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Cultural Blueprint: A Smart and Sustainable Management Approach Against Nematodes

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Rolling back time our ancestors always considered soil to be pious, living and enriching. Cultural methods and local ITK's were adopted for management of various insect, pest and diseases as the pesticides and insecticides were viewed negatively. Approaches such as crop rotation with non-hosts, incorporation of organic amendments, use of resistant varieties, deep ploughing, soil solarization, cover cropping, and optimized planting dates provided sustainability, reserved the soil microbes, provided time to reset and use the natural resources in efficient way for benefit of our soil. This leads to an economic, farmer friendly environmentally safe approach for long term nematode management. This cultural blueprint thus represents an efficient, scalable, and ecologically sound strategy for mitigating the impact of nematodes in diverse agro-ecosystems.

Introduction

Plant parasitic nematodes have played significant role in ancient agriculture causing severe crop loss leading to famine and migration of human population **(**Kumar *et.al*., 2020). It is estimated that average annual loss in India due to nematodes is about 21.3%, and states like Tamil Nadu, Karnataka, Odisha & Uttar Pradesh have caused repeated yield loss in vegetable, pulses and plantation crops **(**Reddy, 2021**)**. The devastating parasitic nematode groups such as *Meliodogyne* spp., *Herterodera spp., Radopholus similis, Pratylenchus spp.* and *Rotylenchulus spp.* forms major constraints causing severe damage to roots resulting in reduction of nutrient uptake leading to stunted growth, chlorosis, wilting and poor yield quality (Prasad *et.al*., 1987). To over come nematode infestation for meeting the steep food demand farmers rely on synthetic chemicals which are total microbiome killers. According to major international agencies such as UNEP, WHO, and FAO, chemical-intensive farming systems leads to widespread environmental degradation and increased health risks for farming communities and consumers. UNEP Synthesis Report (2022) documents that environmental and health impacts of pesticide and fertilizer use and calls for minimizing their risks. WHO–FAO JMPR Reports highlight concerns about pesticide residues in food and their toxicological effects.These agencies recommend promoting eco-friendly practices, reducing highly hazardous pesticides, strengthening regulation, and adopting integrated pest management (IPM).

Cultural Methods of pest management and its principle

The soil, that is considered and worshiped as living goddess by our ancestors, is dying because its fauna is fast diminishing. To restore the lost status the policy makers are

advocating organic, cultural and biological methods. The main idea of cultural management is to manage the crop ecosystem in such a way that pests do not get favourable conditions to multiply or damage the crops. Cultural methods of pest management are eco-friendly farming practices that helps to prevent pest infestations by modifying the crop diversity rather than relying on chemical pesticides (Kamra & Sharma, 2000). The main aim is to prevent pest outbreaks through crop rotation and other methods which breaks the life cycle of soil-borne pests and nematodes. Some major cultural techniques are field sanitation that involves removing of weeds, infected plant residue and burninng infected plants. Intercropping and trap cropping reduce the pest population and deep ploughing helps to reduce pest eggs, pupae and larval stages. Overall cultural pest management is cost effective, sustainable and eco-friendly which contributes to long term agricultural productivity and promotes good soil health (Jain *et.al*.,2012).

Mitigation of nematodes in cultural web

In recent times cultural management practices forms the foundation of sustainable and environmentally safe strategies for controlling plant parasitic nematodes. These methods primarily aim to reduce nematode populations by enhancing soil health and without relying on toxic chemicals. Cultural approaches include crop rotation, use of resistant varieties, organic amendments, green manuring, bio-fumigation, soil solarization and field sanitation. Crop resistant varieties break the continuity of host availability. Organic amendment such as farm yard manure and neem cake improves soil fertility by releasing active compounds like azadiractin and limonoids which are toxic to the nematodes and inhibits their egg hatching and movement. Similarly, bio-fumigation with brassica crops (mustard & radish) produce isothiocyanates, natural volatile compounds that kill and suppress nematodes while soil solarization inhibits nematode communities through thermal toxicity. These cultural practices also stimulate beneficial soil microorganisms that acts as natural antagonists to nematodes. Overall the integration of these eco-friendly approaches creates a toxic environment for nematodes while improving crop vigour and crop productivity.

