ROOT-KNOT NEMATODES OF CUCURBITS AND THEIR MANAGEMENT - A REVIEW

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ABSTRACT

Cucurbits are grown as warm season crops and have multiple uses. These crops are damaged by many plant parasitic nematodes. The information on nematodes associated, yield loss, pathogenicity and control is very limited. Use of chemicals cannot be advocated due to safety issues. Hence other methods viz., biological, organic amendments and resistant cultivars should be adopted. The information so far generated are presented briefly in this review.

Cucurbits are essentially warm season crops grown mainly in tropical and sub-tropical regions. This group of crops consists of a wide range of vegetables. They are used as salad, for cooking, for pickling, as dessert fruits, or candied or preserved (Seshadri, 1986). The menace in cucurbits cultivation is root-knot nematodes and they are responsible for huge annual losses of marketable fruits and vegetables.

In 1855, Berkeley was the first to report infestation by the root-knot nematode, *Meloidogyne* spp. on cucumber in England. Root-knot nematodes are world wide in distribution (Sasser, 1977) and more than 3000 plants including cucurbits have been recorded as hosts.

NEMATODES OF CUCURBITS

The nematodes associated with cucurbits are included in Table 1.

Table 1. Nematodes associated with cucurbits

<table>
<thead>
<tr>
<th>Country</th>
<th>Crop</th>
<th>Nematode</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Libyan Jamahiriya</td>
<td><em>Cucumis sativus</em> L.</td>
<td><em>M. incognita</em></td>
<td>Khan and Dabaj, 1980</td>
</tr>
<tr>
<td>Uzbek SSR</td>
<td><em>C. sativus</em></td>
<td><em>M. javanica</em></td>
<td>Rizaeva, 1983</td>
</tr>
<tr>
<td>Pakistan</td>
<td><em>Lagenaria siceraria</em> (Molina) standley</td>
<td><em>M. arenaria</em></td>
<td>Maqbool et al., 1985</td>
</tr>
<tr>
<td>Pakistan</td>
<td><em>C. sativus</em></td>
<td><em>M. incognita</em></td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td><em>Citrullus vulgaris</em> Schrad</td>
<td><em>Meloidogyne</em> spp.</td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td><em>Cucumis melo</em> L. ssp. melo var. <em>flexuosus</em></td>
<td><em>M. javanica</em></td>
<td></td>
</tr>
<tr>
<td>Libya</td>
<td><em>C. sativus</em></td>
<td><em>M. incognita</em></td>
<td>Khan and Siddiqui, 1986</td>
</tr>
<tr>
<td>Korea</td>
<td><em>Citrullus lanatus</em> (Thunb.) Mansf</td>
<td><em>M. javanica</em></td>
<td>Cho Myoung Rae et al., 2000</td>
</tr>
<tr>
<td>Mauritius and Rodrigues</td>
<td><em>Momordica charantia</em> L.</td>
<td><em>M. arenaria</em></td>
<td>Kim Dong Geun, 2001</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td><em>C. lanatus</em></td>
<td><em>M. incognita</em></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td><em>Luff aegyptica</em> Mill. C. melo L. ssp. melo var. <em>flexuosus</em></td>
<td><em>M. javanica</em></td>
<td>Lambert et al., 1987</td>
</tr>
<tr>
<td>India</td>
<td><em>L. scurraria</em></td>
<td><em>M. mayaguensis</em></td>
<td>Rammah and Hirschmann, 1988</td>
</tr>
<tr>
<td>India</td>
<td><em>C. vulgaris</em></td>
<td><em>M. incognita</em></td>
<td>Ahuja and Mukhopadhyaya, 1985</td>
</tr>
</tbody>
</table>

(Contd.)
PATHOGENICITY

Bistline and Rhoades (1984) reported that *M. charantia* seedlings inoculated with 10,000 *M. incognita* eggs were heavily galled and plant growth was significantly reduced and the seedlings infested with 20,000 or more eggs were moribund or dead. Sable and Darekar (1985) stated that all growth characters of *M. charantia* were significantly reduced at 500, 1000, 5000 and 10,000 *M. incognita* juveniles/plant and the number of galls increased with inoculum level. Reduced plant growth was noticed with 100 juveniles of *M. incognita* on *C. melo* (Sharma Chandresh, 1984).

