



Original Research Paper

Comparative In Vitro Nematicidal Activity of Aqueous Leaf Extracts of *Datura stramonium* and *Lantana camara* Against *Meloidogyne incognita*

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Abstract

Root-knot nematodes have reduced crop production and increased the interest in botanical sources of nematode management. In the present study, the in vitro activity of aqueous leaf extracts of *Datura stramonium* and *Lantana camara* against second stage juveniles of *Meloidogyne incognita* was compared under a common experimental framework. The shade dried leaf powder was extracted in water (1:10 w/v) at 60-70 °C for 3 hours. Three trials were conducted using nominal extract concentrations of 2%, 4% and 6% and juvenile mortality was assessed after 24, 48, 72 and 96 h. Distilled water was used as negative control and carbosulfan as positive control. Prior to two-way analysis of variance, mortality was adjusted for contemporaneous water-control mortality. *Lantana camara* had the quickest response. At 72 h, observed mortality was $36.00 \pm 22.27\%$, $44.00 \pm 24.33\%$, and $50.67 \pm 27.23\%$ at 2%, 4%, and 6%, respectively, compared with $14.67 \pm 2.31\%$, $17.33 \pm 4.62\%$, and $21.87 \pm 3.70\%$ for *Datura stramonium*. By 96 h, observed mortality reached $84.00 \pm 14.42\%$, $96.00 \pm 4.00\%$, and $100.00 \pm 0.00\%$ for *Lantana camara* and $85.87 \pm 3.70\%$, $94.67 \pm 9.24\%$, and $100.00 \pm 0.00\%$ for *Datura stramonium*. After control adjustment, 96-h mortality remained 76.47-100.00% and 80.37-100.00%, respectively. The effects of the plants were significant at 24, 48 and 72 h, the effects of the concentrations were significant at 24, 48 and 96 h, and no plant $\times$ concentration interaction was observed. Carbosulfan produced 60-64% mortality at 24 h, 84-88% at 48 h, and 100% by 72 h. Both extracts thus showed distinct exposure- and concentration-dependent activity; *Lantana camara* was more fast acting and both botanicals were 100% effective at 6% at 96 h. These results aid in formulation, recovery and greenhouse investigations.

Keywords: botanical nematicide, *Datura stramonium*, *Lantana camara*, *Meloidogyne incognita*, second-stage juvenile, aqueous extract, control-adjusted mortality

1. Introduction

Plant-parasitic nematodes weaken and stunt plants and decrease yield and marketability by impairing root function and water and mineral nutrient uptake. Root-knot nematodes are particularly significant because they can infect a wide variety of plant species and produce distinct feeding sites which result in distinct root galls. *Meloidogyne incognita* is one of the most impactful species affecting tropical and subtropical production systems, with a wide host range and high reproductive potential that makes crop protection challenging (Abd-Elgawad, 2024; Belle et al., 2024; Habteweld et al., 2024; Lilley et al., 2024; Sikora & Fernandez, 2005; Taylor & Sasser, 1978).

Production costs, residue management, non-target effects and regulatory constraints have led to a search for biologically based nematicides that will have the ability to suppress nematode populations quickly, and synthetic nematicides have done just that. Products from plants are of particular interest because the components may affect the motility, integrity of the cuticle, respiratory metabolism, egg hatching, development or host defense of the juveniles.

However, their efficacy is highly dependent on the plant species, plant parts, extraction methods, concentration, and exposure time, and comparative essays must be standardized (Chitwood, 2002; Degroote et al., 2024; Klimpel et al., 2011; Natarajan et al., 2006; Oka et al., 2000; Tsay et al., 2004; Zaidat et al., 2020).

Lantana camara is a medicinal shrub that is a source of triterpenoids and other secondary metabolites that have been reported to be active against root-knot nematode. The nematicidal activity of aqueous leaf preparations was observed in immobilizing and killing juveniles of *Meloidogyne incognita*, while compounds extracted from aerial tissues and roots, such as camarinic acid, lantanilic acid, camaric acid, oleanolic acid and related pentacyclic triterpenoids, have been found to have nematicidal activity in vitro (Ahmad et al., 2010; Begum et al., 2000, 2008; Ghafoor et al., 2025; Ghimire et al., 2015; Qamar et al., 2005). These results indicate that *Lantana camara* is a promising species to be tested in low concentration aqueous formulations.

