MANAGEMENT OF **Rotylenchulus reniformis** IN AGRICULTURE CROPS - A REVIEW

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**ABSTRACT**

The reniform nematode *Rotylenchulus reniformis* is sedentary endoparasite commonly associated with various agricultural and horticultural crops and causes reduction in crop yields. Since the complete eradication of this nematode by single method is exceedingly remote, hence integrated management system such as cultural control, crop rotation, host resistant, chemical and biological control has been reviewed.

The main objective of management is usually a matter of reducing the nematode population by one or more methods to a low level so that the damage is negligible or at an economically acceptable level. To be of economic value, any control must be profitable, that is the increase in monetary value of the crop must be more than enough to offset the cost of control measure. This theory stands equally sound in case of nematode management as well.

The destructive nature of *Rotylenchulus reniformis* is one of the major limiting factors in vegetable, fibre and pulse crops production. Consequent upon the feeding of nematode on the roots, uptake of the moisture and nutrients from the soil is obstructed resulting in reduced functional metabolism. Visible symptoms of nematode attack include reduced growth of individual plant, varying degree of chlorosis, wilting of foliage and finally death of plants occurs under severe infection. To overcome this effect, management of nematode is, therefore, important for higher yield and quality that are expected from the higher cost of crop production.

Once nematodes are established in field, the possibilities of complete eradication are exceedingly remote and impractical on field scale due to soil inhabitant nature of nematode. However, several measures are adopted to decrease nematode population upto an acceptable level. Nematode management can broadly be divided into cultural, chemical, biological, legal, host resistant etc. The integrated crop protection system utilizes the best combination of resistant cultivars, crop rotation and minimum use of nematicides.

Thus, the methods of nematode management involving non-chemical approaches have gained importance in recent crop management scenario due to hazardous and polluting effects of chemicals, which have been attempted to review here.

**CULTURAL CONTROL**

Control of nematode by cultural practices is more economical or practical especially on low acre value crops. This operation is feasible and can be adopted and carried out at or no extra expenses. Secondly the produced can be consumed at any time after harvest, as there is no residual effect of chemical.

1. **Crop rotation**: By this method, the population is reduced to low level at which the crop damage is reduced to minimum. Non host crops reduced the nematode number. This process should be repeated for several years depending upon the initial population and decrease rate of population. Rotation must also provide economically useful crops. Choosing rotation, care should be taken to avoid a new set of pathogens in place of the one to be controlled. A number of crops and other plants have been found resistant to reniform nema-
tode, *R. reniformis* which include sugarcane, *Coffeea robusta*, jack bean (*Canavalia ensiformis*), velvet bean (*Stizolobium deeringianum*), chillies, maize, sorghum, *Lacaena glauca*, finger millet, crotalaria, onion, *Brassica compestris*, *B. rapa*, *Capsicum frutescens*, carrot and coriander. (Khan and Khan, 1973). Continuous cropping with cotton increases the population of *R. reniformis* 10 times, but can be reduced by growing cotton followed by sorghum. (Thames and Heald, 1974). Gilman et al. (1978) also reported soybean CV pickett 71 resistant to reniform nematode and CV Lee 68 to be susceptible and cotton CV Deltapine 45A was grown in 6 rotations. Growing resistant soybean CV pickett 71 in rotation with either susceptible soybean CV Lee 68 or was extremely effective in reducing the population and increasing the yield immediately following susceptible crop. Inclusion of resistant CV in rotation for two consecutive years before a susceptible crop resulted in significant increase in yield but did not benefit over 1 year.

Later on, Williams et al. (1983) reported that five years rotation study involving susceptible cotton and Lee 68 soybean and resistant pickett 71 soybean was done in soil infested with *R. reniformis*. Of 14 cropping sequences tested, growing resistant cultivars for two consequent years eliminated the need of fumigation for nematode control when growing cotton or susceptible soybean cultivars in following year is practiced.