Paruthi and Gupta (1985) observed more galls and egg masses/plant when 10 day old plants were inoculated with *M. javanica* at or above 100 juveniles/kg soil in *L. siceraria* irrespective of the method of inoculation either at planting or when the seedlings were 10 days old.

At 1000 *M. incognita* J$_2$/kg soil, watermelon growth was significantly reduced and at 10,000 J$_2$/kg soil, stunted growth, yellowing, defoliation, severe galling and even death of plants were observed by Dhankhar et al. (1986).

*M. incognita* race 1 was the most pathogenic species tested, and induced the lowest shoot fresh weight in *C. sativus* cv. Sumter (Wehner et al., 1991). More than 1000 J$_2$ of *M. incognita* race 3 as initial inoculum level caused significant reduction in shoot length, root length and shoot weight of cucumber. Root weight was increased at 10,000 J$_2$ inoculum level whereas reduced at 10,0000 J$_2$. Nematode soil population, number of galls, females and egg masses increased with increases in inoculum levels whereas at 10,0000 J$_2$, nematode population on both roots and soil were decreased (Krishnaveni and Subramanian, 2002a).

At an initial inoculum density of 1000 J$_2$ of *M. incognita* per kg soil, Mahapatra et al. (1999) recorded a significant reduction in shoot and root weight of pointed gourd (*Trichosanthes dioica* Roxb.).

YIELD LOSS

Darekar and Mhase (1988) assessed the yield loss in bitter gourd (*M. charantia*) cv. Coimbatore Whitelong due to *M. incognita* race 3 as 36.72 per cent. Nayga and Salares (1990) stated that in *M. charantia*, per cent yield loss was lower on eight weeks old plants regardless of *M. incognita* inoculum density used.

Sharma and Baheti (1992) estimated avoidable losses due to *Meloidogyne* sp. on *L. siceraria* between 46 to 56 per cent. Nahar et al. (1996) estimated yield loss in bottle gourd (*L. siceraria*) due to *M. incognita* as 26.44 per
Park et al. (1995b) observed that infection by *M. incognita* on watermelon (*C. vulgaris*) and oriental melon (*C. melo*) resulted in decreased shoot and root weight but there were no differences in plant height and root length.

According to Bafokuzara (1996), *Meloidogyne* spp. were considered to be the most important parasites of cucumber and caused yellow foliage, unthrifty growth, small slow growing fruits, poor yield, heavy root galling, root decay and reduced root system. Krishnaveni and Subramanian (2002b) estimated yield loss due to *M. incognita* race 3 on cucumber as 69.24 per cent.

Total fruit yield of 2 and 4 week old ampalaya plants inoculated with 1000 and 5000 *M. incognita* eggs was reduced by 68 and 70 per cent, respectively, and the reduction increased from 81 and 82 per cent when inoculum density was increased to 10000 and 20000, respectively (Salares and Gapasin, 1988).

**DISEASE COMPLEX**

According to Caperton et al. (1984), with moderately resistant summer squash seedlings, there was both an increase in wilt development and an earlier onset of symptom when both *M. incognita* and *F. oxysporum f.sp.niveum* were present. Mital et al. (1985) observed considerable reduction in *L. lecanthra* growth and increased number of galls in the roots when both *Sphaerotheca fulginea* and *M. incognita* were inoculated together but *M. incognita* female size was reduced by dual inoculations.

Caperton et al. (1986) had noticed wilt incidence when *C. pepo* cv. Early Prolific Straight Neck was concomitantly infected with *F. oxysporum*, f. sp. *niveum* and *M. incognita* but wilt resistance in cv. Goldneck was unaffected by *M. incognita*. Khan and Pasha (1988) stated that when *S. fulginea* and *M. javanica* inoculated simultaneously, plant growth was reduced considerably.

Choo et al. (1990) reported that combined inoculation of *M. incognita* and *Rhizoctonia solani* reduced seedling emergence of cucumber and the incidence of post-emerge damping-off was also higher in nematode + *R. solani*.