Table 1: Examples of commonly advised cultural management strategies against nematodes to farmers.

Nematode (Common spp.)	Cultural Management practices	Management Strategy/ Field application	Mechanism of nematode suppression	References
Root-knot nematode (*Meliodogyne* spp.)	Crop rotation, resistant/ tolerant cultivars, marigold (*Tagetes* spp.) as cover crop	Crop Rotation with non-host crop (cereals, maize or legumes). Use of marigolds mustard as trap crop	Breaks host availability and reduces reproduction, marigold produces nematocidal compounds which prevent rise of nematode population.	(Jain *et.al*.,2012)
Cyst Nematode (*Heterodera*/ *Globodera*)	Long term rotation, resistant cultivars, field sanitation	Rotate with non host crops (Maize, sunflower), destroy crop residue, Use certified and clean seed.	Long rotation reduces egg hatch and cyst survival by removing hosts, resistant varieties restrict nematode life cycle & lower soil inoculum	(Chandel *et.al*.,2020)
Lesion nematodes (*Pratylenchus* spp.)	Green manuring & organic amendments	Crops like mustard or sunhemp, Incorporate decomposed farmyard manure or biofumigants.	Organic matter enhances microbial antagonists and releases toxic volatiles, improvers soil health and plant tolerance.	(Prasad *et.al.*, 1987)

Reniform nematode (*Rotylenchulus* reniformis)	Crop rotation with non host, organic amendments	Rotate cotton with maize or sorghum, enrich soil with neem cake or ver6micompost.	Rotation interrupts the nematodes life cycle, neem compound inhibits egg hatching.	*(Das and* Mahalik, 2024)
Dagger nematodes (*Xiphinema* spp.)	Sanitation and weed host removal	Remove alternate host & volunteer plants, avoid movement of contaminated soil and planting materials	Minimizes nematode population & associated virus transmission, sanitation prevent field to filed spread.	(Khan *et.al*.,2014)
Multiple nematode genera	Soil solarization	Cover moist soil with transparent polythene sheet in hot summer for 4-6 weeks.	Increases soil temperature which helps to reduce inoculum density and weed growth.	(Khan and Hasan,2010)
Multiple nematode genera	Bio-fumigation using *Brassica* spp. residue	Grow mustard or radish before planting main crop.	Hydrolysis of glucosinolates produces isothiocyanates toxic to nematodes which helps in suppressing their population	(Ghosh and mandal, 2018)
General integrated approach	Integrated cultural management	Combines rotation, resistant cultivars, solarization, soil amendment,	Disrupts eggs, enhances microbial activity and maintains soil health.	(Khan and Hasan,2010)

Innovative cultural methods for nematodes management

Beyond conventional crop rotation and organic amendments new strategies emphasize bio intensive and climate smart practices that modify soil eco system to suppress nematode naturally. Bio-fumigation using improved brassica and tagetes cultivars have gained importance as their high glucosinolate and triphone content releases volatile compounds toxic to nematodes during decomposition. Carbon rich organic amendments (biochar, vermicompost) enhance soil microbial diversity. Moreover, precision nutrient and irrigation management reduces nematode favourable soil conditions by maintaining optimum moisture and root vigour. Integration of these innovative cultural methods with biological and botanical controls forms a holistic approach for integrated nematode management (INM) that promotes both crop productivity and soil resilience (Sivasubramaniam *et.al*.,2020).

Conclusion

Global water scarcity is only going to make the nematodes problem worse and with chemicals getting banned each day managing nematodes are going to be an serious agricultural issue. To secure future agricultural productivity emphasis must be placed on farmer awareness, regular soil health diagnostic facilities and promoting biological, cultural and genetic tools. Overall, adopting sustainable nematode management strategies will not only protect crops but also ensure long term food security, environmental safety and economic stability for farming communities. Implementing sustainable cultural management practices can help India to secure higher yields, reduce pesticide application and promote long term food and economic security.

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