Crops, which have shown to reduced/suppress *R. reniformis* are broadbean, kochia, marigold (Alam et al., 1977). Sorghum, pea and mustard grown alone or together in alternate rows reduced population significantly after 4 months (Dunn, 1988). Mung, sesbania, marigold, wheat and barley cropping system or fallow (Khan et al., 1974) and barley, maize, onion, rice, crotalaria spp and resistant cultivars of soybean (Robinson et al., 1997) also were recorded to reduce nematode population. On the contrary, Castillo et al. (1975) reported that two crops of bush Sitao, peanut or sweetpotato or three crops of mungbean or sunflower favor a built up in population of *R. reniformis* while two crops of maize or sorghum or three fallow period checked the nematode population.

*R. reniformis* on *P. betle* was drastically reduced if crop was rotated with rice (Sivakumar Marimuthu, 1986). Gazeway et al. (1998) found that three successive years of maize followed by cotton produced highest yield and *R. reniformis* population dropped to non-damaging level after one year of non-host crop but rebounded to damaging levels after just one growing season of cotton.

2. Fallow: Nematode can be easily controlled by depriving them of plants on which they feed. Keeping land fallow for the required length of time, not only minimizes nematode population but also kills soil-borne pathogens which are harmful to crop. Turning the soil during fallow/ploughing to depth of 6 inch gives an additional kill to the nematode. Best nematode control obtained when fallow is maintained during hot dry weather. The cycles of drying and wetting are more effective than continuous summer fallow in reducing the nematode. Weeds that are susceptible to nematode should not allow growing during fallow.

Fallowing effectively suppressed the soil population of *R. reniformis* which was as good as growing non-host plant corn (Braithwaite, 1974). Castillo et al. (1975) also observed that two crops of maize or sorghum or three fallow periods drastically checked nematode.

3. Fertilizer application: Fertilizer application to soil has impact on *R. reniformis* population. Application of potash in combination with phosphorus or nitrogen or potash alone check the reniform nematode multipli-
cation on okra to a great extent (Sivakumar and Meerzainuddin, 1974). Badra and Elbary (1978) also reported soil and root population of *R. reniformis* which reduced steadily with increasing doses of nitrogen incorporated with organic amendments, slight increase in infestation and invasion of *R. reniformis* were associated with lower doses of potash. Incorporation of nitrogen and phosphorus was promising for plant growth as well. Badra (1980) again stated that ammonical nitrogen maintained in amount up to 576 kg/ha at two intervals decreased damage caused by *R. reniformis* to tomato. The lower dose 72 and 144 kg nitrogen/ha reduced density slightly whereas, higher doses of 216 to 576 kg nitrogen/ha depressed infestation considerably. The male-female ratio was also more seriously affected by higher rate of nitrogen.

4. Flooding: Keeping the land submerged in water decreases oxygen contents of the soil and kills nematodes by asphyxiation. Chemicals lethal to nematodes such as butyric and propionic acids, hydrogen sulfide and NH$_3$ often develop in flooded soils.

Flooding for 1, 4 and 7 days in mung bean (*Phaseolus mungo*) reduced the population of *R. reniformis*. Flooding on 10th day resulted no nematode recovery from the soil and reduction in nematode in root count ranged from 25 to 75 and flooding on 30th day reduced soil population by 80% and 95% and root count 53% to 73% (Castillo et al., 1976). Rodriguez et al. (1981) demonstrated that the population of *R. reniformis* decreased greatly when irrigation was applied only during the period extending from 60 to 100 days in sweet potato (*Ipomea batata*). Sivakumar and Marimuthu (1986) noticed that flooding of *P. betle* reduced the population of *R. reniformis*.

5. Plant extract: Chopped leaves (5%) of eight plant species or dry raw sewage sludge (10%) reduced the soil population of *R. reniformis* in eggplant seedling. The greatest reduction in number was recorded with *Azadirachta indica* leaves followed by sewage sludge and *Melia azadirachta* (Lal et al., 1977).

