

Studies on the Nematicidal Efficacy of *Khaya senegalensis* Methanol Leaf Extract on Root-Knot Nematodes of Tomatoes

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ABSTRACT: Root-knot nematode infestations represent a severe agricultural crisis, aggressively diminishing the vegetative growth and harvest yields of vital crops both within Nigeria and on a global scale. This greenhouse-based investigation evaluated the therapeutic potential of *Khaya senegalensis* leaf extracts in mitigating root-knot nematode damage in tomato plants. To identify candidate botanicals, a localized survey was conducted among farmers in Sokoto State to document traditional plant-based remedies used against suspected nematode attacks. The researchers distributed 300 questionnaires evenly across the state's three senatorial districts. The survey revealed nine utilized plant species, from which three were isolated for experimental focus—representing the most frequently cited botanical from each respective district.

For the biological assay, thirty 15 cm open-mouth plastic pots were prepared with sterilized soil. One-week-old, independently raised tomato seedlings were carefully transplanted into these receptacles. With the exception of a designated healthy control group, each seedling environment was artificially infested with 1,000 nematode juveniles. A

methanol-derived extract of *Khaya senegalensis* leaves was then administered to the infected plants at graduating concentrations (100 mg/ml, 200 mg/ml, 300 mg/ml, and 400 mg/ml), alongside an untreated, infected control group. Following a four-week incubation period, researchers evaluated several developmental metrics, including total plant height, root extension, galling severity, and final nematode counts. The data revealed marked physiological improvements across all measured parameters in the extract-treated cohorts compared to the untreated infected plants, with the most robust recovery observed at the maximum dosage of 400 mg/ml. Initial phytochemical analysis confirmed the presence of bioactive constituents, which likely drive the observed parasitic suppression. Nonetheless, comprehensive biochemical modeling is required to isolate the specific phytochemicals responsible for these defense mechanisms across diverse plant species.

Keywords: *Botanical nematicides, Khaya senegalensis, Meloidogyne, phytomedicine, tomato yield, Sokoto agriculture.*

Introduction

Background of the Study

The agricultural sector encompasses the cultivation, processing, and distribution of a vast array of commodities, stretching from raw horticulture and sericulture to livestock, forestry, and fisheries. Historically, agriculture catalyzed the dawn of human civilization, and it continues to serve as an indispensable pillar of modern societal survival. Regardless of a nation's developmental status, foundational reliance on agricultural outputs remains a universal constant. While traditionally synonymous merely with food crop generation, the industry's modern scope is vast. It remains the ultimate economic engine, dictating financial stability by supplying essential raw materials, securing global food pipelines, and generating massive employment opportunities. Consequently, safeguarding agricultural integrity is of paramount importance.

Plant-parasitic nematodes—specifically those responsible for conditions like wheat ear cockle—were scientifically documented as early as 1743. However, their devastating economic implications were not broadly recognized until the mid-20th

century. Following World War II, the agricultural community's introduction to accessible chemical nematicides suddenly highlighted the sheer scale of the destruction caused by these microscopic soil dwellers. Tomatoes and a myriad of other cash crops are highly vulnerable; for example, specific bean cultivars routinely suffer devastating harvest depressions ranging from 45% to 63% purely due to nematode activity. Furthermore, researchers have recorded catastrophic losses in the Mediterranean and Southern Europe, where root nematodes obliterate up to 50% of gross vegetable outputs and 2% of fruit yields. On a global macro-scale, various pathogens and pests degrade approximately 34% of all agricultural crops annually, with nematodes single-handedly responsible for roughly 11% of that total deficit.

