes (*Globodera spp.*). T1 recorded the lowest mean number of eggs (11.67), indicating the highest level of egg hatch inhibition among all treatments. This suggests strong ovicidal activity, which is critical in preventing the emergence of infective second-stage juveniles (J2). In terms of juvenile counts, T1 showed a moderate mean (6.67), indicating some effect on juvenile survival, although less pronounced compared to its impact on egg hatching. Other treatments, such as T2 and T4, demonstrated moderate efficacy, while T5 showed the least effectiveness, with the highest egg count (48.67). Overall, the superior performance of T1 highlights its potential as an effective plant-based nematicide, primarily acting by suppressing egg hatching rather than directly causing high juvenile mortality. This finding is consistent with studies reporting that plant extracts, particularly those rich in bioactive compounds like alkaloids and flavonoids, exhibit strong inhibitory effects on nematode egg development (Ntalli & Caboni, 2012; Okechalu et al., 2020).

Table 2. Comparison of Egg and Juvenile Stages Across Treatments

Treatment	**Mean Number of Eggs**	**Mean Number of Juveniles**	**Interpretation**
T0 (Control)	32.33	5.33	Normal hatching, baseline
T1	11.67	6.67	Strong egg inhibition, moderate juvenile effect
T2	17	8	Moderate egg inhibition, low juvenile mortality
T3	27	7.33	Weak egg inhibition, moderate juvenile effect
T4	17.67	6.67	Moderate egg inhibition, moderate juvenile effect
T5	48.67	6.33	No egg inhibition, low effectiveness

Legend: T0 = Positive Control (vinegar), T1 = Neem aqueous leaf extract, T2 = Madre de cacao aqueous leaf extract, T3 = Mahogany aqueous leaf extract, T4 = Hagonoy aqueous leaf extract, T5 = Papaya aqueous leaf extract

Table 2 presents a comparative analysis of the effects of different treatments on the egg and juvenile stages of potato cyst nematodes (*Globodera spp.*), clearly demonstrating variation in nematicidal activity across treatments. The mean number of eggs shows wide variation, with T1 recording the lowest value (11.67) compared to the control (32.33), indicating strong inhibition of egg hatching. Treatments T2 (17.00) and T4 (17.67) also exhibited moderate egg suppression, while T5 showed the highest egg count (48.67), suggesting little to no inhibitory effect. In contrast, the mean number of juveniles shows relatively minimal variation across treatments, ranging from 5.33 to 8.00, indicating that the extracts had less pronounced effects on juvenile survival. This pattern suggests that the plant leaf extracts are more effective at interfering with egg development and hatching (ovicidal effect) rather than causing significant mortality in the second-stage juveniles (J2). The observed stage-specific activity supports previous findings that plant-derived phytochemicals such as alkaloids, flavonoids, and tannins primarily disrupt egg viability and embryonic development, while juveniles tend to be more resistant due to their more developed physiological structure (Ntalli & Caboni, 2012; Okechalu et al., 2020), as also indicated in. Therefore, the table provides strong evidence that these plant extracts are more suitable as preventive control agents, targeting the early life stage of nematodes to reduce population buildup.

CONCLUSION

The study demonstrated that the selected plant leaf extracts possess nematicidal activity against potato cyst nematodes (*Globodera spp.*) under in vitro conditions. Among the treatments, Treatment 1 exhibited the highest efficacy, showing the greatest inhibition of egg hatching and a moderate reduction in juvenile survival. Overall, the plant extracts were found to be more effective in suppressing the egg stage than the juvenile stage, indicating stage-specific activity and suggesting their potential as ovicidal agents. These findings highlight the potential of plant-based extracts as eco-friendly and sustainable alternatives to synthetic nematicides, particularly for preventing nematode population buildup. However, further studies are recommended to evaluate their effectiveness under field conditions, explore different concentrations, and identify the active compounds responsible for their nematicidal properties.

RECOMMENDATIONS

Based on the findings of the study, it is recommended that selected plant leaf extracts, particularly the most effective treatment, be further explored as eco-friendly alternatives to synthetic nematicides for managing potato cyst nematodes (*Globodera spp.*). Future studies should evaluate the effect of varying concentrations and longer exposure periods to determine optimal application rates and enhance nematicidal efficiency. It is also recommended to conduct field-based experiments to validate the effectiveness of these extracts under natural environmental conditions. Moreover, further research should focus on the isolation and identification of bioactive compounds responsible for the nematicidal activity to improve formulation and application. Lastly, integrating these plant extracts into sustainable pest management strategies (IPM) is encouraged to reduce reliance on chemical pesticides and promote environmentally safe agricultural practices.

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