Mahmood et al. (1979) reported that the extract of plant tissue viz. leaves of *Tagetes erecta*, *Annona squamosa* and *Aloe barbadensis* (vera) and seed of cabbage, pumpkin, pawpaw, *Momordica charantia*, *Phaseolus lunatus* and *Trichosanthes anguina* were effective against *R. reniformis* but extract of Aloe and Pawpaw is most toxic. Later in 1982, they again found that leaves of *Anagallis arvensis* and seeds of *Linum usitatissimum* and *Sida cardifolia* were highly toxic. Mortality of *R. reniformis* was highest with root extract of *Solanum hispidium* and shoot extract of *Solanum hispidum*, *Melia azadirachta*, *Chenopodium ambrosioides*, *Nicotiana tabacum* and *Canabis sativum* (Haseeb et al., 1978).

Chopped leaves of *Azadirachta indica* suppressed *R. reniformis* in soil (Aktar and Alam, 1989). El-Nagar-Hi et al. (1993) reported that 50 or 1000g/pot chopped leaves *Azadirachta indica*, *Calotropis procera*, *Clerodendrum inerme*, *Eucalyptus citriodera*, *Lantana indica*, *Melia azedarach*, *Ricinus communis* or *Thuja orientalis* significantly suppressed *R. reniformis*. Chopped leaves of *Calotropis procera* drastically reduced nematode population (Aktar and Alam, 1989), Margosan (active ingredient of neem) and sicosin also reduced the population (Farahat et al., 1993). El-Nagar-Hi et al. (1993) reported that 2.5 and 5.0g/pot of dry ground leaves of Egyptian neem (*Melia azadirachta*), *Asparagus sprengeri*, *Eucalyptus* sp. and *Psidium guatava* significantly reduced number of egg masses/root at both combinations. Asparagus and neem achieved highest rate of reduction plant extracts of *Crotalaria juncea*, *Agrographis paniculata*, *Medicago media* and *Anona squamosa* (Poornima and Vadivelu, 1990). *Bougainvillea spectabilis*, *Ocimum sanctum*, *Allium cepa*, *Prosopis juliflora*, *Calotropis procera*, and
Leucaena leucacephila @ 5g/kg soil on tomato suppressed final nematode population (Sundarababu et al., 1990). Prasad et al. (1997) and Rao et al. (1996) found that Calotropis leaves @ 10 q/ha and 80 t/ha respectively suppressed the nematode population in groundnut and betel garden. Ajith and Sheela (1996) reported that green neem leaves and Eupatorium (15 t/ha) effectively reduced R. reniformis in okra and cowpea.

6. Oil cakes: Amending oil cakes in soil not only decrease the nematode population but also increases plant growth and yield. Oil cakes viz. neem, groundnut, castor and mahua amendments significantly reduced population of R. reniformis in egg plant (Khan et al., 1974), cotton seed cake (Badra et al., 1979; Poornima and Vadivelu, 1990).

Phenolic content of oil cakes of mahua (Madhuca indica), castor (Ricinus communis), mustard (Brassica compestris), neem (Azadirachta indica) and groundnut (Arachis hypogaea) were toxic to R. reniformis (Alam et al., 1979), neem cake, karanj (Pongamia pinnata) or prolong (Beta vulgaris var. orientalis) @ 1 t/ha and 2 t/ha was effective in controlling nematode population in okra and french bean (Rao et al., 1987; Padhi and Misra, 1987). Kumar and Vadivelu (1996) reported reduction in R. reniformis in brinjal by neem, castor, mahua cakes each @ 500 kg/ha except pressmud.

CHEMICAL CONTROL

The primary advantage of chemical control is that the nematode population is reduced drastically to very low level within matter of days after chemical is applied. Most crops are especially vulnerable to nematode attack during seedling stage when young root system is becoming established. Crops planted in treated soil develop good root system so that usually in case of annuals, the crop is matured before residual population of nematode has increased to a damaging level. Seed treatment and nursery treatment offers minimum application of nematicides into the soil and provides nematode free seedlings. These means of chemical control are safer and can be coined as an integral component of integrated nematode management (INM).

1. Nursery treatment: Considerable loss occurs from nematode infestation in plant nurseries. An effective and economical control can often be achieved by elimination of nematode from nursery bed by soil treatments.