The agricultural burden is disproportionately heavy in developing nations like Nigeria compared to Europe or the Americas, with total annual crop losses attributed to nematodes hovering around 12.3%. Specific Nigerian crop sectors experience profound degradation, including estimated losses of 20.6% in tomatoes, 20.4% in peppers, and up to a staggering 70% in cowpea harvests. Developed nations are not immune; historical data illustrates that the United States lost over 7% of its annual crop value to these pests in the 1960s, while England suffered multi-million dollar deficits due to the potato cyst nematode. Today, root-knot variations routinely decimate between 29% and 90% of global vegetable plantings. In Nigeria alone, they restrict tomato yields by nearly half. Similarly, legume and cereal populations—from pigeon peas to barley—are severely compromised by cyst-forming and root-knot nematode species.

Because nematodes dwell beneath the soil line, early diagnostic symptoms are frustratingly ambiguous. Infested plants frequently exhibit stunted architecture, patchy field emergence, and discolored leaves—traits easily misdiagnosed as nutritional deficits, adverse soil physics, or secondary bacterial and viral infections. This is further complicated by the fact that nematode feeding wounds provide direct entry points for secondary opportunistic pathogens. Above-ground physiological stress manifests as morphological distortion, chlorosis, and severe stunting proportional to the parasite load. The characteristic yellowing, which can darken to deep purple or black, is a direct result of the ruined root system failing to mobilize

vital nutrients upward into the canopy. Specialized stem-feeding species can also cause aerial swelling and twisting.

Beneath the soil, the damage is distinct. Root systems may entirely deplete or cease growing altogether. Conversely, rather than outright decay, the plant might attempt to overcompensate by rapidly clustering new roots behind the damaged tissue. The hallmark of a root-knot nematode invasion is extensive galling and swelling along the root surface. Other genera, such as *Globodera*, manifest as distinct colored cysts protruding from the plant tissue.

Ultimately, mitigating this agricultural damage hinges on aggressively suppressing the local nematode population below economically devastating thresholds. Traditional maintenance requires either direct chemical eradication or the strategic introduction of soil amendments that simultaneously boost plant resilience and introduce antagonistic, nematode-killing elements. Historically, the agricultural sector has relied on synthetic chemicals, crop rotation, resistant breeding, and biological controls. However, managing endoparasitic species that have already breached the root wall is notoriously difficult, as any applied chemical must permeate the plant without displaying phytotoxic traits. While systemic agents like Oxamyl exist, their profound toxicological risks strictly limit their legal application.

Although numerous synthetic nematicides are marketed for annual crops, they require dangerous, repeated applications that are rarely economically viable for perennial farming. These compounds possess exceptionally low LD50 values, posing lethal risks to agricultural workers operating the dispersal machinery. Emulsifiable liquid concentrates demand rigorous safety protocols that are frequently ignored or misunderstood in regions lacking educational infrastructure. Furthermore, applying these synthetics too close to harvest times triggers dangerous residue accumulations that threaten the end consumer.

Parasite population explosions are dictated by the availability of vulnerable host plants. Consequently, agricultural scientists have invested heavily in breeding nematode-resistant flora. Resistant cultivars naturally trigger a hypersensitive necrosis upon nematode penetration. By preventing the formation of giant feeding

cells, the plant starves the surrounding nematodes to death. Specific cowpea variants have demonstrated remarkable resilience against varying races of *Meloidogyne incognita*. This genetic manipulation involves splicing resistant genes into otherwise vulnerable, high-yield crops to naturally synthesize nematicidal compounds within the plant itself.

Alternatively, crop rotation attempts to starve local pest populations by alternating vulnerable cash crops with immune species. This ancient land management strategy disrupts the nematode lifecycle while simultaneously rebuilding soil health. In traditional Nigerian mixed-cropping systems, farmers intersperse vegetables, root crops, and legumes. Studies indicate that planting maize alongside cowpeas significantly shields the vulnerable legumes from root-knot devastation. However, rotation isn't flawless; starving one specific nematode species often inadvertently creates a biological vacuum that allows a different pest species to multiply rapidly. Moreover, immune rotational crops frequently yield lower profit margins, discouraging widespread farmer adoption.

