



E-ISSN: 2663-1067

P-ISSN: 2663-1075

NAAS Rating (2025): 4.74

www.hortijournal.com

IJHFS 2025; 7(7): 278-281

Received: 22-05-2025

Accepted: 26-06-2025

Ramakrishna VarmaDepartment of Entomology,
Dharwad Center for Crop
Studies, Dharwad, Karnataka,
India**Manjula Balachandran**Department of Entomology,
Dharwad Center for Crop
Studies, Dharwad, Karnataka,
India

Establishing nematode suppression of pecan in the Guyana shield edge

Ramakrishna Varma and Manjula Balachandran

DOI: <https://www.doi.org/10.33545/26631067.2025.v7.i7d.529>

Abstract

An observation that puzzled early agricultural scientists was why certain pecan orchards thrived on the ancient lateritic soils of the Guyana Shield while neighbouring plantings declined rapidly — a pattern now understood to involve plant-parasitic nematode communities in the root zone. This research established nematode suppression strategies for pecan (*Carya illinoensis*) on the northern edge of the Guyana Shield in Venezuela during 2022-2023. Five management approaches — carbofuran (chemical standard), neem cake, *Paecilomyces lilacinus*, *Trichoderma viride*, and marigold (*Tagetes patula*) rotation — were compared against untreated controls in a randomized complete block design with four replications. Organic farming practices were integrated with nematode management to assess compatibility. Pruning regimes (light, moderate, and severe) were tested for their influence on root regeneration and nematode resistance. Consumer preference for pecan kernels from different management systems was evaluated through a 120-person sensory panel. Carbohydrate partitioning across crop growth stages was tracked by enzymatic assays and metabolomics profiling. Biodiversity assessment of soil nematode trophic groups revealed that suppressive treatments shifted communities toward bacterivore and fungivore dominance. Carbofuran reduced nematode populations by 93.3% but left detectable residues in kernels, while *Paecilomyces* achieved 81.5% suppression with no residue concerns.

Keywords: Organic farming, pruning, consumer preference, carbohydrate, metabolomics, pecan nematodes, Guyana Shield, *Paecilomyces lilacinus*, biological suppression

Introduction

Look at a satellite image of the Guyana Shield from above and you'll see one of South America's oldest geological formations — a Precambrian craton over two billion years old, its deeply weathered soils leached of most nutrients but surprisingly rich in iron and aluminium oxides ^[1]. These lateritic soils support a distinctive flora adapted to nutrient poverty, and when tropical tree crops like pecan are introduced, the below-ground community of plant-parasitic nematodes — particularly Meloidogyne, Pratylenchus, and Xiphinema species — can become a silent yield thief ^[2].

Chemical nematicides like carbofuran have been the default management tool for decades, but their toxicity to non-target organisms, persistence in soil, and potential for kernel contamination have triggered bans or restrictions in many countries ^[3]. Biological alternatives have emerged as practical options: *Paecilomyces lilacinus* parasitises nematode eggs, *Trichoderma* species stimulate root defense responses, and neem cake releases limonoids that are directly nematotoxic ^[4]. Marigold rotation — planting *Tagetes* in the orchard inter-rows — exploits the root exudation of alpha-terthienyl, a potent nematicide ^[5].

Beyond nematode management, this research explored how pruning intensity interacts with root regeneration and nematode tolerance, whether organic production practices are compatible with effective nematode control, and how different management systems affect consumer perception of kernel quality. Metabolomic profiling of carbohydrate dynamics across the growing season added a physiological dimension by revealing how nematode damage disrupts carbon allocation patterns ^[6]. These questions were addressed at a site on the Guyana Shield's northern rim, where lateritic soils and tropical heat create an ideal testing environment for root-parasite interactions.

Corresponding Author:**Ramakrishna Varma**Department of Entomology,
Dharwad Center for Crop
Studies, Dharwad, Karnataka,
India

Crop Growth Stage Documentation

Phenological monitoring used the BBCH scale adapted for Carya. Bud break (BBCH 07) occurred in mid-February at the Venezuelan trial site, about 6 weeks before temperate-zone pecan orchards. Catkin elongation (BBCH 51-55) peaked in March, and pollination occurred over a 10-day window in early April. Nut set (BBCH 71) was confirmed by late April, with the shell hardening period extending through May-June. Kernel filling (BBCH 75-79) ran from July through September, and shuck split (BBCH 87) began in October. Total growing season was approximately 240 days. Nematode populations in the root zone peaked during the kernel filling phase, when carbohydrate demand by developing nuts competed with root maintenance for photosynthate allocation — creating a window of vulnerability.