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Datura stramonium is a weedy medicinal plant of the solanaceous family, which possesses tropane alkaloids, fatty acids and other biologically active components. Extracts of its leaves, shoots, roots and mixed tissues have inhibited juvenile movement and egg hatching of *Meloidogyne incognita*. The response is usually progressive and varies depending on the concentration of the extract and the contact time (Babaali et al., 2017, Imafidor et al., 2023; Oplos et al., 2018). This temporal profile is important for comparison of *Datura stramonium* with botanicals that have a faster mode of action.

In the present study, an aqueous leaf extract of *Datura stramonium* was directly compared to aqueous leaf extract of *Lantana camara* under similar extraction, concentration, replication and observation

conditions. The 2, 4 and 6 per cent of each extract were tested on *Meloidogyne incognita* juveniles for 96 h along with distilled-water and carbosulfan controls. It was assumed that mortality would be greater with the increase in concentration and exposure time, the *Lantana camara* extract would cause the earlier response, and both extracts would have significant endpoint activity.

2. Materials and Methods

The same aqueous-extraction protocol was used for both plant species and the same nematode preparation, concentrations, numbers of juveniles, and observation schedule were used for all treatments. The experimental sequence is outlined in Table 1 and the key isolation and bioassay procedures are described in the following subsections.

stramonium and *Lantana camara* aqueous leaf extracts.

Step	Experimental stage	Procedure	Output
1	Plant collection	Healthy leaves were collected, sorted, washed, and rinsed with distilled water.	Clean leaves
2	Drying and milling	Leaves were shade-dried to constant mass and milled to a uniform powder.	Leaf powder
3	Aqueous extraction	Ten grams of powder were mixed with 100 mL water and stirred at 60-70 °C for 3 h.	Crude extract
4	Clarification	The cooled suspension was centrifuged at 5000 rpm for 10 min and filtered through Whatman No. 1 paper.	Clear extract
5	Infected-material collection	Galled roots, infected plants, and associated soil were collected.	Infected samples
6	Juvenile isolation	A modified Baermann arrangement allowed motile juveniles to migrate into water.	Juvenile suspension
7	Cleaning and standardization	The suspension was cleaned and counted; 125 juveniles were assigned per replicate.	Standardized inoculum
8	Treatment allocation	Extracts at 2%, 4%, and 6% were prepared with water and carbosulfan controls.	Treatment series
9	Mortality assessment	Viability was recorded at 24, 48, 72, and 96 h by response to stimulation.	Observed mortality
10	Data analysis	Triplicate data were summarized, control-adjusted, and analyzed by two-way ANOVA.	Comparative inference

2.1 Plant sampling and preparation of aqueous extracts

The fresh leaves of *Lantana camara* and *Datura stramonium* were taken from the local study area. Damaged or visibly infected leaves were cut off and the rest of the leaves were thoroughly washed with distilled water. The leaves were shaded dried at room temperature until constant weight and ground to a uniform powder. 10 g of powder was added to 100 mL of distilled water (1:10, w/v) and stirred continuously for 3 h at 60-70 °C for each species. The suspension

was cooled to room temperature, centrifuged at 5000 rpm for 10 min and filtered through Whatman No.1 filter paper. The same procedure was used for both plant species.

2.2 Collection, isolation, and microscopic confirmation of nematodes

The source of *Meloidogyne incognita* was root-knot infected plants, galled roots and associated soil. Roots were carefully washed to remove soil, and the root- and soil-samples were transferred to a modified Baermann-type isolation system on tissue or mesh

supports over water in Petri dishes. Motile juveniles were collected and coarse debris was removed to get a cleaner suspension. The recovered material was placed on a counting plate and analyzed using a stereomicroscope. The preparation was confirmed using standard nematode extraction and inoculum procedures (Hooper et al., 2005; Hussey & Barker, 1973), by juvenile morphology, movement and association with characteristically galled roots.

The isolation procedure was performed sequentially, plants with root-knot were collected, the root were washed, root and soil samples were set on tissue or mesh support over water in Petri dishes, the motile juveniles were allowed to migrate into the water, the suspension was collected and the coarse debris was removed, the suspension was transferred to a counting plate, and the juveniles were examined with a stereomicroscope.

