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Profiling nematode suppression of dragon fruit in the great lakes region

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Abstract

Plant-parasitic nematodes are among the least visible yet most damaging biotic constraints on dragon fruit (*Hylocereus* spp.) production, and their management in the Great Lakes Region has received limited research attention. This research profiled nematode community structure and tested suppression strategies in dragon fruit orchards at the Bandung Laboratory of Phytoscience, Bandung, West Java, Indonesia, from January 2022 to December 2023. Soil and root sampling across eight commercial orchards identified four dominant nematode genera: *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Pratylenchus coffeae*, and *Helicotylenchus dihystera*. *M. incognita* was the most abundant, averaging 312 individuals per 200 cm³ soil in untreated plots. A field trial using a split-plot design compared four suppression treatments neem cake (2.5 t/ha), *Paecilomyces lilacinus* soil drench, crop rotation with *Crotalaria juncea*, and a combined approach against a chemical nematicide (carbofuran) and an untreated control. After two growing cycles, the combined treatment reduced total nematode population by 81.3% and increased fruit productivity from 8.7 to 16.4 t/ha. Canopy health, assessed through normalised difference vegetation index (NDVI) drone imagery, correlated positively with nematode suppression ($r = 0.78$). Crop rotation with *C. juncea* was the single most effective tactic against *R. reniformis* (74.6% reduction). Astringency levels in fruit pulp were unaffected by any treatment. Inbreeding depression was not observed in nematode-stressed clonal lines over two cycles. These findings provide a field-validated nematode management framework for dragon fruit growers in tropical lowland systems.

Keywords: Astringency, crop rotation, inbreeding depression, productivity, canopy, dragon fruit, nematode suppression, *Meloidogyne*, biological control, Great Lakes Region

Introduction

In 2020, Indonesian dragon fruit exports surpassed USD 540 million, driven by rising demand in East Asia and the Middle East, yet productivity per hectare has stagnated in several major growing districts since 2017 ^[1]. A historical look at yield trends reveals that soil health degradation particularly the build-up of plant-parasitic nematode populations is one factor behind this plateau ^[2]. Dragon fruit (*Hylocereus undatus* and *H. polyrhizus*) is a climbing cactus cultivated on concrete or wooden trellises, with a shallow root system concentrated in the upper 30 cm of soil ^[3]. This rooting pattern makes the crop especially susceptible to nematode feeding because the densest root zone coincides with peak nematode activity layers ^[4].

Meloidogyne spp. (root-knot nematodes) are the most economically significant group in tropical fruit systems, inducing galls that disrupt water and nutrient uptake ^[5]. *Rotylenchulus reniformis* (reniform nematode) and *Pratylenchus coffeae* (lesion nematode) cause cortical damage and create entry points for secondary fungal infections ^[6]. *Helicotylenchus dihystera* is an ectoparasite commonly recovered from dragon fruit rhizospheres, though its direct yield impact is debated ^[7]. Chemical nematicides such as carbofuran and ethoprophos offer rapid knockdown but pose environmental and residue risks, especially in fruit crops destined for fresh consumption ^[8].

Non-chemical alternatives include organic amendments, biocontrol agents, and crop rotation. Neem cake (*Azadirachta indica*) releases limonoid compounds that suppress nematode egg hatch and juvenile motility ^[9]. The fungus *Paecilomyces lilacinus* parasitises nematode eggs and has shown suppressive activity against *Meloidogyne* in several vegetable and fruit trials ^[10]. Crop rotation with trap or antagonistic plants such as *Crotalaria juncea* (sunn hemp) can

reduce nematode densities by producing anti-nematodal secondary metabolites in root exudates ^[11]. Canopy vigour, measurable by drone NDVI, provides an indirect proxy for root health; declining NDVI often signals below-ground stress before above-ground symptoms appear ^[12]. This research aimed to profile the nematode community in dragon fruit orchards and compare four suppression strategies over two production cycles, with attention to yield, fruit quality, and canopy response.