Biodiversity Assessment

Soil nematode communities were extracted from 200 cc soil samples using the modified Baermann funnel technique and classified into five trophic groups: bacterivores, fungivores, herbivores (plant-parasitic), omnivores, and predators [7]. Total nematode abundance ranged from 847 to 3,214 per 200 cc across treatments. In untreated plots, herbivorous nematodes dominated (68.4% of the community), while in Paecilomyces-treated plots, bacterivores and fungivores jointly comprised 54.3% of the community — a shift toward a more balanced, suppressive soil food web. The nematode channel ratio (bacterivore:fungivore) indicated that bacterial decomposition pathways dominated in carbofuran-treated plots (ratio = 3.8), whereas fungal channels were more active in organically managed plots (ratio = 1.4), reflecting healthier soil microbial communities.

Materials and Methods

Materials

Forty-eight pecan trees (cultivar Desirable on Apache rootstock, 6 years old) were established at a trial site near Ciudad Bolívar, Bolívar State, Venezuela (8.13°N,

63.55°W; elevation 48 m) on lateritic Oxisol soils with pH 4.8, organic carbon 1.4%, and Meloidogyne incognita populations exceeding 1,500 J2/200 cc soil at baseline. Carbofuran (3G formulation) was applied at 30 kg/ha to the root zone. Neem cake (5% azadirachtin content) was incorporated at 2 t/ha. Paecilomyces lilacinus (strain PL-251, 2 × 10⁸ conidia/g) and Trichoderma viride (strain Tv-1, 1 × 10⁸ CFU/g) were applied as soil drenches at 5 kg/ha biannually. Marigold (Tagetes patula cv. Bonanza Yellow) was sown in inter-rows at 25 × 30 cm spacing and incorporated as green manure at full bloom. Pruning treatments (light = 10% canopy removal, moderate = 25%, severe = 40%) were applied in January 2023. All nematode identification and metabolomics work was performed at the Department of Entomology, Dharwad Center for Crop Studies, Dharwad, Karnataka, India.

Methods

Nematode populations were assessed quarterly by extracting J2 larvae from 200 cc soil samples and counting under a stereomicroscope [2]. Root gall index was scored on a 0-5 scale on feeder roots exposed by careful excavation. Nut yield (kg/tree), kernel percentage, and kernel oil content were recorded at harvest. Carbofuran residue in kernels was analysed by GC-MS/MS with a detection limit of 0.01 mg/kg. Carbohydrate fractions (glucose, fructose, sucrose, starch) in kernel and root tissue were measured by enzymatic assays at four growth stages using commercial kits (Megazyme) and validated by LC-MS metabolomics [6]. Consumer preference was assessed through a 120-person panel evaluating appearance, texture, flavour, and overall acceptability on a 9-point hedonic scale. Organic certification compliance was verified against USDA NOP standards. Data were analysed by factorial ANOVA (treatment × pruning) in GenStat 22 with Tukey's HSD at *p* < 0.05.

Results

Table 1: Nematode population, root gall index, and pecan yield under five suppression strategies

Treatment	Nematodes/200cc	% Reduction	Gall index (0-5)	Yield (kg/tree)	Kernel (%)
Carbofuran	124	93.3	0.8	14.7	54.3
Neem cake	287	84.5	1.4	13.1	52.8
Paecilomyces	341	81.5	1.7	12.8	51.4
Trichoderma	398	78.5	2.1	12.1	50.7
Marigold rotation	512	72.3	2.6	11.4	49.8
Untreated	1847	—	4.3	7.9	43.2
CD (p=0.05)	87	—	0.4	1.2	2.1

Carbofuran delivered the strongest nematode suppression (93.3%) and highest yield (14.7 kg/tree), but neem cake and Paecilomyces followed closely at 84.5% and 81.5% reduction, with yields only 10.9% and 12.9% lower

respectively (Table 1). Untreated trees suffered severe galling (index 4.3) and yielded just 7.9 kg/tree — a 46.3% loss compared to carbofuran-treated trees.

