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AGROTECHNICAL METHODS FOR CONTROLLING MELOIDOGYNE NEMATODES

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Abstract

Meloidogyne nematodes, more commonly known as root-knot nematodes, constitute one of the most devastating groups of plant-parasitic nematodes in global agriculture. They attack various crops, causing root galls (knots), weakening plant vigor and substantially reducing yields. Globally, these nematodes are recognized for their adaptability, wide host range, prolific reproduction, and resilience, making their management a significant challenge for producers and researchers. Their feeding induces physiological, morphological, and biochemical changes in host plants, making them more susceptible to other pathogens and environmental stresses.

Key words

Meloidogyne nematodes, crop rotation, resistant varieties, soil solarization, organic amendments, green manuring, trap crops, soil hygiene, mulching, irrigation management.

INTRODUCTION

Agrotechnical control methods are essential in integrated nematode management programs, especially in sustainable and organic farming systems, where heavy reliance on chemical nematicides is neither permitted nor advisable. Agrotechnical techniques utilize crop biology, ecological interactions, and cultural practices to reduce nematode populations, interrupt their life cycle, and promote overall soil and plant health. They offer advantages such as environmental safety, improved soil fertility, cost-effectiveness, and compatibility with other pest management strategies. Successful agrotechnical management begins with an understanding of the nematode's biology and environmental preferences. Meloidogyne nematodes progress through an egg, four juvenile stages, and an adult stage. The second-stage juvenile (J2) is the infective form that emerges from eggs, migrates through the soil, and penetrates plant roots. Once inside the roots, it induces giant cell formation and establishes feeding sites, leading to gall formation and plant debilitation. Nematodes complete several generations per season, especially under favorable conditions of warmth and moisture. Soil type, organic matter, cropping history, and host availability influence the buildup or suppression of nematode populations.

MATERIALS AND METHODS

Crop rotation is one of the most reliable and widely used agrotechnical strategies against Meloidogyne nematodes. Since these nematodes have a range of host and non-host crops, alternating susceptible crops (e.g., tomato, cucumber, eggplant) with resistant or non-host crops (such as cereals, maize, wheat, barley, onions, or marigold) prevents the completion of their life cycle, reducing soil nematode numbers over time. Multi-year rotational systems (two or more years of non-hosts) are highly recommended for areas infested with root-knot nematodes. The benefits are even greater when rotational crops are chosen based on local nematode species and pathotype profiles. Trap cropping, a variation of rotation, uses plants that stimulate egg hatching but are destroyed before nematode reproduction. Planting resistant cultivars is among the most effective agrotechnical means of nematode suppression. Advanced breeding programs have

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developed crop varieties with genetic resistance to Meloidogyne spp. In tomatoes, resistance genes such as Mi-1 have been introgressed and widely utilized. Other crops like sweet potato, cotton, and pepper also have resistant lines developed and released in various agroecological contexts. While single-gene resistance can be overcome by the emergence of virulent nematode races, combining resistant varieties with other methods such as crop rotation and organic amendments helps retain effectiveness over time. Management practices should also encourage the use of multilines or pyramided resistance to minimize adaptation by nematode populations [1].

Careful sanitation practices form the backbone of nematode management, especially in seedling production and nursery areas where initial infestations often begin. Utilizing nematode-free seed and planting material, sterilizing tools and containers, cleaning machinery before moving between fields, and preventing the movement of infected soil are all necessary to reduce the risk of introducing or spreading nematodes. Proper weed control is also crucial since many weeds serve as alternative nematode hosts, perpetuating the problem in rotational or fallow fields.

RESULTS AND DISCUSSION

Soil solarization is an agrotechnical method that uses solar radiation to heat the topsoil to temperatures lethal for nematodes, their eggs, and various soil-borne pathogens. This process involves irrigating and thoroughly covering moist soil with transparent plastic sheeting for four to six weeks during the hottest months. Under optimal solarization conditions, soil temperatures can reach 45–50°C at depths up to 20 cm, effectively killing most life stages of root-knot nematodes and reducing the pathogen load. Solarization is most effective in warm, sunny climates and is often used in vegetable growing, nurseries, and high-value crop contexts. Incorporating organic materials into soils is an effective and ecologically sound method for nematode management. Organic amendments include animal manures, green manure (cover crops incorporated into soil before flowering), compost, oilseed cakes, and crop residues. These amendments improve soil structure, promote beneficial soil microflora, and release nematicidal compounds as they decompose. Green manures, especially from Brassica species, contain glucosinolates that degrade into isothiocyanates—volatile compounds toxic to soil nematodes, a process referred to as biofumigation. Regular addition of organic material also encourages populations of predatory nematodes and antagonistic fungi and bacteria which further suppress root-knot nematodes [2].