To bridge this gap, researchers are pivoting toward biological controls, which utilize living organisms or organic derivatives to suppress pathogen density naturally. This includes deploying antagonistic fungi, bacteria, or other predatory nematodes. Furthermore, exhaustive in-vitro testing has identified numerous botanical species whose barks, stems, and leaves harbor potent nematicidal traits. Aqueous extracts derived from neem oil cakes, for instance, dramatically decrease root penetration by *Meloidogyne* species, severely retarding the pests' feeding and reproductive capabilities. Plants like *Ageratum conyzoides* and *Brassica nigra* have similarly demonstrated profound toxicity against various nematode classifications.

Statement of the Problem

Microscopic root-knot nematodes silently inflict catastrophic damage upon staple crops such as tomatoes and cowpeas. Despite deploying an array of traditional defense mechanisms—from synthetic chemicals to crop rotation—sustainable success remains elusive. Synthetic pesticides carry a heavy burden of unintended consequences that often eclipse their immediate benefits. Prolonged reliance on these

chemicals has spawned pesticide-resistant super-strains while devastating local biological ecosystems. The accompanying financial strain and severe toxicological threats to human and environmental health have forced regulatory bodies to ban infamous agents like DDT entirely. To secure the global food supply chain against yield loss, the scientific community urgently requires safer, natural disease management protocols. This urgency directly drives the current investigation into utilizing indigenous botanical materials to eradicate root-knot *Meloidogyne* infestations.

Justification

This research carries profound implications for the global farming community by presenting a viable, sustainable alternative to combat a relentless agricultural menace. By shifting away from synthetic dependencies, farmers can adopt a highly economical and biologically secure framework for pathogen management. Plant-derived biopesticides naturally integrate with the environment, promoting overall crop health while maintaining absolute biocompatibility. Furthermore, this data establishes a crucial scientific baseline, empowering future researchers to refine eco-friendly interventions against root-knot nematode species.

Aim and Objectives of the Work

The core objective of this study is to definitively evaluate the nematicidal properties of *Khaya senegalensis* extracts when deployed against root-knot nematode infections in tomato plants. To achieve this, the researchers pursued the following specific milestones:

1. Survey local agricultural workers to catalog, identify, and harvest *K. senegalensis* specimens within Sokoto State.
2. Isolate the most frequently utilized traditional botanicals for experimental validation.
3. Execute comprehensive phytochemical screening on the finalized test plant.

- Quantify the extract's impact on infected tomato growth metrics—specifically monitoring plant height, root extension, gall formation, and surviving nematode density.

Materials and Methods

Study Area

The investigation was physically anchored in Sokoto State, situated in Nigeria's extreme northwestern corridor. Occupying 28,232 square kilometers within the arid Sahel domain, it borders the Niger Republic, Kebbi State, and Zamfara State. Supporting a populace of approximately 4.2 million people, the region is predominantly inhabited by the Hausa and Fulani, alongside notable Yoruba, Igbo, and indigenous tribal communities. While many residents engage in civil service, artisanship, and weaving, the state's economic heartbeat is agriculture. Both subsistence and commercial farming dominate the wet and dry seasons, with extensive irrigation networks facilitating year-round vegetable cultivation. The climatic conditions are intense; average temperatures hover around 28.3°C, but pre-monsoon heat from February to April frequently spikes above 45°C. A brief rainy period from June to October brings cooling relief, though it is accompanied by dense, dust-laden harmattan winds blowing off the Sahara.