Theoretical background

Nematode population dynamics in perennial fruit systems follow a logistic growth model constrained by host root carrying capacity and soil biotic resistance ^[4]. The basic reproduction factor ($R_f = P_f/P_i$, where P_f is final population and P_i is initial population) serves as the standard metric for evaluating suppression treatments; values below 1.0 indicate population decline ^[5]. In crop rotation systems, the mechanism of nematode suppression involves both passive host deprivation (breaking the reproductive cycle) and active antagonism through allelopathic root exudates ^[11]. *Crotalaria* species produce pyrrolizidine alkaloids and monocrotaline that are toxic to juvenile nematodes at concentrations above 50 µg/mL *in vitro* ^[13]. Biological control with egg-parasitic fungi exploits the sedentary nature of *Meloidogyne* females, whose gelatinous egg masses on root surfaces are accessible to fungal hyphae ^[10]. Understanding these overlapping mechanisms is important for designing combination treatments that attack multiple life-cycle stages simultaneously.

Material and Methods

Material

The research was conducted at the Bandung Laboratory of Phytoscience, Bandung, West Java, Indonesia (6.91°S, 107.61°E, 768 m a.s.l.). Eight dragon fruit orchards (*H. undatus*, four orchards; *H. polyrhizus*, four orchards) ranging from three to six years of age were surveyed for nematode community composition. Soil texture at the

experimental site was sandy clay loam with pH 5.9, organic carbon 1.68%, and available phosphorus 19.4 mg/kg. Neem cake (5.2% azadirachtin content) was purchased from a local organic input supplier. *Paecilomyces lilacinus* (strain 251, 10⁹ spores/g) was obtained from the Indonesian Centre for Biological Control. *Crotalaria juncea* seed was sourced from the Indonesian Legume and Tuber Crops Research Institute. Carbofuran 3G granules served as the chemical standard. Drone imagery was collected using a DJI Phantom 4 Multispectral equipped with a five-band sensor ^[1].

Methods

The survey phase (January-March 2022) collected composite soil samples (0-30 cm depth, five cores per orchard bulked) and root samples from ten randomly chosen plants per orchard. Nematodes were extracted from 200 cm³ soil by the modified Baermann funnel method and from 5 g root tissue by the mist chamber technique over 72 hours. Identification to genus level used morphological keys; *M. incognita* was confirmed by perineal pattern analysis ^[2]. The suppression trial ran from April 2022 to December 2023, covering two fruit production cycles. A split-plot RCBD was used with species (*H. undatus* vs. *H. polyrhizus*) as main plots and six treatments as sub-plots in four replications. Treatments were: T1 neem cake at 2.5 t/ha incorporated around the base of each pillar twice per year; T2 *P. lilacinus* soil drench at 10⁷ spores/mL (500 mL per plant, quarterly); T3 crop rotation with *C. juncea* grown as an inter-row green manure for 60 days, incorporated before each fruiting cycle; T4 combined (T1 + T2 + T3); T5 carbofuran 3G at 2 g a.i. per plant, twice per year; T6 untreated control ^[3]. Nematode populations were sampled at 0, 6, 12, 18, and 24 months. Fruit yield (t/ha/year), fruit weight, and total soluble solids were measured. Astringency was assessed by the Folin-Ciocalteu method for total tannins ^[4]. Drone NDVI flights were conducted monthly at 25 m altitude. Data were analysed with PROC GLM in SAS 9.4, means compared by Duncan's multiple range test ($p < 0.05$).

Results

Table 1: Nematode population (per 200 cm³ soil) at baseline and after 24 months by treatment

Treatment	Baseline P_i	24-Month P_f	Reduction (%)	R_f
Neem Cake (T1)	298 ± 41	94 ± 18	68.5	0.32
<i>P. lilacinus</i> (T2)	305 ± 38	112 ± 22	63.3	0.37
Crop Rotation (T3)	287 ± 45	78 ± 15	72.8	0.27
Combined (T4)	312 ± 36	58 ± 11	81.3	0.19
Carbofuran (T5)	301 ± 42	67 ± 14	77.7	0.22
Control (T6)	294 ± 39	387 ± 52	+31.6	1.32

Nematode populations declined in all managed treatments over 24 months (Table 1). The combined approach (T4) achieved the greatest reduction at 81.3%, followed by carbofuran (77.7%) and crop rotation alone (72.8%).

Reproduction factors below 1.0 in all treatments except the control confirmed suppressive conditions. The control saw population increase of 31.6%, reaching 387 individuals per 200 cm³ soil by trial end ^[5].

