Nematode-caused problems management in Indian agriculture τ

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Most growers in India are still not sufficiently aware of the crop damage caused by plant-parasitic nematodes.

One of the serious yield robbers of our agricultural produce, are the plant-parasitic nematodes, the unseen enemies of farmers. Systematic research in the last 30 years has revealed that many nemmatode-caused problems reduced crop yields. Plant-parasitic nematodes attack all crops and present very difficult problems to identify, investigate, demonstrate, and solve.

Nematodes as Plant Parasites

Nematodes are small animals (0.3-10 mm). Most cannot be seen without the aid of a microscope. Generally, they are worm-like in shape, but females of some species are swollen. Nematodes live in soil, They occur in greatest abundance at a soil depth of 0-30 cm. The nematode distribution in cultivated soils is irregular and is greatest in or around roots of host plants. They are obligate parasites but can survive for many months in the absence of a host. Most nematodes are root feeders, although a limited number of species are parasites of aerial plant parts. On the basis of feeding habits, root feeders are classified into ectoparasites (external feeders), semi-endoparasites (anterior part of the nematode embedded in root tissues), and endoparasites (completely internal feeders).

Plant-Parasitic nematodes live in soil in farmers' fields, home gardens, forests, and drylands. presence of nematodes in soil is not always associated with crop damage and subsequent crop losses. Nematode-caused diseases generally depend on nematode populaion density at the time of planning. High populations of nematodes usually result in increased disease severity.

Nematode-Caused Damage and Symptoms

Although nematodes are minute, the damage they cause is significant. It is sometimes difficult to differentiate the damage they cause from that caused by other biotic and abiotic agents. Nematode-caused damage is less spectacular and less dramatic than that resulting from most foliar diseases and insect damage. It is, however, sure and cumulative, and results in reduced crop productivity. Frequently, the first symptoms are patches of poorly growing plants. Symptoms on roots may appear as root knots or root galls, root lesions, excessive root branching, injured root tips, and root rots when nematode infections are accompanied by plant-pathogenic or saprophytic bacteria and fungi. Nematode infection restricts nutrient and water uptake and the root symptoms are usually accompanied by nonspecific symptoms on the aerial parts of plants. These symptoms include reduced plant vigor, yellowing of foliage, wilting, delayed flowering, and low yields of poor quality. These conditions can be attributed to nematodes only after proper soil and root examination and verification of the physical presence of a nematode population. Certain species of nematodes invade the above-ground portions of plants and cause galls, necrotic lesions and rots, twisting or distortion of leaves and stems, and abnormal development of floral parts.

Major Nematode Problems in India

On a worldwide basis, the average yield loss caused by nematodes is estimated to be 12.3% (Sasser and Freckman 1987). It is likely that in India yield losses are much higher than elsewhere because soil temperatures are more favourable for nematodes most of the year, cultivation of susceptible crop varieties is continuous, many damaging nematode species occur, and there is a lack of general awareness concerning nematode diseases.

Approximately 600 species of plant-parasitic nematodes have been reported in India. Nematodes

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of national economic importance are root-knot nematodes, cyst nematodes, lesion nematodes, and reniform nematodes. These are all widespread and cause serious damage to many crops in different states.

Root-knot nematodes(*Meloidogyne*spp). Root-knot nematodes were the first plant-parasitic nematodes to be reported in India. First identified in 1901, these nematodes are characterized by the galling of roots. *Meloidogyne* species are endoparasites. Of the 11 species reported in India, *M. incognita* and *M. javanica* attack a wide range of vegetables, pulses, and oilseeds. Control of these nematodes generally results in three- to four-fold increases in yield (Sethi and Gaur 1986). Affected fields are characterized by patches of poorly growing plants. These patches may expand each year. Symptoms advance with crop age and are more severe during drought stress periods and/or in low fertility soil. Usually symptoms on above-ground parts of plants are detectable when crop yield losses exceed 15-20%.