2.3 Preparation of treatments, juvenile suspension, and controls

The clear aqueous extracts were diluted with distilled water to give nominal working concentrations of 2%, 4% and 6%. Three trials were performed for each plant × concentration combination and each treatment replicate began with 125 juveniles. The distilled-water negative control was a combination of 5 mL nematode suspension and 5 mL distilled water. A treatment with carbosulfan was used as positive control. All treatments and controls were held under the same laboratory conditions and the same observation schedule was followed.

The bioassay procedure involved preparation of the juvenile suspension, loading the juvenile suspension onto the counting plate, standardizing each replicate to 125 juveniles, allocation of the juveniles to the extract treatments and controls in the Petri dishes, maintaining all the dishes under the same laboratory conditions, and making microscopic assessments according to the observation schedule.

To set up the treatment, three separate series of Petri-dish were prepared for 2%, 4% and 6% aqueous extracts of *Lantana camara* and *Datura stramonium* and three trials were conducted for each plant × concentration.

2.4 Juvenile mortality assessment and control adjustment

Aliquots of the standardized juvenile suspension were subjected to each concentration of extract. Treatment dishes were checked after 24, 48, 72 and 96 hours. A juvenile was non-viable if it failed to respond to gentle mechanical stimulation under the microscope and was immobile. This operational criterion is in line with the accepted in vitro mortality assays where the second-stage juveniles are stimulated before they are classified (Devi & Bora, 2019; Khan et al., 2024). The observed mortality was determined for each replicate of a treatment as follows:

2019; Khan et al., 2024). The observed mortality was determined for each replicate of a treatment as follows:

Observed mortality (%) = (number of non-viable juveniles / total number of juveniles) × 100

Because mortality in the distilled-water controls increased with exposure duration, treatment mortality was also adjusted against the contemporaneous negative control. For each replicate, control-adjusted mortality was calculated as:

Control-adjusted mortality (%) = [(M_t - M₀) / (100 - M₀)] × 100

where M_t is the observed mortality in an extract treatment and M₀ is the observed mortality in the corresponding distilled-water control. Means and standard deviations were computed after correcting each trial value individually.

Microscopic assessment procedure included the examination of each treatment dish, the separation of juveniles from plant and soil debris, the gentle stimulation of immobile juveniles and the record of those which failed to respond as non-viable before mortality was calculated.

2.5 Statistical analysis

The mortality following extract treatment is expressed as mean ± sample standard deviation of three trials. Control adjusted mortality was subjected to a balanced two-way fixed effects analysis of variance (ANOVA) at each exposure time with plant extract (*Datura stramonium* or *Lantana camara*), concentration (2%, 4% or 6%) and the plant × concentration interaction in the model. Type II sums of squares were used. Descriptive summaries were generated for the parallel controls as only one control observation was available at each time point for each plant-assay series. All statistical results were considered significant at a 0.05 level and exact p values were reported. No letter grouping was assigned and treatment means were used to interpret the direction of significant main effects.

3. Results and Discussion

3.1 Control response and overall mortality pattern

For the distilled-water controls, mortality was 0%, 4%, 8% and 32% at 24, 48, 72 and 96 h, respectively, while for the *Datura stramonium* assay, it was 0%, 2.4%, 4% and 28% at 24, 48, 72 and 96 h, respectively. Carbosulfan caused 64%, 84%, 100% and 100% mortality in the *Lantana camara* series and 60%, 88%, 100% and 100% in the *Datura stramonium* series. The positive control, therefore, was rapid and 100% mortality was achieved at 72 h for both assay series. Mortality due to water-control was added to the control adjusted analysis at 96 h. The observed treatment mortality is summarized in Table 2, while the control adjusted values are given in Table 3.

stramonium and *Lantana camara* aqueous leaf extracts (n = 3).

Exposure time	D. stramonium 2%	D. stramonium 4%	D. stramonium 6%	L. camara 2%	L. camara 4%	L. camara 6%

24 h	0.00 ± 0.00	0.00 ± 0.00	6.13 ± 2.01	2.67 ± 2.31	5.33 ± 2.31	9.33 ± 2.31
48 h	4.27 ± 0.46	7.73 ± 0.46	9.07 ± 2.57	10.67 ± 2.31	14.93 ± 1.85	17.33 ± 2.31
72 h	14.67 ± 2.31	17.33 ± 4.62	21.87 ± 3.70	36.00 ± 22.27	44.00 ± 24.33	50.67 ± 27.23
96 h	85.87 ± 3.70	94.67 ± 9.24	100.00 ± 0.00	84.00 ± 14.42	96.00 ± 4.00	100.00 ± 0.00

Note. Each trial began with 125 juveniles. Values are uncorrected observations and therefore retain the direct response recorded in each treatment dish.