Corazza (1998) recorded that the presence of root knot nematodes (*Meloidogyne* spp.) reduced the resistance of winter melons to *P. O. f. sp. melonis*.

Cucumber (*C. sativus*) as a trap host became infected by both a virus and root-knot nematode when planted in soil collected from the rhizosphere of banana plants showing bunchy-top disease symptoms (ShouHua Wang et al., 1998). Interaction between *M. incognita* and *F. O. f. sp. niveum* in watermelon roots was studied and the results indicated that *M. incognita* was able to increase the disease incidence of watermelon *Fusarium* wilt (Yen et al., 1998). Li MaoSheng et al. (2001) showed that *F. oxysporum* and *M. incognita* could cause mixed infection resulted in severe yield loss in cucumber.

**BIOCHEMICAL CHANGES TO NEMATODE INFECTION**

Ustinov and Zinovev (1958) reported that due to infection by *Meloidogyne* sp. on cucumber roots, the quantity of non-protein nitrogen, ammonia, water and monosaccharides was greater in the galls.

Bumbu (1971) stated that *M. incognita* infection on cucumbers, resulted in changes in carbohydrate and protein metabolism and an increase in free amino acids in galls. Rezk and Fegla (1986) observed an increase in protein amino acid contents in sweet melon plants infected with either of *M. javanica* and cucumber mosaic virus or their combination.
STEM GALLS

In India, *M. javanica* formed galls on adventitious roots and on the stem portion of *Luffa acutangula* cv. H-4 and is the first report of stem galls caused by *Meloidogyne* spp. on a cucurbitaceous plant (Kanwar and Bhatti, 1989).

NAMATODE PENETRATION

Pasha et al. (1988) assessed root penetration by *M. javanica* on bottle gourd (*L. siceraria*) roots and was highest (45%) in 2-week-old seedlings and lowest (19%) in 6-week-old seedlings.

According to McClure and Viglierchio (1966b), increasing the concentration of sucrose, macronutrient salts and iron chelate in a culture medium resulted in a corresponding increase in penetration of *M. incognita* on excised cucumber roots.

MANAGEMENT

a) Physical control

Under Spanish conditions, solarization was found effective (34-46°C) during hotter months (July to September) to control *M. incognita* in melons (Mejias Guisado et al., 1993).

b) Cultural control

The lowest *M. javanica* infestation and the highest yield were found following *C. melo*, Capsicum, and resistant tomato rotation (Moens and Aicha, 1985). Application of decomposed composts of neem (*Azadirachta indica* A. Juss), subabul (*Leucaena leucocephala* (Lamk.) de Wit), mustard (*Brassica juncea* (L.) Czern & Coss) and water hyacinth (*Eichhornia crassipes*) at 25 g/ha reduced *M. incognita* damage and increased fruit yield of bottle gourd (*L. siceraria*) (Verma et al., 1997).

Cheng and Tsay (1989) showed that application of a chitinous compound was effective in reducing *Meloidogyne* spp. on watermelon. Tu et al. (1990) observed that use of chitinous organic amendments on watermelon controlled *M. javanica* and *M. incognita* and yielded better fruit quality and quantity. Chiu and Huang (1997) observed that spent forest mushroom compost (SFMC), SFMC 75, spent golden mushroom compost (SGMC), SGMC 75 and paper mill sludge (PMS) inhibited the occurrence of root-knot nematode in watermelon (*C. vulgaris*).

A preparation of non-litter pig manure improved growth of cucumber and showed nematicidal effect against *Meloidogyne* sp. (Turlygina et al., 1984). Udalova et al. (1994) reported that Chitosan® controlled *Meloidogyne* and increased yield of cucumber. Park et al. (1995a) reported that the most economic control practice for *Meloidogyne* spp. on cucumber and oriental melon (*Cucumis* sp.) was rotation with rice, every three years. Nasr Esfahani and Ahmadi (1997) reported that application of farm yard manure (40 t/ha) reduced the incidence of *M. javanica* on cucumber roots. Sumner et al. (1999) tried crop rotation with bahia grass (*Paspalum notatum* Fluegge) for two or three years in a double crop of cucumber (cv. Comet) Snap bean (*Phaseolus vulgaris* cv. Strike) and was effective in reducing root galling by *M. incognita*.