Nursery bed treatments with DBCP at 50 l/ha and Metham sodium at 250 l/ha were effective in reducing reniform nematode population in tomato nursery and in increasing seedling growth (Sivakumar et al., 1977). Patel and Makwana (1992) reported that rabbing nematode infested nursery area with bajra (millet) husk @ 7 kg/m² or soil solarization by tarping the bed with LDPE clear plastic film of 400 gauge for two months alone or in combination of both or combination of each with carbofuran @ 1.5 kg/ha or all the three together gave economical and effective management.

2. Seed treatment: Seed treatment with nematicides is being used increasingly to cut down the cost of chemicals without any adverse effect on plant growth. Seed treatments give adequate initial protection from nematode larvae to seedlings leading to better plant growth and increased yield. Cotton seed treated with nematicides viz. carbofuran, phorate and fensulfothion can effectively be employed to reduce population of R. reniformis from 32.45 to 49.06% (Muralidharan and Sivakumar, 1975). Seed treatment with aldicarb and carbofuran both at 6 and 12% was effective against R. reniformis infecting okra (Sivakumar et al., 1976). Lordello and Brancalion (1986) worked on cotton and reported that seed treatment with carbofuran at 700g/100kg was more effective in reducing the number of R. reniformis more than 87% up to 29 days and 82% up to 61 days after sowing.
Seed treatment with carbofuran @ 0.1% in cotton and 1 kg /100kg in mungbean were effective in reducing soil and number of eggs/plant of *R. reniformis* (Branclalon and Lordello, 1982; Patel and Thakar, 1986). Khan and Husain (1988) concluded that seed of *Vigna unguiculata* treated with aldicarb or bavistin significantly reduced nematode population and increased plant growth. Seeds of mung treated with 1.0% fensulfothion and lentil seeds with aldicarb, sulfone, carbofuran at 0.5% or 0.1% reduced population of *R. reniformis* and increased yield (Misra and Gaur, 1989). Misra and Gaur (1989) and Prasad *et al.* (1997) observed that seeds of mung treated with 1.0% fensulfothion and groundnuts seeds treated with carbofuran at 2% w/w and triazophos (40EC) at 500 PPM reduced nematode population and increased plant growth.

3. Seedling bare root dip treatment: Nematode damage is more harmful to seedlings than to older plants. For example, the yield loss was greater when young tomato plants were infested with reniform nematode. Hence treatment with nematicides applied only at seedling roots may, therefore, lessen nematode damage and may be more economical.

Bare-root treatment of brinjal seedlings with aldicarb, carbofuran and terbufos at 500 and 1000 PPM was effective in reducing nematode population (Prasad and Krishnappa, 1981). Bare-root dip treatment with pyridoxine hydrochloride (vitamin B6) solution of 0.1, 0.3 or 0.5% concentration for 30 min. resulted in improved plant growth (Ahmad and Alam, 1997).

4. Soil treatment in main field: Most of the important plant parasites are inhabitants of soil. A chemical can be brought into contact with soil inhabiting nematode by mechanical mixing. Experiments have demonstrated that mixing granular chemical with soil mechanically can control nematodes. This method might enable the grower to prepare the land to a good tilt and incorporate both fertilizer and nematode in one operation. Soil fumigation with mocap and/or DBCP reduced *R. reniformis* population on susceptible (Bagg and Lee 68) but not on resistant (Pickett and Pickett 71) soybean varieties (Birchfield and Williams), and tobacco CV NC 3555 yielded high when treated with mocap 7 kg/ha (Hutton, 1979) similarly in pigeon pea DBCP (20 l/ha) significantly reduced *R. reniformis* population (Sharma and Rupela, 1993). Application of ethylene dibromide or ethylene dibromide + chloropicrin in *Phaseolus vulgaris*, dibromo-chloropropane (DBCP) @ 6 kg in pigeon pea reduces the soil population of *R. reniformis* (McCorley and Parrado, 1983 and Sharma and Rupela, 1993). Application of Temik, thimet + nemaphos and nemaphos alone, Nemacur or Nemacur-Disyston in cotton seedling effectively control *R. reniformis* population in soil (Oteifa, 1970; Oteifa *et al.*, 1976 and Bost, 1985).

