

Harnessing Physical Methods for Sustainable Nematode Management

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Abstract: -

Cereals, vegetables and plantation crop accounts around one fifth of the crop damage due to parasitic nematode attack while chemical nematicides can harm the environment and usually act only as a curative measures where as physical methods like soil solarisation, flooding, steam treatment, hot water seed treatment and tillage offer sustainable control by using heat, moisture and aeration when combined with cultural, biological and botanical practices they enhance long-term efficacy and improve soil health these methods align strongly with sustainable agriculture goals by reducing chemical inputs while maintaining nematode populations below economic thresholds level.

Introduction:

Nematodes are microscopic and plantation crops. Conventional method roundworms that inhabit soil and plant tissue. often depends on chemical nematicides which are effective but cause long-term risk to the environment and are often very late as One tenth of all nematodes are parasitic and cause extensive damage to roots, leading to stunted growth, chlorosis and yield reduction. nematodes have already caused visible damage to the plant. To avoid this risk factor and as a preventive measure physical method can be an alternative solution to suppress nematode In India annual crop losses due to nematodes are estimated at around 21.3% (Kumar *et.al.*, 2020), particularly affecting vegetable, cereals

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problem (Khan *et.al.*, 2020).

Advantages and its integration with other management practices:

The physical approach of nematode management is purely eco-friendly, has minimal probability of resistance development, and low chances of emergence of new insect pests. In long run it is preserves and simultaneously improves the soil health and is economically viable to the farmers. It is a holistic approach of nematode and other insect pest management that in recent past is being sidelined due to the increasing demand of amplifying the productivity rate. Although of integrated nematode management which is a holistic approach and aims at maintaining level

below economic threshold while conserving soil health (Yaduraju and Mishra, 2004). physical methods alone can significantly reduce nematode population, integration with cultural, biological and botanical practices boosts long-term efficacy and magnitude of management (Singh and Pandey, 2012). For instance soil solarisation combined with organic amendments (bio solarisation) increases the soil temperature and release volatile toxic compound that the suppress harmful nematode population. Similarly, incorporating hot water treatment of seeds with bio control agent ensure that the infestation from planting material is minimised. Such combination forms the basis

Physical Methods of nematode management and its Mechanisms :

Physical Method	Description	Mechanisms	Crops	References	Photos
Soil Solarization	Ploughing and covering the soil with transparent polythene (10-15 um) for several weeks during hot season.(April-June)	Rise in soil temperature is lethal for for eggs or juvenile phase and many pathogens	Nursery vegetables like tomato, Cucumber, Brinjal (Eggplant), Chilli, Watermelon, Onion, Potato, Strawberry	(Gill <i>et.al.</i> , 2017) (Yaduraju and Mishra, 2004)	
Hot water or steam treatment.	Hot water dips for planting material, steam for Nursery soil.	Thermal mortality of nematodes in planting material or soil	Sweet potato, propagative material, Onion (bulbs), Garlic(cloves), Sugarcane (setts), Tobacco (seedlings) Ginger and Turmeric (rhizomes), Ornamentals (bulbs like tulip, lily, gladiolus), Banana (suckers/planting material)	(Singh and Pandey, 2012)	

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Flooding or an aerobic disinfection.	Prolonged water logging or induced an aerobic soil condition.	Creates toxic environment for nematode survival.	Crop rice based rotation and vegetables.	(Snehi, 2023)	
Solarisation + biofumigation.	Incorporation of Brassica or tagetes residue, then incorporating into solarised soil.	Thermal plus volatile biocidal compounds (isothiocyanates /thiophene) from decomposing residue.	Crop rotation with Cabbage and other vegetables like Onion, Potato, chilli, tomato, cucumber.	(Reddy, 2011)	

Physical Method	Description	Mechanisms	Crops	References	Photos
Deep ploughing or fallow	Mechanical inversion or long fallow periods	Disrupt life cycle	Wheat, maize, rice and millet.	(Khan <i>et.al.</i> , 2020)	
Soil steaming (field/nursery)	Incorporate steam into soil profile.	Sterilisation or disinfection of soil to specific depth.	Tomato nursery, Flower nurseries (e.g. gladiolus, lily, tulip) Strawberry nurseries Vegetable seedbeds (e.g. lettuce, cabbage)	(Singh and Pandey, 2012)	

Advantage and limitation

The physical methods of nematode management offer several significant advantage as well as certain limitation. These technique are environmentally safe and reduce free, making them highly suitable for organic and sustainable farming system. By relying on natural forces such as heat, moisture and aeration they not only suppress population but also improve soil, microbial activity and nutrient availability leading to healthier and more resilient soil (Timper, 2014). However, these methods have practical constraints their effectiveness depends upon favourable climatic condition, particularly for solarisation and flooding which requires higher temperature and sufficient water availability. In addition, most physical method are labour and time intensive making them less able for large scale field operation compared to control

environment such as nursery or greenhouses.

Moreover, the effect are temporary if not supported by cultural or biological practises nematode population can rebound under favourable condition therefore physical method provides a sustainable and eco-friendly solution, they are most effective when integrated with other complimentary management approach within an integrated nematode management framework (Stirling, 2011).

Future prospects

Advance in smart climate agriculture and renewable energy can enhance the physical methods which includes bio-solarisation, steam-assisted composting , and infrared soil heating are emerging technologies that combine physical and biological suppression mechanism. As well as development of low cost solar films and

portable steam unit could make these method more accessible to small and medium scale farmer's expanding extension and diagnostic services to promote awareness and proper application will further strengthen their role in nematode management (Evans *et.al.*, 2025).

Conclusion

Physical methods provide an eco-friendly and preventive approach to nematode management by using heat, moisture and aeration to suppress populations without chemical residue or harm to beneficial organisms. Emerging technologies such as bio-solarisation and renewable energy based soil heating improve their applicability. Overall these methods offers a sustainable pathway for nematode control while supporting soil health, productivity and environmental resiliences.

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