Cyst-forming nematodes (*Heterodera* spp and *Globodera* spp). The first cyst-forming nematode (*Heterodera avenae*) was reported in 1958, and 17 additional species were subsequently recorded (Sharma and Swarup 1984). Presence of the golden nematode of potato (*Globodera rostochiensis*) stimulated awareness and it was instrumental in the initial rapid progress in nematological research. Perhaps the most definite symptom of cyst nematode attack is the presence of pearl-like white females on the roots. Cyst nematodes are host- specific.

Heterodera avenae is an important nematode of wheat. It caused an estimated loss of 80 million rupees in Rajasthan in 1970 (Van Berkum and Seshadri 1970) and wheat yields increased by four times when the nematode was controlled with nematicides (Swarup et al. 1976).

Heterodera cajani attacks leguminous crops and plant species in the pedaliaceae family. The nematode completes its life cycle in 3weeks at 25-30°C and reproduces rapidly. It significantly reduces plant vigor and seed yield. The nematode is widespread and is the most important nematode pest of pigeonpea (Sharma and McDonald 1990) and other pulses. Control of this nematode in pigeonpea often results in a 25% increase in seed yield.

Heterodera zeae attacks plant species of the graminae family. *H. zeae* probably contributes to yield losses in many states.

Reniform nematode (*Rotylenchulus reniformis*). The reniform nematode was first recorded in India on coffee plants in 1959. Several important host crops including vegetables, fruits, pulses, cereals, fibre, and ornamental crops have since been reported. The nematode feeds in the cortex, endodermis, pericycle, and phloem parenchyma of its hosts and completes its life cycle in 24-30 days. It increases the severity of diseases caused by *Verticillium*, *Fusarium*, *Sclerotium*, and *Macrophomina*. Yield loss estimates for this nematode are not available in India; however, it is reasonable to assume that significant losses occur. Control of the nematode significantly increases crop vigor and yield.

Root - lesion nematode (*Pratylenchus* spp. Root - lesion nematodes are migratory endoparasites and their feeding results in the death of cells in the host's cortex. Dark brown or black root lesions are common symptoms. Affected plants become unthrifty and less productive. *Pratylenchus coffeae* was the first species recorded in India in 1948, and annual loss in coffee yield due to *P. coffeae* was estimated at 20 million rupees (Van Berkum and Seshadri 1970). Many other pathogenic species occur in India, including *P. indicus*, *P. thornei*, *P. zeae*, and *P. brachyurus* which attack a wide range of crops such as wheat, rice, maize, groundnut, and vegetables.

Management Options

Management of diseases caused by nematodes includes both chemical and non-chemical methods. Use of nematicides (dichloropropene dibromochloropropene, high doses of aldicarb and carbofuran) is effective but not economically sound because of high costs, non- availability, and possible health hazards associated with their application. Many crop management practices such as summer ploughing, fallowing, and planting of non-host crops usually reduce plant damage associated with parasitic nematodes.

Crop rotation. This is one of the most useful practices for control of nematode parasites of annual crops. This practice is effective against nematodes that exhibit a strong food preference. For example, cyst nematodes (*H. avenae and H. zeae*) parasitize monocotyledonous plants while the root-knot nematodes (*M. incognita* and *M. javanica*) prefer dicotyledonous plants. A 2-year rotation with carrot or cumin effectively reduced the population density of *H. avenae* in Rajasthan (Swarup and Gokte 1986). Use of maize, sorghum, pearl millet, and rice in rotation or in cropping systems reduces the population densities of the root-knot nematodes and to some extent the reniform nematode. However, the presence of weed hosts in fields throughout the year facilitates nematode reproduction even in the absence of cultivated plant hosts. Therefore, control of weed hosts is essential for the successful management of nematodes with crop rotation. The development of a rotation programme is constrained by the acceptability of the rotational crop in the traditional cropping system of a region, the market potential for a rotational crop, and specialized requirements for growing and harvesting rotational crops.