Table 3. Control-adjusted mortality (mean ± SD, %) of *Meloidogyne incognita* juveniles exposed to *Datura stramonium* and *Lantana camara* aqueous leaf extracts (n = 3).

Exposure time	D. stramonium 2%	D. stramonium 4%	D. stramonium 6%	L. camara 2%	L. camara 4%	L. camara 6%
24 h	0.00 ± 0.00	0.00 ± 0.00	6.13 ± 2.01	2.67 ± 2.31	5.33 ± 2.31	9.33 ± 2.31
48 h	1.91 ± 0.47	5.46 ± 0.47	6.83 ± 2.63	6.94 ± 2.41	11.39 ± 1.92	13.89 ± 2.41
72 h	11.11 ± 2.41	13.89 ± 4.81	18.61 ± 3.85	30.43 ± 24.21	39.13 ± 26.45	46.38 ± 29.60
96 h	80.37 ± 5.13	92.59 ± 12.83	100.00 ± 0.00	76.47 ± 21.21	94.12 ± 5.88	100.00 ± 0.00

Note. Correction used the contemporaneous distilled-water mortality for each plant-assay series: *Datura stramonium* = 0%, 2.4%, 4%, and 28%; *Lantana*

3.2 Juvenile mortality after 24 h

Low but concentration ordered mortality was observed during the first observation. *Lantana camara* produced 2.67 ± 2.31%, 5.33 ± 2.31%, and 9.33 ± 2.31% mortality at 2%, 4%, and 6%, respectively. There was no mortality in 2% or 4% *Datura stramonium* treatments, but mortality was 6.13 ± 2.01% in the 6% treatment. Observed and control adjusted values were the same for both water controls which were set at 0%. The plant-extract effect was significant (F (1, 12) = 18.766, p = 0.0010), as was the concentration effect (F (2, 12) = 20.468, p = 0.0001). The plant × concentration interaction was not significant (F (2, 12) = 0.894, p = 0.4347).

3.3 Juvenile mortality after 48 h

By 48 h, there was an increase in mortality in all extract treatments. Observed mortality in *Lantana camara* was 10.67 ± 2.31%, 14.93 ± 1.85%, and 17.33 ± 2.31% at 2%, 4%, and 6%, respectively; after water-control adjustment, the corresponding means were 6.94 ± 2.41%, 11.39 ± 1.92%, and 13.89 ± 2.41%. *Datura stramonium* produced observed means of 4.27 ± 0.46%, 7.73 ± 0.46%, and 9.07 ± 2.57%, with adjusted means of 1.91 ± 0.47%, 5.46 ± 0.47%, and

camara = 0%, 4%, 8%, and 32% at 24, 48, 72, and 96 h, respectively.

6.83 ± 2.63%. Both plant identity (F (1, 12) = 42.949, p < 0.0001) and concentration (F (2, 12) = 14.532, p = 0.0006) were significant, whereas the interaction was not (F (2, 12) = 0.410, p = 0.6729).

3.4 Juvenile mortality after 72 h

The two extracts were clearly separated at 72 h. *Lantana camara* produced observed mortality of 36.00 ± 22.27%, 44.00 ± 24.33%, and 50.67 ± 27.23% at 2%, 4%, and 6%, respectively, compared with 14.67 ± 2.31%, 17.33 ± 4.62%, and 21.87 ± 3.70% for *Datura stramonium*. After control adjustment, *Lantana camara* means were 30.43 ± 24.21%, 39.13 ± 26.45%, and 46.38 ± 29.60%, whereas *Datura stramonium* means were 11.11 ± 2.41%, 13.89 ± 4.81%, and 18.61 ± 3.85%. The plant-extract effect remained significant (F (1, 12) = 7.118, p = 0.0205). Concentration (F (2, 12) = 0.561, p = 0.5850) and the plant × concentration interaction (F (2, 12) = 0.077, p = 0.9267) were not significant. The higher standard deviations for *Lantana camara* indicate that the time of the intermediate response was different for each trial, but the mean was still in the same order of 2% to 6%.