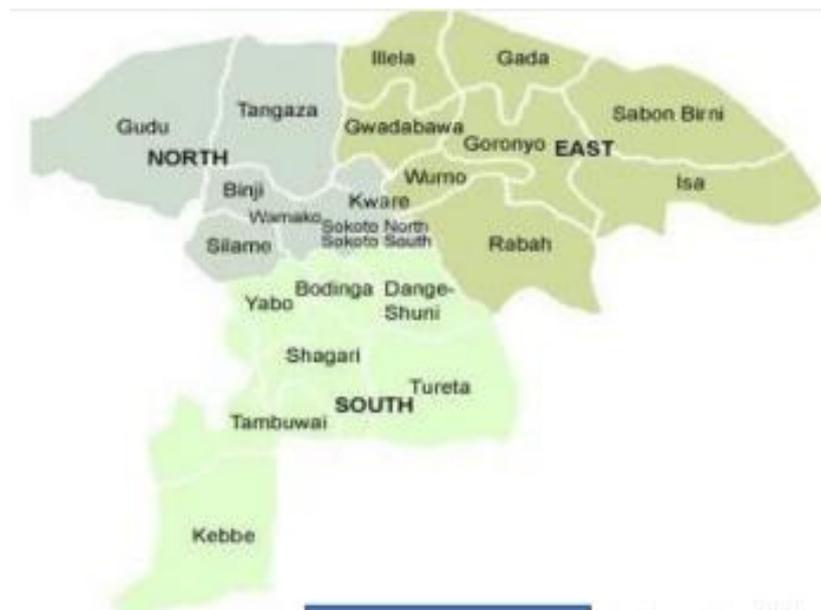


Fig.1 Map of Sokoto state showing the three (3) senatorial zones (Collection Centres)

Source:

www.Researchgate.net

Administration of Questionnaire and Plant Collection

To isolate candidate botanicals, a structured survey was circulated among localized farming groups. The six-part questionnaire captured demographic data, location specifics, crop types, and traditional botanical treatments deployed during suspected nematode outbreaks. The data harvested from these surveys directly dictated the plant selections for the bioassay.

The geographical study area was stratified into three distinct zones (A, B, and C), mirroring the state's senatorial districts. These districts were further subdivided into three local collection centers each, creating nine targeted survey nodes. Based on the statistical frequency of farmer responses within each zone, researchers selected one dominant plant species per senatorial district: *Khaya senegalensis*, *Azadirachta indica*, and *Vernonia amygdalina*. These specimens were subsequently transported to Usmanu Danfodiyo University's Department of Biological Science, where a resident taxonomist verified their botanical identity and assigned official voucher numbers (UDUH/ANS/0984, UDUH/ANS/0985, and UDUH/ANS/0986, respectively).

Collection of Inoculums and Nematode Isolation

Pathogenic soil samples were manually excavated from a known, infested tomato plot located in the Kwalkwalawa district near the university campus. The presence of root-knot nematodes was visually verified via the distinctive galling on local plant roots. Supplementary samples were gathered from the rhizosphere of tomatoes situated behind the campus bursary using a shovel to penetrate 3 cm into the topsoil. These soil collections were sealed in polythene bags and stabilized at room temperature.

To extract the live pests, the researchers utilized the Cobb decantation and sieving technique. The infected soil was submerged in water, gently agitated to dissolve large lumps, and allowed to briefly settle. The resulting nematode-rich supernatant was carefully decanted through a tiered battery of fine-mesh sieves (40, 80, and 120 cm diameter) to trap the microscopic juveniles. To ensure maximum capture efficiency, the runoff was collected and cycled through the sieving apparatus a second time. The retained organic residue housed the necessary biological inoculum.

Extraction of Plant Extracts

The authenticated leaves of the chosen experimental plant were thoroughly shade-dried to preserve their chemical integrity. Once brittle, they were pulverized via mortar and pestle and passed through a fine sieve. Two hundred grams of the resulting powder was combined with 500 ml of distilled water inside a conical flask. The slurry was subjected to vigorous manual agitation, allowed to steep undisturbed for 48 hours, and agitated once more before being passed through Whatman No. 1 filter paper. Finally, the filtered aqueous solution was gently reduced in an electric drier calibrated to 45°C to yield the concentrated extract.