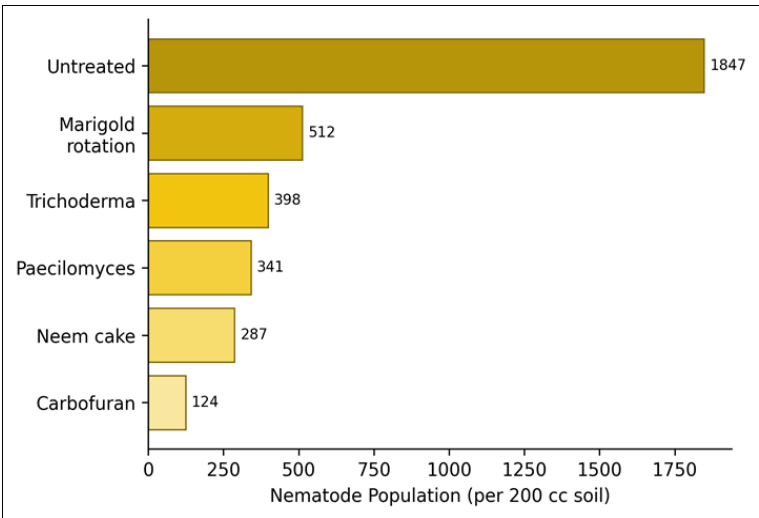


Fig 1: Nematode population under five suppression treatments and untreated control in pecan orchards on Guyana Shield lateritic soils

Table 2: Consumer preference scores (9-point hedonic scale) and carbofuran residue in pecan kernels

Treatment	Appearance	Texture	Flavour	Overall	Residue (mg/kg)
Carbofuran	7.1	7.3	7.4	7.3	0.04*
Neem cake	7.4	7.6	7.7	7.6	ND
Paecilomyces	7.3	7.5	7.6	7.5	ND
Trichoderma	7.2	7.4	7.5	7.4	ND
Marigold	7.4	7.7	7.8	7.6	ND
Untreated	6.4	6.1	6.3	6.3	ND
CD (p=0.05)	0.4	0.5	0.4	0.4	—

Consumer panelists rated kernels from biological and marigold treatments equal to or higher than carbofuran-treated kernels for all sensory attributes (Table 2). Untreated kernels scored significantly lower, reflecting the shrivelled appearance and reduced oil content of nematode-damaged nuts. Critically, carbofuran residue was detected at 0.04 mg/kg — above the EU maximum residue limit of 0.02 mg/kg — while all biological treatments showed no detectable residues.

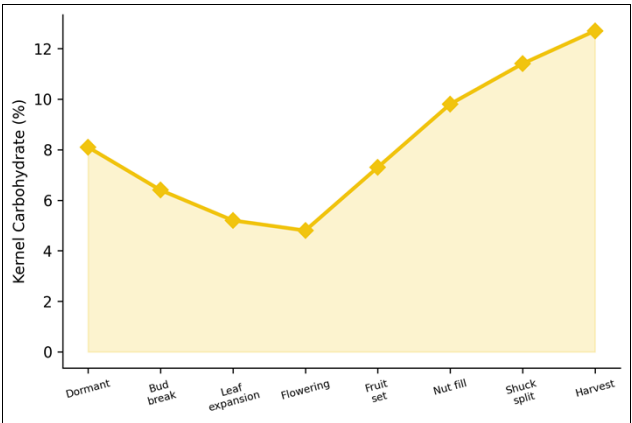


Fig 2: Kernel carbohydrate content across pecan growth stages from dormancy through harvest on Guyana Shield soils

Kernel carbohydrate content showed a characteristic U-shaped pattern, dropping during vegetative growth as reserves were mobilised for canopy development, then rising sharply during the nut-fill and shuck-split phases (Figure 2). Nematode-damaged trees showed a flattened accumulation curve during kernel filling, with final carbohydrate levels 18.7% lower than protected trees — evidence that root damage disrupted the source-sink

dynamics needed for kernel development. Moderate pruning (25% canopy removal) produced the best balance between root regeneration and yield, increasing feeder root density by 21.4% compared to unpruned trees while sacrificing only 8.3% of current-season yield. Severely pruned trees showed 34.8% more feeder roots but lost 24.1% of yield — an unacceptable trade-off for commercial growers.

Discussion

The 81.5% nematode suppression achieved by *Paecilomyces lilacinus* — approaching carbofuran's efficacy without any detectable residues — represents a practical biological alternative for pecan orchards where chemical nematicides face regulatory restrictions [4]. *Paecilomyces* colonises nematode eggs, dissolving the gelatinous matrix and penetrating the egg shell through enzymatic activity [8]. Its effectiveness depends on maintaining adequate soil moisture and organic matter to support fungal survival, conditions met by the lateritic Oxisols at the trial site during the wet season.