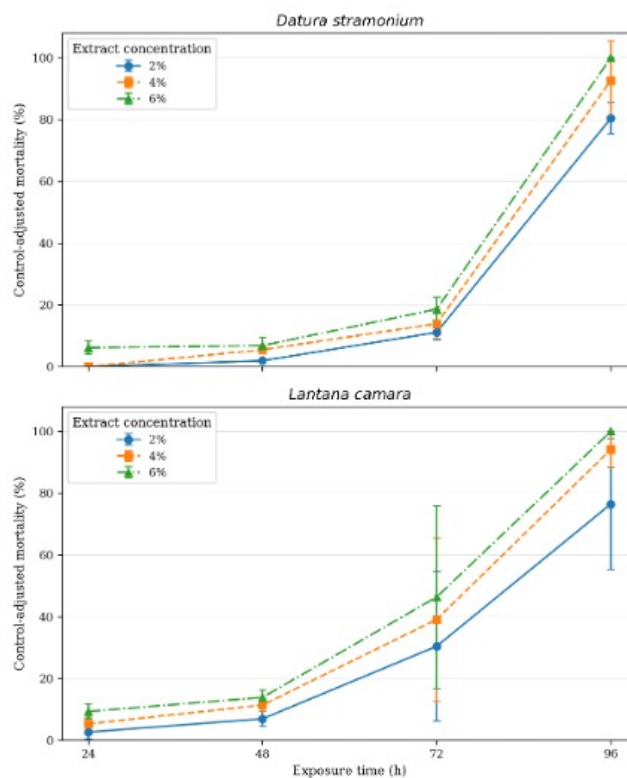


Figure 1. Time course of control-adjusted mortality of *Meloidogyne incognita* juveniles exposed to 2%, 4%, and 6% aqueous leaf extracts of *Datura stramonium* and *Lantana camara*. Points show mean $\pm$ SD (n = 3).

Figure 1 shows the mortality of juveniles of *Meloidogyne incognita* was directly related to the exposure time for both *Datura stramonium* and *Lantana camara* extracts at 2%, 4% and 6% concentrations after the mortality was adjusted for the control. Both extracts caused high mortality by 96 h, with *Lantana camara* having a quicker response until that time. The mean $\pm$ SD overall is given as points.

3.5 Juvenile mortality after 96 h

High endpoint mortality was observed with both extracts. Observed mortality in *Lantana camara* reached $84.00 \pm 14.42\%$, $96.00 \pm 4.00\%$, and $100.00 \pm 0.00\%$ at 2%, 4%, and 6%, respectively; the

corresponding *Datura stramonium* values were $85.87 \pm 3.70\%$, $94.67 \pm 9.24\%$, and $100.00 \pm 0.00\%$. After correction for the 96-h water controls, mortality remained $76.47 \pm 21.21\%$, $94.12 \pm 5.88\%$, and $100.00 \pm 0.00\%$ for *Lantana camara* and $80.37 \pm 5.13\%$, $92.59 \pm 12.83\%$, and $100.00 \pm 0.00\%$ for *Datura stramonium*. Plant identity was no longer significant ($F(1, 12) = 0.025$, $p = 0.8769$), whereas concentration retained a significant effect ($F(2, 12) = 6.511$, $p = 0.0122$). The interaction was not significant ($F(2, 12) = 0.104$, $p = 0.9018$). In all three trials, 6% of the mortality was observed for both the extracts.

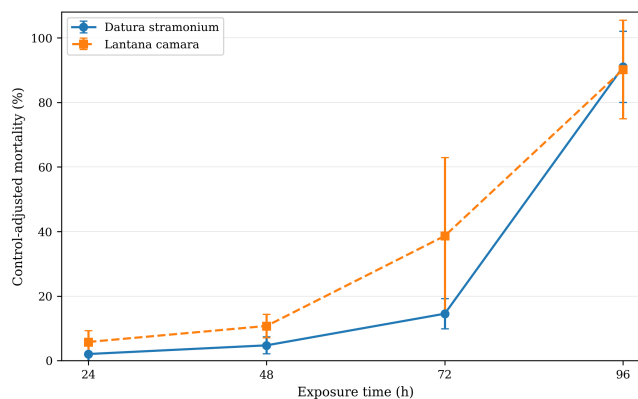


Figure 2. Comparative control-adjusted mortality of *Meloidogyne incognita* juveniles averaged across the three extract concentrations. Points show the descriptive mean $\pm$ SD across nine treatment observations (three concentrations $\times$ three trials) at each exposure time.