Birchfield and Martin (1976), Badra and Elgindi (1979) and Jaiswal *et al.* (1987) reported significant reduction in soil population of reniform nematode by ethoprop, fensulfothion, carbofuran on sweet potato, fensulfothion (18kg/ha) on cowpea, fensulfothion (2kg/ha) and aldicarb (2kg/ha) in pigeon pea and application of aldicarb 12ppm, carbofuran 12ppm and fensulfothion 12ppm in cotton, carbofuran and aldicarb (both 2 and 4kg/ha) or aldoxycarb (4kg/ha) in cotton, carbofuran and aldicarb (4kg/ha) in mungbean were effective in reducing *R. reniformis* population in soil and increasing the growth (Abu-Elamayen *et al.*, 1979; Lordello *et al.*, 1984; Padhi and Misra, 1987 and Misra and Guar, 1989).

Application of fosthiozate 6 or 12pt/acre before or after bed preparation of fields of sweet potato increased the yield by 15.6 and 88.9 lb/acre (Mclean and Lawrence, 1996). Vadhera *et al.* (1997) reported that
drenching of soil with bavistin (0.1%) completely eradicate the nematode population.

5. Foliar application: Foliar application of oxamyl was applied 24 hrs before transplanting to soil infested with *R. reniformis* with single application of oxamyl, tomato seedlings required 600ppm to significantly inhabit *R. reniformis* penetration (Rich and Bird, 1973). Penetration of *R. reniformis* into pigeon pea was significantly reduced at 2, 4 and 5 days after transplanting by doses of oxamyl of 2,500, 1,250 PPM (Singh, 1975). Singh (1975) reported that single foliar spray of oxamyl @ 2500 PPM restricted the penetration of *R. reniformis* into pigeon pea roots. Later on Mcsorley (1980) reported six weekly spray of oxamyl @ 0.5kg/ha combined soil drench with oxamyl @ 2.24 kg/ha at planting reduced soil population of *R. reniformis* in snap bean. Oxamyl as 2 foliar applications of vydate @ C-LV applied to cotton at pinhead square and 14 days later reduced population of *R. reniformis* (Hammes and Mitchell, 1996).

### HOST RESISTANCE

Plant resistance is regarded as extremely feasible method for controlling nematodes. It is cost effective, economically and environmentally safe means of reducing losses. Use of resistance plant enables the grower to control plant parasitic nematodes without increasing production costs associated with purchase of expensive chemicals.

**Nematode resistant cultivars**

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<th>Resistant cultivars</th>
<th>Moderately resistant</th>
<th>References</th>
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<tbody>
<tr>
<td>Soybean</td>
<td>1. Pickett and Dyer</td>
<td>Hardee, Cookes, 318</td>
<td>Birchfield and Brister(1969)</td>
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<td></td>
<td>3. DS-9, EC-93741</td>
<td>D.68-201, D.68-214</td>
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<td>D.68-216 and D 68-204</td>
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<td>Macs-190, Macs-153</td>
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<tr>
<td>Cotton</td>
<td>1. K7 and K8</td>
<td>-</td>
<td>Muralidharan and Sivalumar(1975)</td>
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<td></td>
<td>2. G. stocksli, G. somalense, G. barbadense</td>
<td>-</td>
<td>Yik and</td>
</tr>
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<td>Pigeonpea</td>
<td>1. 4658(M.P), 2387(A.P) 5561(Bihar),4160 (T.N)</td>
<td>AGB,1070,1114, 1116</td>
<td>Birchfield(1984)</td>
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<td></td>
<td>3830(W.B), Norman(USA)</td>
<td>AGS 579, Gaut 82-56,</td>
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<td></td>
<td></td>
<td>82-77, 84-13 and HY-3</td>
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<td></td>
<td>2. AGS 522, Gaut 82-74, 83-23, 84-22</td>
<td>Pusa sweta</td>
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<td>Green gram</td>
<td>1. ML-80, ML-62, TT8E, Pusa-103, PDM 14</td>
<td>IC 8955, IC 9125,IC11379</td>
<td>Routaray et al. (1986)</td>
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<td>2. IC 8924, IC11312</td>
<td>IC 10166, IC 10489</td>
<td>Patel et al. (1989)</td>
</tr>
<tr>
<td>Black gram</td>
<td>1. Ratnapur-4, UG-201 and UG 135</td>
<td>-</td>
<td>Routaray et al. (1986)</td>
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<td></td>
<td>2. -</td>
<td>-</td>
<td>Mida and Trivedi(1988)</td>
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<td></td>
<td>2. IC 19739</td>
<td>IC 20463</td>
<td>Patel and Patel (1990)</td>
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(Contd.)
**BIOLOGICAL CONTROL**