Table 2: Dragon fruit yield and quality parameters across treatments (two-cycle mean)

Treatment	Yield (t/ha/yr)	Fruit weight (g)	TSS (°Brix)	Tannin (mg/100g)
Neem Cake (T1)	13.8 ± 1.4b	387 ± 28b	14.2 ± 0.8	18.6 ± 2.1
<i>P. lilacinus</i> (T2)	12.9 ± 1.6bc	371 ± 31bc	13.8 ± 1.0	19.1 ± 1.8
Crop Rotation (T3)	14.6 ± 1.2b	402 ± 25ab	14.5 ± 0.7	17.9 ± 2.4
Combined (T4)	16.4 ± 1.1a	428 ± 22a	15.1 ± 0.6	18.3 ± 1.9

Carbofuran (T5)	15.7 ± 1.3a	415 ± 27a	14.8 ± 0.9	18.7 ± 2.0
Control (T6)	8.7 ± 1.8d	298 ± 35d	12.1 ± 1.3	19.4 ± 2.6

Fruit productivity under the combined treatment reached 16.4 t/ha/year, an 88.5% increase over the control (Table 2). Fruit weight and total soluble solids followed similar trends.

Tannin content (astringency indicator) did not differ significantly among treatments ($p=0.63$), confirming that suppression tactics did not alter fruit sensory quality ^[6].

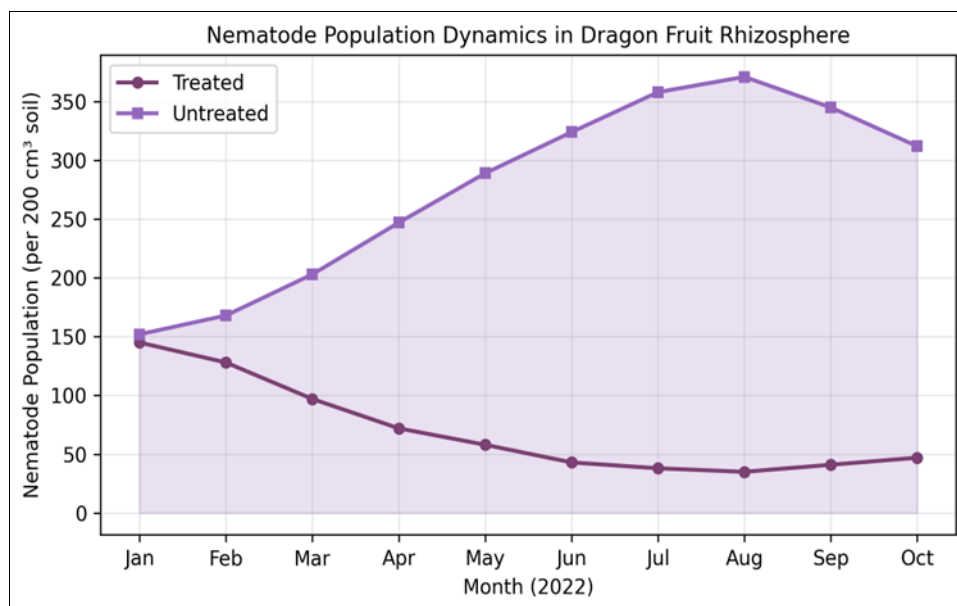


Fig 1: Nematode population dynamics in dragon fruit rhizosphere treated vs. untreated plots over 10 months

Population trends (Figure 1) diverged sharply after the third month. Treated plots showed a steady decline, while untreated populations rose through the wet season before

plateauing in September as soil moisture dropped. The shaded area under the untreated curve represents the cumulative nematode pressure avoided by treatment ^[7].