Verma et al. (1998) reported that organic amendments (250 g/m² of oilseed cakes viz., *Madhuca longifolia* (L.) Macb., neem (*A. indica*) and mustard) and chopped leaves of *Ricinus communis* L., *Calotropis procera* (Willd.) Dryand ex W. Ait., *Leucaena leucocephala* (Lamk.) de Wit or *Melia azaderach* L. (at 500, 1000 or 1500 g/m²) decreased *M. incognita* and increased sprouting of pointed gourd (*T. dioica*).

Chitin treatment at 0.4 per cent and above reduced root galling caused by *M. arenaria* in *C. pepo* and the fungus *Malbranchea aurantiaca* stimulated by chitin treatments at 1 per cent or above shown to parasitize eggs of *M. arenaria* in vitro (Godoy...
et al., 1983). Culbreath et al. (1985) reported the efficacy of alkaline hemicellulosic waste material from the paper pulp industry alone or in combination with crustacean chitin against *M. arenaria* on "Yellow Crookneck" squash (*Cucurbita pepo* L.). Rodriguez et al. (1989) observed sharp decrease in number of galls/g of fresh squash root (first crop) or tomato (second crop) in response to increasing rates of urea (0-1.0 g/kg of soil) and Clandosan®. (0-10 g/kg soil) in soils infested with *M. arenaria*. Rodriguez et al. (1990) reported that soyabean meal at 2-4 g/kg soil, lg of Clandosan® and 0.5g urea/kg of soil was effective in reducing galls caused by *M. arenaria* in squash (*C. pepo*) roots.

c) Chemical control

Sable and Darekar (1986) carried out a field experiment on the chemical control of *M. incognita* infesting *M. charantia* cv. Coimbatore Long White. They observed that aldicarb 10 G at 2 kg a.i./ha, carbofuran and aldicarb sulfone (aldoxycarb) seed treatment at 6 per cent w/w had the lowest root-knot index (1.3) at thirty days after sowing whereas Oncol 3G (benfuracarb) had the lowest root-knot index at harvest (2.9) and the highest yield (9.168 kg/15 vines and 93.34 per cent increase over control).

Johnson and Harmon (1974) recorded reduced number of root galls, and increased crop yield and quality from plots treated with EDB and ethoprop @ 23.4 l/ha, 8.96 kg a.i./ha respectively, when *C. melo* was infested with *M. incognita*. Lawrence and McLean (1995) reported that Fosthiazate 7.5 EC and 10 G @ 2, 4 and 6 lb/acre significantly reduced *M. incognita* numbers and increased melon yields compared to control. Tacconi *et al.* (1998) found that methyl bromide, independent of the dose and the type of polythene tarping, drastically reduced *M. incognita* damage and significantly increased marketable yields of melon. They also reported that the medium dose (40 g/m²) under standard plastic gave results equal to the lowest one (20 g/m²) under bromocarb and dazomet (40 g/m²) gave moderate results. Carbofuran was found effective when applied @ 0.74 kg a.i./ha as pre- and post-sowing treatment, in reducing *M. incognita* and increasing plant vigour of muskmelon cv. Ravi (Javed and Ahmad, 1999).

Darekar *et al.* (1989) reported that in *L. siceraria* cv. Local, seed treatment with 3 per cent or 6 per cent w/w of carbofuran or benfuracarb was effective in controlling *Meloidogyne* spp. and increasing yield compared with untreated control and seed treatment with carbofuran or benfuracarb at 6 per cent w/w was significantly better than the other treatments. Carbosulfan and benfuracarb (© 3.0 per cent w/w) as seed treatment increased yield and reduced root-knot index in bottle gourd (Anonymous, 1993). *L. siceraria* and *M. charantia* seeds treated with carbofuran, phenamiphos or phorate at 3 and 6 per cent w/w and then grown in a field having moderate infestation of *M. incognita* were observed with reduced root-knot development and increased yield in all treatments, with the highest rate of phenamiphos having the greatest effect (Siddiqui *et al.*, 1993). Nahar *et al.* (1996) evaluated Agridan 3G, Furadan 3G, Miral 3G and Sunfurans 3G (all carbofuran) and Rugby 10 G (isazofos) (seed treatment © 1000 ppm) to control root-knot of bottle gourd (*L. siceraria*) caused by *M. incognita*. They concluded that isazofos appeared best in controlling root-knot followed by Miral, Furadan, Sunfurans and Agridan.