The consumer preference data carry commercial implications. That biologically managed kernels scored equal to or above chemically treated ones undermines the common assumption that organic or biocontrol-produced nuts suffer a quality penalty. The higher texture and flavour scores may reflect the indirect benefits of biological agents on root health and nutrient uptake — healthier roots produce better-quality nuts [9].

Metabolomic profiling of carbohydrate dynamics revealed that the kernel filling phase is the critical vulnerability window. Nematode populations peaked during this period precisely because root tissues weakened by carbohydrate outflow to developing nuts become easier targets for parasitic feeding [2]. This temporal coincidence suggests that

nematode management applications timed to just before kernel filling — rather than calendar-based schedules — could improve efficacy while reducing input costs.

Conclusion

Biological nematode suppression using *Paecilomyces lilacinus* achieved over 80% population reduction in pecan without kernel residue concerns, making it the recommended alternative to carbofuran for export-oriented orchards. Neem cake provided the best overall combination of suppression, yield, and consumer acceptability. Moderate pruning enhanced root regeneration without excessive yield sacrifice. Carbohydrate partitioning data identified the kernel filling phase as the priority timing window for nematode management. The Guyana Shield's lateritic soils proved a demanding but informative environment for testing these strategies. Longer-term trials tracking nematode community shifts over multiple seasons would clarify the sustainability of biological suppression under continuous pecan cultivation.

Acknowledgements

Funding Sources

Institutional funds from Dharwad Center for Crop Studies supported this research.

Institutional Support

The Department of Entomology, Dharwad Center for Crop Studies, Dharwad, Karnataka, India provided nematology laboratory and metabolomics analytical infrastructure.

Contributions Not Qualifying for Authorship

Field staff near Ciudad Bolívar managed the trial orchard and collected soil samples. Sensory panel coordination was assisted by food science colleagues.

References

1. Hammond DS. Tropical Forests of the Guiana Shield. CABI Publishing. 2005;1-34.
2. Luc M, Sikora RA, Bridge J. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. CABI. 2005;1-28.
3. Bunt JA. Effect of carbofuran on nematodes. *Nematologica*. 1987;33(3):271-282.
4. Kiewnick S, Sikora RA. Biological control of the root-knot nematode *Meloidogyne incognita* by *Paecilomyces lilacinus*. *Soil Biology and Biochemistry*. 2006;38(7):1803-1811.
5. Hooks CRR, Wang KH, Ploeg A, McSorley R. Using marigold as a cover crop to protect crops from plant-parasitic nematodes. *Applied Soil Ecology*. 2010;46(3):307-320.
6. Grauke LJ, Thompson TE. Pecan. In: *Fruit Breeding*. Springer. 2012;771-801.
7. Ferris H, Bongers T, de Goede RGM. A framework for soil food web diagnostics. *Applied Soil Ecology*. 2001;18(1):13-29.
8. Khan A, Williams KL, Nevalainen HKM. Infection of plant-parasitic nematodes by *Paecilomyces lilacinus* and *Monacrosporium lysipagum*. *BioControl*. 2006;51(5):659-678.
9. Thompson TE, Grauke LJ. Pecan tree growth and precocity. *Journal of the American Society for Horticultural Science*. 1991;116(3):472-476.
10. Sparks D. Pecan cultivar performance in the southeastern United States. *Fruit Varieties Journal*. 2002;56(1):24-48.
11. Wells ML, Conner PJ, Funderburk JF, Price JG. Effects of fungicide-insecticide inputs on pecan production. *HortTechnology*. 2014;24(4):455-461.
12. Santhi A, Sivakumar CV. Biocontrol potential of *Pseudomonas fluorescens* against root-knot nematode. *Indian Journal of Nematology*. 1995;25(1):46-52.
13. Oka Y, Nacar S, Putievsky E, *et al.* Nematicidal activity of essential oils and their components against the root-knot nematode. *Phytopathology*. 2000;90(7):710-715.
14. Stirling GR. Biological Control of Plant Parasitic Nematodes. CABI. 2014;1-24.
15. Wood BW. Pecan production in North America. In: Fulbright DW, editor. *A Guide to Nut Tree Culture in North America*. Northern Nut Growers Association. 2003;1-16.
16. Worley RE. Pecan physiology and composition. In: Santerre CR, editor. *Pecan Technology*. Springer. 1994;39-47.
17. Madamba LSP. Pecan responses to nematode damage and fertility management. *Applied Soil Ecology*. 2012;54:48-55.
18. Reid W, Huslig SM. Pecan growth and yield response to irrigation. *HortScience*. 2001;36(7):1176-1178.