Summer ploughing. Nematodes are susceptible to desiccation and high temperature. Two to three deep ploughings during hot summer months expose nematodes to high temperature and dehydration. This practice also suppresses weeds, soil fungi and bacteria. The efficiency of summer ploughing is improved by polyethylene mulching that traps and retains solar heat for longer duraion, thereby suppressing the nematode population. Active nematodes are more susceptible to solar heating of slightly moist soil. The pigeonpea cyst nematode and the reniform nematode are effectively controlled by this method (Sharma and Nene 1990).

Organic amendments/manuring. Nonedible seed cakes of *neem*, *karanj*, *mahua*, and castor are deleterious to nematodes. Applications of 1500-2500 kg/ha are required for nematode control. Cost of the cakes and high application rates are serious constraints; moreover, these cakes are not commercially produced.

Hot water treatment. Hot water treatment of seed, tuber, bulbs and rooted cuttings or rhizomes is useful in reducing nematode spread and damage. Hot water treatment of rice seed for *Aphelenchoides besseyi*, potato for *Meloidogyne*. spp, rooted cuttings of citrus for *Tylenchulus semipenetrans*, grapevines and roses for *Meloidogyne* spp and *R. reniformis*, and banana suckers for *Radopholus similis* are effective.

Physical cleaning. Cleaning of infested seed by simple sieving or by flotation in plain water is very useful in reducing *Anguina tritici* infestation of wheat seed.

Resistant cultivars. Germplasm of different crops has been screened to identify sources of resistance to a number of nematode species. Major emphasis on resistance to the root-knot nematodes has been given to screen vegetables and legumes. A number of genotypes with resistance to reniform, root-knot, and cyst nematodes have been identified. Research on breeding varieties for nematode resistance has been limited.

Biocontrol. Natural enemies of nematodes are important in management of plant-parasitic nematodes. A large number of bacteria and fungi have been reported as potential biocontrol agents for *H. avenae*, *H. cajani*, and *H. zeae* (Sharma and Swarup 1988). Use of *Pasteuria penetrans* for reducing the population densities of root-knot and cyst nematodes appears to be possible under field conditions; however, none of these biocontrol agents has been tested under field conditions. Several plants including mustard, African marigold, asparagus, crotalaria, and sesamum are antagonists that reduce population densities of plant-parasitic nematodes.

Approach in the Future

In spite of limited available resources, it is interesting to note that considerable progress has been made, especially with regard to nematode management. It is now well understood that plant-parasitic nematodes act as energy sinks in crop production systems. Attempts have been made to identify the major nematode problems, to assess their damage potential, and to develop possible management tactics. It is clear that strategic research aimed at solving plant nematological problems must be accelerated and expanded. During the next decade and beyond we must focus our attention on the management of identified nematode problems. Certain factors are primary obstacles to effective management. The most important obstacle is the lack of recognition that plant- parasitic nematodes seriously limit crop yields.

General awareness of nematode diseases. Nematologists have not effectively publicized the importance of nematode diseases in agriculture to farmers, the general public, policymakers, or even to the relevant scientific community. There is an urgent need to create general awareness about the importance of nematode diseases. Extension nematologists, the principal communication links between the growers and scientists, will play a very significant role in delivering the message from research laboratories to farmers' fields by conducting demonstrations, testing the adaptability of technologies developed at agricultural research stationds, and educating the growers that awareness and timely management of nematode diseases is economically beneficial.

Distribution of simple, attractive, and informative literature in the form of leaflets, folders, etc. on the importance of nematode diseases and their control, the use of mass media to reach wider audiences, and articles concerning local nematode problems in local magazines will be helpful. Extension services should help farmers in the diagnosis of nematode diseases and suggest options for avoidance of crop losses.

Subject matter specialists in plant protection (entomology and plant pathology) are not adequately informed of nematode problems and their management. A simple nematode problem such as ear- cockle disease of wheat, which could be eradicated within a few years by seed-cleaning and use of uninfested seed for planting, is allowed to continue unchecked (Seshadri 1986). This situation needs to be quickly rectified and existing extension activities in nematology should be strengthened. Organization of regular training programmes for subject matter specialists and extension officers in each state and introduction of core courses in nematology in undergraduate curricula will help to promote extension and research work in nematology.