A wide variety of organisms have been shown as potential biological control agent of phytonematodes. This includes fungi, bacteria and viruses etc. Extensive works have been done on various mechanism nematophagous fungi. Vascular Arbuscular Mycorrhiza (VAM) reduces nematode infestation. *Glomus mosseae* a VAM fungus reduces *R. reniformis* penetration and development on bush bean, cucumber and muskmelon. In VAM infected bush bean, the number of nematode that penetrated was reduced by 35% and 41% after 4 and 8 days respectively after inoculation as compared to control (Sitaramaiah and Sikora, 1981).

Lingaraju and Goswami (1990); Babu *et al.* (1996); Sitaramaiah and Sikora (1996) reported *G. fasciculatum* to reduce *R. reniformis* in cowpea, ragi and cotton (40% to 80%). *Paecilomyces lilacinus* significantly reduced the damage to cowpea and tomato caused by *R. reniformis* (Khan and Husain, 1988, 1990; Walters and Barker, 1994). Significant reduction in *R. reniformis* was observed with *Rhizobium* inoculated simultaneously with the pathogen in *Vigna unguiculata* and lentil (Khan and Husain, 1998; Fazal *et al.*, 1992). On the contrary Vadhera and Dave (2000) reported that there was mark reduction in *Rhizobium* nodules in the presence of reniform nematode. Plants of chickpea suffered less damage from nematode when inoculated with *Bradyrhizobium japonicum* (Siddiqui and Mahmood, 1994).

**INTEGRATED CONTROL**

The integrated management procedures are based on principles of prevention of population, reduction and tolerance. Integrated nematode (INM) seeks to stabilize population of target nematode at acceptable levels resulting in favorable long economic and environmental consequences. To achieve better management, a several diverse control measures are involved.

Deep ploughing (20cm) followed by sowing after either of the culture practices or deep ploughing (20cm) together with carbofuran or aldicarb seed treatment resulted in control of reniform nematode and better yield of tomato (Lakshmann and Sivakumar, 1981). Rao *et al.* (1987) demonstrated that application of aldicarb (1 kg/ha) + neem oil cake (0.5t/ha) + urea (15kg N/ha) gave greatest reduction in nematode population and increased yield (Gaur and Misra, 1989). Patel and Makwana (1992) reported...
that rabbing of nematode infested nursery with bajra (millet) husk @ 7 kg/m² + solarization with LDPE film 400 gauge or combination each with carbofuran @ 1.5kg/ha were found economical and effective in management of *R. reniformis* in tobacco nursery.

**CONCLUSION**

Amongst the polyphagous plant parasitic nematodes reniform nematode have wide occurrence and associated with almost every crop of economic importance. Cultural control such as crop rotation, keeping the land fallow, use of fertilizer, plant extract, oil cake etc. are most effective measures in reducing the nematode population and increasing vigor and yield of crop. Use of nematicides in nursery bed, seed treatment, root dip treatment and soil application have been an effective and economical. Use of resistant plant is cost effective and environmentally safe means of reducing losses from diseases. Biological agents such as VAM, *Paecilomyces* spp etc. may be exploited for integrated nematode management (INM).

**REFERENCES**