Deep plowing, dry fallowing, and periodic soil disturbance expose nematode eggs and juveniles to sunlight, desiccation, and predation, decreasing their survival rates. Tillage disrupts root debris, which shelters nematodes, and brings eggs to the surface, where they are more easily destroyed by environmental factors. Practices such as summer plowing in arid or semi-arid zones are especially effective. Extended fallowing, if combined with weed management, starves nematodes by removing the host plants they need to reproduce, further reducing population densities. Organic and synthetic mulches can support nematode management in several ways. Organic mulches (straw, leaves, sawdust) enhance soil microbial activity and decomposition processes that are antagonistic to nematodes. Some mulching materials, such as those obtained from neem (Azadirachta indica) or marigold (Tagetes spp.), contain substances with direct nematicidal activity. Plastic mulching, especially in combination with solarization, further elevates soil temperatures and reduces nematode activity in the root zone [3].

The movement of Meloidogyne juveniles is facilitated by moist soil. Hence, optimizing irrigation practices is a useful cultural control method. Avoiding over-irrigation, maintaining proper drainage, and using drip or trickle irrigation systems that deliver water directly to the root zone can limit nematode movement, survival, and distribution. Irrigation schedules that alternate

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periods of moderate moisture and drying cycles place physiological stress on nematodes, interfering with their reproduction. Good drainage also prevents secondary root pathogens from exacerbating nematode damage. Strategic use of trap crops (plants that induce hatching of nematode eggs but do not allow reproduction and are destroyed before nematode maturity) forms an important aspect of agrotechnical control. For example, planting castor, Sesamum indicum, or certain marigold species as short-cycle trap crops reduces nematode numbers before the main crop is established. Biofumigation, achieved by growing and incorporating mustard, radish, and other Brassicaceae green manures, is a promising method in nematode suppression, especially when carried out during periods of high soil moisture and temperature.

Cover crops, living mulches, and intercropping with non-host or antagonistic plant species can reduce nematode levels by increasing biodiversity, enhancing soil health, and changing rhizosphere dynamics unfavorably for nematodes. Leguminous cover crops such as sunn hemp, velvet bean, and field pea, as well as grass species, are effective choices, particularly in regions where off-season cultivation is possible. These living covers physically shield soil surfaces, suppress weeds, and provide a reservoir for beneficial soil organisms. Rigorous field hygiene—including cleaning tractors, tillers, and other machinery of adhering soil before moving from infested to clean fields—prevents spread of nematodes. Quarantine regulations, especially for seed, tuber, or root crops, are essential in checking nematode introduction into non-infested regions. Certification programs that guarantee nematode-free propagation material are a foundation for national nematode management programs [4].

Maximum and durable suppression of root-knot nematodes is achieved only through integration of multiple agrotechnical methods. Crop rotation by itself is more effective when combined with resistant varieties, organic amendments, irrigation optimization, and sanitation practices. Agrotechnical controls can serve as the cornerstone for integrated pest management (IPM) programs, often enhanced by compatible biological and, where allowed, judicious use of chemical tactics. Coordinating agrotechnical methods over entire cropping cycles, rather than responding on an ad hoc basis, is necessary for area-wide nematode control. Despite their utility, agrotechnical methods have limitations. Constraints include the long time required for significant population decline; incomplete effectiveness if improper rotation crops or poor-quality organic amendments are used; loss of market options due to enforced rotation; variable results due to environmental factors; and the challenge of upscaling these methods across diverse farming landscapes. Nevertheless, these techniques are indispensable, particularly where safe and sustainable methods are prioritized. Increased research into locally adapted agrotechnical innovations and greater extension support can address many practical challenges faced by farmers.

Agrotechnical methods offer significant long-term economic and environmental benefits. They reduce expenditure on nematicides, enhance soil structure and fertility, increase water-use efficiency, and foster greater resilience to pests, diseases, and abiotic stresses. Health and environmental risks from chemical inputs are minimized, biodiversity is promoted, and regulatory compliance in export markets is improved. The participatory adoption of these techniques strengthens farmer knowledge, autonomy, and sustainability in the face of evolving nematode threats. Ongoing research continues to develop and refine agrotechnical approaches against root-knot nematodes. Innovations include new resistant genotypes, locally suitable trap and cover crops, advanced composts and bioamendments, and the use of molecular tools to select non-host species. Digital agriculture, precision irrigation, and decision support systems help farmers time operations for greatest effect. More emphasis is being placed on participatory research and knowledge exchange, ensuring solutions are not only scientifically valid but practical for farmers' real-world contexts [5].

CONCLUSION

Root-knot nematodes of the Meloidogyne genus pose enduring challenges to agriculture, but the effective application and integration of agrotechnical methods can achieve significant and lasting control. By altering cropping patterns, harnessing resistant varieties, improving soil health with organic amendments, optimizing physical soil conditions, and employing rigorous hygiene, producers can sustainably lower nematode pressures and safeguard crop health and yields. Key to the success of these methods are locally adapted solutions, farmer training, timely interventions, and continuous innovation. In the context of increasing agricultural intensification, environmental concerns, and the need for food security, agrotechnical strategies against Meloidogyne nematodes represent not only a technical necessity, but an ethical and ecological imperative for the future of agriculture.

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