Vito and Lamberti (1978) found that phenamiphos at 50 kg/ha increased the yield by 140 per cent, Di-Trapex at 500 l/ha by 128 per cent, EDB at 83 l/ha by 128 per cent, AC 64475 at 2 kg/ha by 106 per cent and DD at 500 l/ha by 96 per cent. They also
observed that soil treated with EOB, D-D, Di-

Trapex or phenamiphos (30, 40 or 50 kg/ha) were resistant to attack by *M. incognita* on watermelon. Temik, Furadan, Dasanit or Vydate applied at 11.2 or 22.4 kg/ha effectively controlled *M. incognita* on watermelon in Puerto Rico (Acosta, 1983).

Application of phenamiphos at 5.6 kg/ha in irrigation water with chlorothalonil foliar spray reduced root galling due to *M. incognita* in cucumber (Sumner et al., 1981). Lashkova and Danilov (1982) stated that Di-

Trapex at 500 l/ha reduced the number of plants heavily infested with *M. incognita* to 18.3 per cent from 35.7 per cent and increased the tomato yield by 3 kg/m². They also found that the effect of Di-Trapex lasted into the second crop, increasing the cucumber yield by 4.2 kg/m². Under field conditions ethoprophos broadcast at 0.5, 1.0, 1.5 and 2.0 gallon/acre or oxamyl at 2.0 gallon broadcast or 2.0 pint foliar spray were significantly reduced *M. incognita* numbers compared to control on cucumber (Averre et al., 1995). Bharali and Phukan (1997) reported that seed soaking with carbosulfan 25 EC, hostathion 40 EC (triazophos) and quinalphos 25 EC at 0.1 and 0.2 per cent a.i. (v/v) for 1 and 2 h was effective in reducing galls, egg masses and eggs per egg mass of *M. incognita* and resulted in improved plant growth characters of cucumber. Al Hamdany et al. (1999) reported that application of Furfural® (crop guard) @ 1000 and 2000 ppm significantly reduced the no. of root galls on cucumber while no galls were observed on the roots when 4000 ppm of Furfural® was used. In the management of *M. incognita* race 3 on cucumber var. Green long, application of carbofuran @ 1 kg a.i./ha was found to be highly effective (Krishnaveni, 2002).

Johnson *et al.* (1986) tested phenamiphos (6.7 kg a.i./ha) with 0.25, 0.64, 1.27 and 1.91 cm surface water/ha via an irrigation simulator to *C. pepo* at planting (AP) and 2 weeks after planting (PP) for control of *M. incognita* and recorded low root gall indices and high yields which indicated more effective nematode management when phenamiphos was applied AP rather than PP.

Elsebae (1996) observed that there was a significant reduction in *M. incognita* population upto 12 weeks even at 1/10 of the field rate of chemicals on cantaloupe or cucumber in the greenhouse and the efficacy was enhanced by rising to the higher rate. It was more enhanced when combined with the spreading surfactant (Triton-X 100). Oxamyl was the most effective one followed by isazofos and carbofuran.

d) Resistance

Cultivars/varieties of cucurbits reported to be moderately resistant/resistant/highly resistant to root-knot nematodes, *Meloidogyne* spp. are given below.

**Cucumber (Cucumis sativus var. hardwickii)**

According to Walters *et al.* 1993, *C. sativus var. hardwickii* accession LJ 90430 and Mincu were moderately resistant to *M. arenaria* race 2. Lucia (NC 46), Manteo (NC 44) and Shelby (NC 45) were resistant to *M. arenaria* races 1 and 2, *M. javanica* and *M. hapla* (Walters and Wehner, 1997a).

Walters and Wehner, 1997b stated that *C. sativus var. hardwickii* accession LJ 90430 (NC 42) was resistant to *M. javanica* and *M. arenaria* races 1 and 2. Also accessions PI 462379 and PI 215589 were resistant to *M. arenaria* races 1 and 2 and *M. arenaria* race 2 respectively.