Determination of Nematicidal Effect

To test the biological efficacy, thirty standard 15 cm plastic pots were prepared with 1 kg of heavily autoclaved (sterilized) soil and segmented into six testing blocks. Aside from one designated healthy control group, every pot was inoculated with 1,000 isolated nematode juveniles. 'Dan Zaria' tomato seedlings—a highly susceptible cultivar sourced from the Sokoto central market—were cultivated independently for one week before being transplanted into the prepared pots.

The experimental groups received 10 ml applications of the *K. senegalensis* extract at specific concentration tiers (100, 200, 300, and 400 mg/ml). The remaining infected block received no treatment, acting as a baseline metric for disease progression. Standardized watering protocols were maintained for four weeks, after which the plants were carefully uprooted for final evaluations. Researchers measured physical growth (height and root reach) and quantified the exact nematode populations. Root trauma was graded visually on a standard severity index ranging from 0 (pristine roots) to 5 (extreme deformation exceeding 100 localized galls).

Data Analysis

Statistical variances among the test groups were calculated utilizing a one-way Analysis of Variance (ANOVA) protocol. To determine exact significance thresholds at the 5% level, the researchers applied Duncan's multiple range tests.

Results

Common Nematicidal Plants in the Study Area

The grassroots survey successfully identified nine indigenous plant species utilized by rural agriculturalists for nematode control. The documented botanicals included *Azadirachta indica*, *Balanites aegyptiaca*, *Carica papaya*, *Khaya senegalensis*, *Tamarindus indica*, *Psidium guajava*, *Ricinus communis*, *Tagetes* species, and *Vernonia amygdalina* (detailed in Table 1). Based on localized popularity, the three focal plants chosen for further study were *Khaya senegalensis*, *Vernonia amygdalina*, and *Azadirachta indica* (detailed in Table 2).

Table 1: List of Indigenous Plants used as Nematicides as Responded by Local Farmers in the Study Area

S/No	Scientific Name	English Name	Local Name	Plant Part Used
1.	<i>Azadirachta indica</i>	Neem Tree	Dogon Yaro	Leaves
2.	<i>Balanite aegyptiaca</i>	Desert date	Aduwa	Stem bark
3.	<i>Tamarindus indica</i>	Tamarin	Tsamiya	Stem bark
4.	<i>Khaya senegalensis</i>	Mahogany	Madacci	Leaves
5.	<i>Carica papaya</i>	Pawpaw	Gwanda	Leaves
6.	<i>Psidium guajava</i>	Guava	Gwaba	Leaves
7.	<i>Ricinus cummunis</i>	Castor Bean	Mamudu	Leaves
8.	<i>Tagetes spp.</i>	Marigold	Danya	Fruits
9.	<i>Vernonia amygdalina</i>	Bitter Leaf	Shuwaka	Leaves

Table 2: Regional Plant Selection Breakdown

S/No	Scientific Name	English Name	Local Name	Plant Part Used	Senatorial District Collected
1.	<i>Khaya senegalensis</i>	Mahogany	Madacci	Leaves	Sokoto East (Zone A)
2.	<i>Azadirachta indica</i>	Neem Tree	Dogon Yaro	Leaves	Sokoto Central (Zone B)
3.	<i>Vernonia amygdalina</i>	Bitter Leaf	Shuwaka	Leaves	Sokoto South (Zone C)

Phytochemical Screening

Table 3: Phytochemical Constituents of the Methanol Extracts of *Khaya senegalensis*

Phytochemical Constituents	Inferences
Alkaloids	++
Flavonoids	+
Tannins	++
Phenol	-
Saponins	++
Steroids	+
Glycosides	-