Figure 2 shows the comparative control-adjusted mortality of *Meloidogyne incognita* juveniles was higher as exposure time increased for both plant species, at all three extract concentrations. The

mortality of *L. camara* was higher in the early and intermediate periods, especially at 72 h, and mortality was similar at 96 h. Descriptive mean $\pm$ SD are indicated as points.

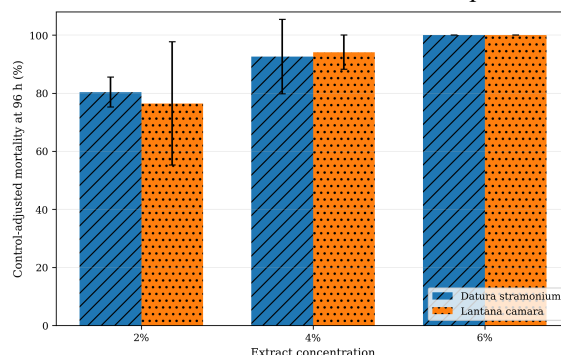


Figure 3. Control-adjusted mortality of *Meloidogyne incognita* juveniles after 96 h of exposure to 2%, 4%, and 6% aqueous leaf extracts. Bars show mean $\pm$ SD (n = 3).

Figure 3 shows the extract concentration of both *Datura stramonium* and *Lantana camara* caused a linear increase in the control adjusted mortality of *M. incognita* juveniles after 96 h. Both extracts had lower mortality rates of 2%, higher rates of 4% and death rates of 100% at 6%. Bars are treatment means $\pm$ standard deviations of three independent replicated trials.

3.6 Two-way ANOVA summary

The factorial analysis showed that the main difference between the plant extracts was the time. Plant identity was a significant factor at 24, 48 and 72 h, indicating the quicker effect of *Lantana camara*, but the plant effect was lost at 96 h when both extracts agreed with high mortality. Concentration had an effect at 24 and 48 h, and at the 96-h end point. The concentration gradient was broadly similar in the two plant extracts as no plant $\times$ concentration interaction was significant at any observation time.

Table 4. Two-way ANOVA of control-adjusted juvenile mortality with plant extract and concentration as fixed factors at each exposure time.

Time	Source	SS	df	MS	F	p value
24 h	Plant extract	62.720	1	62.720	18.766	0.0010
24 h	Concentration	136.818	2	68.409	20.468	0.0001
24 h	Plant $\times$ concentration	5.973	2	2.987	0.894	0.4347
24 h	Error	40.107	12	3.342	-	-
48 h	Plant extract	162.262	1	162.262	42.949	<0.0001
48 h	Concentration	109.803	2	54.902	14.532	0.0006
48 h	Plant $\times$ concentration	3.094	2	1.547	0.410	0.6729
48 h	Error	45.337	12	3.778	-	-
72 h	Plant extract	2615.881	1	2615.881	7.118	0.0205
72 h	Concentration	412.208	2	206.104	0.561	0.5850
72 h	Plant $\times$ concentration	56.330	2	28.165	0.077	0.9267
72 h	Error	4410.121	12	367.510	-	-
96 h	Plant extract	2.820	1	2.820	0.025	0.8769

96 h	Concentration	1465.747	2	732.874	6.511	0.0122
96 h	Plant × concentration	23.481	2	11.741	0.104	0.9018
96 h	Error	1350.751	12	112.563	-	-

Note. Type II sums of squares were used. p values are rounded to four decimal places; values below 0.0001 are shown as <0.0001.

Both the aqueous leaf extracts showed two complementary response patterns, where the activity increased with increasing exposure and *Lantana camara* was more active in the first 72 h. The higher mean of *Lantana camara* at each concentration for 24, 48 and 72 h was associated with the significant plant effects at these times. At 96 h, the plant effect was no longer evident as both extracts were similarly high in mortality, including complete mortality at 6%. The control adjusted endpoints also support the idea that this convergence was not just due to the late rise in the water-control mortality.