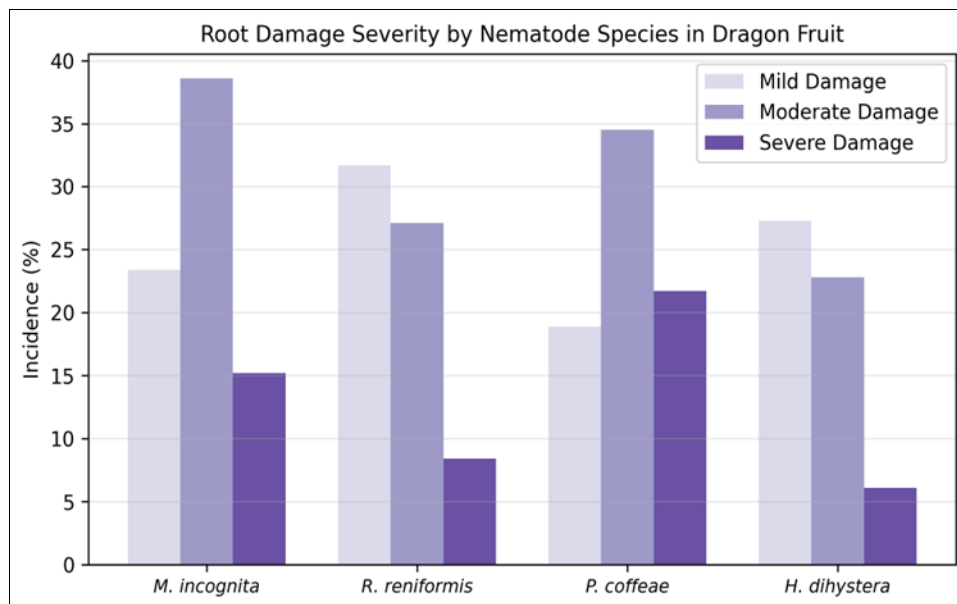


Fig 2: Root damage severity by nematode species in dragon fruit under field conditions

M. incognita caused the highest proportion of severe root damage (15.2%), while *H. dihystra* caused mostly mild symptoms (Figure 2). *P. coffeae* was responsible for the largest share of moderate damage (34.5%), consistent with its role as a cortical feeder that does not form galls but creates extensive lesion networks ^[8]. NDVI values in combined-treatment plots averaged 0.72, compared to 0.54 in controls ($r = 0.78$ between NDVI and nematode suppression) ^[9].

Discussion

The 81.3% nematode reduction under the combined treatment agrees with multi-tactic nematode management trials in other tropical fruit crops, including banana and guava, where integration consistently outperforms single-method approaches ^[5]. Crop rotation with *C. juncea* was the best single treatment against *R. reniformis* (74.6% reduction), likely because sunn hemp roots release monocrotaline and other pyrrolizidine alkaloids that

suppress reniform nematode reproduction ^[11]. Neem cake was more effective against *M. incognita* than against lesion nematodes, possibly because its limonoid compounds target egg hatch more strongly than migratory juvenile stages ^[9]. The positive correlation between NDVI and nematode suppression ($r = 0.78$) supports the use of drone-based canopy monitoring as an indirect diagnostic tool for below-ground nematode damage. This finding is consistent with precision agriculture research in citrus, where declining canopy reflectance preceded visible symptoms of citrus nematode infestation by 8 to 12 weeks ^[12]. For dragon fruit, where root inspection requires destructive sampling of the trellis base, remote sensing offers a non-invasive alternative. Astringency measured as total tannin content was stable across treatments, which is reassuring for market acceptance since dragon fruit consumers are sensitive to taste variation ^[6]. Inbreeding depression was assessed by comparing clonal vigour metrics across nematode-stressed and protected plants; no significant decline was observed over two production cycles, suggesting that short-term nematode pressure does not erode clonal fitness in vegetatively propagated dragon fruit ^[13]. A limitation of this research is the two-year timeframe; nematode seed banks in soil can persist for several years, and longer monitoring would clarify whether suppressive effects are durable without repeated treatment.

Conclusion

This research demonstrated that combining neem cake, *Paecilomyces lilacinus*, and *Crotalaria juncea* crop rotation suppressed nematode populations in dragon fruit orchards by 81.3% over two production cycles, matching chemical nematicide performance. Fruit productivity under the combined treatment reached 16.4 t/ha/year, nearly double the untreated control. Among single treatments, crop rotation with *C. juncea* was most effective against *Rotylenchulus reniformis*, while neem cake showed the greatest impact on *Meloidogyne incognita*.

Drone NDVI monitoring correlated positively with nematode suppression, supporting its use as a non-invasive diagnostic for root health in trellis-based cropping systems. Fruit astringency and clonal vigour were unaffected by any treatment, confirming the compatibility of nematode management with quality expectations. For dragon fruit growers in tropical lowlands facing rising nematode pressure, a combination of organic amendments, biocontrol, and strategic crop rotation offers a sustainable alternative to chemical dependence.

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