Key: + = trace, ++ = moderate +++ = high - = not detected

Effects of Extracts on Tomato Growth and Parasite Metrics

The data clearly illustrates that applying the *K. senegalensis* solution positively influenced the physical dimensions of the infected tomato seedlings across all dosage levels. In the absence of pathogenic stress, the un-inoculated seedlings thrived, reaching a mean height of 28.13 cm. Conversely, the untreated infected seedlings were drastically stunted, averaging only 18.40 cm, highlighting the profound physiological tax imposed by the *Meloidogyne* population. Introducing the botanical extract initiated distinct recovery phases. Notably, the maximum 400 mg/ml concentration propelled the infected plants to a robust 26.33 cm height, closely rivaling the pristine controls. Even the lower threshold dosages (100–300 mg/ml) facilitated noticeable upward growth trends proportional to their concentration strength. Statistical P-values confirmed highly significant variance between the assorted treatment blocks.

Table 4: Height of the Tomato Plants Inoculated with Nematodes and Treated with *Khaya senegalensis*

Concentration/Treatment(mg/ml)	Mean of the Plant Height(cm)	<i>p</i> -value
Uninoculated	28.13± 0.176 ^a	0.001
Inoculated	18.40± 0.100 ^f	
100	21.50± 0.058 ^e	
200	23.33± 0.167 ^d	
300	25.13± 0.167 ^c	
400	26.33± 0.033 ^b	
Total	23.81 ± 0.778	

(Values are Mean±SEM of three replicates. Source:)

Root development mirrored the canopy data. Uninfected controls generated optimal root matrices averaging 8.39 cm. The parasitic burden slashed root development in the untreated group down to just 6.17 cm. Administering the mahogany leaf extract sparked steady subterranean recovery. The 400 mg/ml block displayed the most dramatic healing, achieving a 7.17 cm root length, proving that heavy botanical dosing actively shields the rhizosphere from severe stunting. These subterranean developmental shifts were highly significant ($p < 0.05$).

Table 5: Root Length of the Tomato Plants Inoculated with Nematodes and Treated with *Khaya senegalensis*

Concentration/Treatment(mg/ml)	Mean of the Root Length (cm)	<i>p</i> -value
Un-inoculated	8.39± 0.003 ^a	0.000
Inoculated	6.17 ± 0.088 ^d	
100	6.30 ± 0.058 ^d	
200	6.37± 0.186 ^d	
300	6.77± 0.033 ^c	
400	7.17± 0.067 ^b	
Total	6.86 ± 0.188	

(Values are Mean±SEM of three replicates. Source:)

The severity of localized galling and the total surviving pest counts further validated the extract's efficacy. Healthy controls naturally registered a zero galling index, whereas the untreated infected plants were severely deformed, averaging a massive 12.00 galling rate. Remarkably, flooding the soil with the 400 mg/ml botanical concentration entirely suppressed tumor formation, returning the galling index to a perfect 0.00. Weaker solutions managed to diminish tumor outbreaks compared to the control but lacked the overwhelming suppressive power of the top-tier dose. This suppression dynamic provides unequivocal proof that mahogany derivatives can neutralize root-knot pathogenesis. The highest dosage level systematically annihilated the pest population, driving the initial 1,000-juvenile inoculation down to a fractured surviving count of just 114.67 organisms (compared to the 531.67 pests actively thriving in the untreated soil).

Table 6: Number of Galls in the Roots of the Tomato Plants

Concentration/Treatment(mg/ml)	Mean \pm Standard Error	<i>p</i> -value
Uninoculated	0.00 \pm 0.00 ^b	0.040
Inoculated	12.00 \pm 0.577 ^{ab}	
100	13.33 \pm 0.882 ^a	
200	11.33 \pm 0.333 ^{bc}	
300	10.33 \pm 0.333 ^c	
400	0.00 \pm 0.000 ^d	
Total	7.83 \pm 1.370	