The early and intermediate activity of *Lantana camara* was in line with previous studies reporting the fast action of aqueous leaf preparation on *Meloidogyne incognita* juveniles leading to their rapid paralysis and death (Ahmad et al., 2010; Ghimire et al., 2015). Several pentacyclic triterpenoids and their metabolites have been reported from this species, which are nematocidal when isolated from aerial tissues and roots (Begum et al., 2000, 2008; Ghafoor et al., 2025; Qamar et al., 2005). Although the present assay could not be used to identify the active molecules, the ordered increase of mean mortality from 2% to 6% at each observation suggested that the more extractable molecules that were present, the stronger the response. The large standard deviations at 72 h reflect the variation in the timing of the response from trial to trial and not a change in the overall direction of the response.

The *Datura stramonium* showed a slower profile. The 2% and 4% treatments were not lethal at 24 h, while the 6% treatment was already effective. In the following, mortality was found to be continuously rising at all concentrations, and the difference in mortality between 72 and 96 h was significant. This is in line with previous studies that demonstrated that extracts of *Datura* suppressed the movement of juveniles and egg hatching in a time- and concentration-dependent manner (Babaali et al., 2017; Imafidor et al., 2023; Oplos et al., 2018). Cumulative physiological disruption or gradual uptake of tropane alkaloids, fatty acids and other constituents may play a role, but targeted chemical and mechanistic studies are required to determine the individual role played by these constituents.

The distribution of concentrations was quite uniform. In both plants, the mean response was non-decreasing with each observation from 2 to 6 percent and the 6 percent treatment had the highest means or caused total mortality. The main effect of concentration was significant at 24 and 48 h because higher extract concentrations increased the developing response, and at 96 h, the 2% treatment

was less than the 4% and 6% treatments. At 72 h, the variation between the *Lantana camara* trials was relatively large at this intermediate time and concentration was not significant. The rate of action was different for the two plant species, but the overall concentration gradient was not significant and consistent for both, as shown by the consistently non-significant interaction.

Carbosulfan was a good reference point for fast action, as it caused 60-64% mortality at 24 h, 84-88% at 48 h and 100% mortality at 72 h. The botanical extracts took a longer time to develop but were quite active at 96-h. Control adjustment was especially informative at the last observation where the mortality rate in water-control had risen to 28-32%. Following this adjustment, the 4% and 6% treatments still had 92.59-100.00% mortality and the 2% treatments 76.47-80.37% mortality. Thus, the data are indicative of a strong endpoint response at the higher concentrations and the utility of maintaining both observed and control adjusted estimates in extended in vitro assays.

One of the strengths of the study was that the two plants were compared directly using the same extraction procedure (aqueous), the same number of juveniles (12), the same concentration range (0.0001%, 0.01%, 0.1%, 1%, 10%, and 100%), the same replication (4), and the same observation schedule. The four observation periods are distinguished between early speed of action and final activity. The operational mortality criterion applied here is suitable for comparative screening, while further resolution of persistent mortality from reversible immobilization would be achieved by recovery testing in clean water. Further studies are also needed to standardize the extract yield per unit volume, characterize the active chemical fractions, extend the concentration range for the LC50 and LC90 estimation, evaluate egg hatching and plant safety, and validate the most promising treatments in greenhouse and field systems (Abd-Elgawad, 2024; Degroote et al., 2024; Oka et al., 2000).

4. Conclusion

The aqueous leaf extracts of both *L. camara* and *D. stramonium* showed significant in vitro nematocidal activity against the juveniles of *Meloidogyne incognita* and the activity was found to increase with increasing time of exposure. *L. camara* had a relatively quick response, with higher levels of juvenile mortality in the early and intermediate exposure periods, while *D. stramonium* had a more gradual increase in activity. High mortality was observed at all concentrations at 96 h. Notably, 100% mortality was obtained in each of the three trials for

both plant species at the highest concentration tested, 6%. The temporal pattern suggests that nematocidal activity is influenced by the duration of exposure and generally, the higher the concentration of the extract, the more active it was. The relatively fast activity of *L. camara* and high endpoint activity of *D. stramonium* indicate their potential as plant-derived alternative root-knot nematode management tools. Overall, both species are promising candidates for developing botanical nematicides. More research is needed to characterize active constituents, confirm irreversible nematocidal activity, optimize application rates and to determine their practical efficacy under crop-production conditions, including recovery assays, standard formulations, phytochemical characterization, concentration-response experiments and greenhouse experiments.

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Author Contributions

Rashmi Vats: Methodology, Laboratory Analysis, Manuscript text

Dr. Chandrima Mandal: Review of Manuscript text

Conflict of Interest

The authors declare that there is no conflict of interest.

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