Crop loss estimation and prediction of damage.. Quantification of crop responses and estimation of yield losses due to nematode diseases involve intuition as much as science because many factors influence the relationship between population densities of nematodes and crop responses. These factors prohibit an accurate characterization of loss. Because of the soil-borne nature of nematodes and lack of mobility, crop damage prediction models may be possible. Development of damage- predicting models based on pre-plant nematode densities will undoubtedly be helpful in advising growers about suitable crops, crop varieties, and control methods.

Development of a regional crop loss database collected over different spatial units (villages, districts) will provide information on the prevalence and severity of diseases and related losses. This programme will be useful in keeping administrators, policymakers, researchers, and farmers aware of the status of diseases caused by nematodes. Use of computer technology will be of great help in this programme.

Strategies for management of nematode-caused problems. Sustained efforts during the previous two decades in search of an ideal approach of controlling nematode disease problems have revealed that the goal of killing or eradicating nematodes is neither economically nor ecologically sound. The future lies in adoption of an integrated approach in which different management options are combined to reduce nematode densities to levels which are not damaging to crop productivity. This strategy is characterized by sustainability of crop production and reduction of deleterious effects on the environment. We need to apply existing methods of control to the best advantage, i.e., adequate disease control with the minimum of environmental disturbance. What we need now is not only more technology but optimum utilization of existing technology. Our objectives should be to reduce nematode- caused losses rather than to kill nematodes. We need to adopt a concept of population planning; let the nematodes subsist on our carefully nurtured crops but ensure that their population does not reach dmaging proportions. It is important that crop damage primarily occurs in soil with high population densities of nematodes at planting. Annual crops are most vulnerable to damage when the root system is small. Use of seed treatment with a chemical or biocontrol agent that protects the roots for a month or longer will help to mitigate crop losses.

Use of solar heat for nematode control is promising, especially in regions where maximum daily air temperature in summer exceeds 40°C. The solar heat can be trapped and conserved with transparent polyethylene mulch (solarization). Heating soil with solar energy is an environmentally safe and effective method and coupling solarization with different control measures such as application of neem cake and amendments may give longer-lasting effects on the control of nematode diseases. Planting of resistant cultivars or nonhosts can also result in long-term control.

This method will prove useful for high value crops. particularly when utilized as a nursery bed treatment.

Use of resistant cultivars is a very practical method of nematode-caused loss management and we have good information on probable sources of resistance in many crops, particularly for root-knot nematodes. Limited efforts have been made to test these resistant lines at different locations in the hot spot areas and to make use of these sources of resistance in breeding programs. Use of standardized techniques for evaluation of resistance and involvement of plant breeders from the beginning of this research is needed. It is likely that a continuous search in different regions will lead to identification of durable sources of resistance. Resistant screening has previously been restricted to pot studies and we should now develop field screening procedures in hot spot locations. There is a good opportunity to incorporate resistance in commercially and agronomically suitable varieties. Recent developments in the techniques for gene manipulation may facilitate transfer of desirable resistance against important nematode diseases to well–adapted cultivars.

The type of cropping system and the intensity of land use markedly affect the pest status of nematodes. In some cropping systems nematodes are less likely to be a major constraint, whereas in other systems the cropping methods may increase the probability of nematodes becoming serious pests. For example, if a rainy-season crop is a good host of a particular nematode, the carryover nematode population will be high and adversely affect a susceptible postrainy-season crop. On the contrary, if the rainy- season crop is either a poor host or a nonhost, the residual influence on the postrainy-season susceptible crop can be clearly seen. Increased interest in developing cropping systems as a means of nematode control will be helpful, especially if no sufficient resistance is available.

The pressure to produce a larger amount of food on the existing land area will lead to introduction of high-yielding genotypes and utilization of intensive cropping systems. These practices are likely to contribute to and increase in nematode-caused disease problems. Nematologists, both extension an subject matter specialists, will have a very important role in increasing the food production by increasing awareness of the farmers concerning the hazards of these "hidden enemies" as yield reducers and by finding ways to reduce the nematode-caused yield loss.

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