Table 7: Number of Nematodes Surviving in the Tomato Plants

Concentration/Treatment(mg/ml)	Mean Number of the Nematodes	<i>p</i> -value
Uninoculated	0.00 \pm 0.00 ^e	0.010
Inoculated	531.67 \pm 4.409 ^a	
100	263.33 \pm 1.667 ^b	
200	241.00 \pm 1.000 ^{bc}	
300	223.67 \pm 0.667 ^c	
400	114.67 \pm 17.676 ^d	
Total	229.06 \pm 39.499	

Discussion

Root-knot nematodes reign as one of the most destructive agricultural phenomena worldwide, operating as silent, microscopic saboteurs shielded beneath the topsoil. Given the catastrophic ecological and toxicological failures of synthetic chemistry, scientific momentum is rapidly shifting toward botanical, environmentally harmonious remedies. The profound decline in nematode survival rates observed during these trials directly correlates to the deleterious phytochemicals housed within the *K. senegalensis* leaves. Specifically, the prominent presence of saponins—compounds highly regarded for their innate antiparasitic aggression—likely triggered the massive nematode die-offs.

By effectively neutralizing the microscopic predators, the botanical extract removed the physiological roadblocks hampering the tomato seedlings, allowing them to

rapidly accelerate their vertical and subterranean expansion. Furthermore, the near-total eradication of root tumors suggests that the extract may fundamentally fortify the plant's systemic resistance, actively repelling parasitic penetration. These outcomes directly corroborate historical investigations confirming that mahogany derivatives act as potent root-knot inhibitors while simultaneously accelerating general crop vitality.

The data firmly establishes a dose-dependent relationship; maximizing the concentration accelerates the accumulation of active toxic ingredients, leading to faster, more decisive pest elimination. While initial laboratory screening confirmed a rich density of alkaloids, tannins, and flavonoids, it failed to detect distinct phenols or glycosides. This biological variation is completely normal and is generally dictated by the unique environmental stressors and geographical genetics present at the exact harvest site. Despite these minor chemical absences, the remaining secondary metabolites are notorious for their aggressive antifungal, antibacterial, and nematicidal capacities.

These findings align flawlessly with prior in-vivo modeling, reinforcing that mahogany leaf infusions aggressively cleanse agricultural soil of *Meloidogyne* clusters while promoting robust microbial health. The identified flavonoids are particularly adept at shattering the nematode reproductive cycle. Consequently, extracting toxic payloads from various botanical architectures presents an undeniably powerful weapon against agricultural devastation.

Conclusion

This study decisively validates *Khaya senegalensis* leaf extracts as a highly potent, sustainable, and ecologically safe mechanism for dismantling root-knot nematode threats within tomato agriculture. The data unambiguously proves the extract's inherent nematicidal superiority. Because the foliage harbors toxic mechanisms deadly to soil parasites, agricultural workers should be educated on how to actively incorporate these leaves into their tilling routines or directly apply localized extracts to vulnerable crop beds.

The research highlights the critical importance of dosage; weaker botanical solutions lack the concentrated firepower required to yield statistically meaningful differences in plant recovery or pest eradication. The definitive agricultural solution relies heavily on intense, high-saturation treatments. Specifically, flooding the root zone with a 400 mg/ml botanical concentration essentially cures the condition, rivaling the health metrics of entirely uninfected crops.

Embracing mahogany-based interventions provides a tangible pathway away from disastrous synthetic chemicals. By integrating these natural defenses, global farmers can secure their harvest yields while preserving the broader ecological balance. The diverse array of active phytochemicals discovered within the plant ensures multi-tiered disruption of the nematode lifecycle. However, translating these greenhouse successes into massive, open-field frameworks requires continued, rigorous testing to perfectly calibrate application methodologies.

Recommendations

Based on these conclusive findings, the researchers strongly advocate the following:

- Initiate advanced biochemical modeling to isolate and extract the precise nematicidal phytoconstituents utilizing diverse botanical frameworks.
- Aggressively promote the adoption of this botanical methodology among commercial and subsistence farmers to securely neutralize agricultural pest threats.

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