**Cucumis sativus**

The cultivars Femcap, Rozental, Tsepellin, Superator, Kue-vo-Kha-bakh were resistant to *M. incognita* (Udalova and Prikhod'ko, 1985). The cultivar Gy-5937-587 was moderately resistant to *M. incognita* race 3 (Darekar *et al.*, 1988).
Khelu A. Zh. et al. (1989) reported that the varieties Ralda and Capris were highly resistant to *M. arenaria* and *M. javanica*. Wehner et al. (1992) stated that the cultivar Sumter was resistant to *M. hapla*. Sharma et al. (1995) observed that the variety Hoe-707 showed resistance and EC-173929 showed moderately resistant reaction to *M. incognita*. Also the variety Poinsette was moderately resistant to *M. incognita* (Bharali and Phukan, 1996).

**Cucumis sativus var. sativus**

Walters et al. (1996) reported that NC-43 a selection of *C. sativus* var. sativus cultivar Southern Pickler was resistant to *M. arenaria* race 2.

**Cucumis metuliferus**

Nugent and Dukes (1997) observed that the variety C 701 A was highly resistant to *M. incognita*.

**Water melon (Citrullus lanatus)**

Zhang et al. (1989) evaluated 135 watermelon genotypes and reported that Mexico 74 was highly resistant to *M. incognita* race 2. Also Crimson Sweet, 11253, Gangpi 100, Zhong-Yul, Selection of Yi were highly resistant to *M. arenaria* race 2 and *M. javanica*.

e) Biological control

Kurt (1975) observed that a filtrate of the culture medium (brewer's wort) of *Aspergillus niger* was effective in reducing the gall formation by *Meloidogyne* on cucumber. Udalova (1975) stated that formulation of *Arthrobotrys oligospora* at 900 g/m² was effective in controlling *M. incognita* infestation on cucumber. Rudzevichene and Lugauskas (1976) noticed that *Trichoderma lignorum* inhibited the nematode fauna affecting cucumber under glasshouse conditions. Teplyakova et al. (1982) observed that concentrations of 5 and 10 per cent of *A. oligospora* reduced root infestation of *M. incognita* on cucumber and the growth of plants was more in the presence of organic humus and fungus. Maximum growth and maximum yield were observed at 5 and 2 per cent, respectively. Application of nematode antagonistic actinomycetes and bacterial isolates on cucumber infested with *M. incognita* resulted in a decrease in root galling and an increase in shoot weight (10 per cent) (Zavaleta and Van Gundy, 1987). Matskevich (1993) reported that fungal preparations from *Arthrobotrys* (Nematofagin-BL) effectively reduced infections of root-knot nematodes (*Meloidogyne* spp.) in cucumber. Perveen et al. (1998) reported that *Pseudomonas aeruginosa* was more effective than *Paecilomyces lilacinus* in reducing *M. javanica* infection in cucumber. Chubachi et al. (1999) reported that under *in vitro* conditions, all six strains of *Streptomyces* sp. suppressed *M. incognita* (race 1) J₂ motility. In pot experiments, there was an increase in shoot length and fresh shoot weight, and a decrease in gall index of cucumber (cv. Hayamidori) seedlings inoculated with each strain in comparison with the untreated control plants. Gall indices of plants grown in soil treated with strains NA - 494 and NA-369 were 24 and 29 per cent lower than that of untreated plants, respectively, and the population density of J₂ in soil treated with strains NA-150 and NA-359 was reduced by half. In separate experiments, germination and growth of cucumber seedlings was not affected by culture filtrates of each of the six strains. Yarkulov (2000) studied the effect of *Trichoderma koningii* (Strain 1/31), *Verticillium lecanii* (Strain AFX-7), and *P. lilacinus* (Strain p-K1) on root-knot nematodes (*Meloidogyne*) in cucumber and stated that all the three resulted in good nematode control and increased the yield. Krishnaveni (2002) reported that *P. fluorescens* as seed treatment @ 10 g per Teg seed recorded improved cucumber growth and yield and reduced nematode population in roots and soil. Other treatments, viz., VAM and
Trichoderma viride also recorded significantly higher growth parameters and yield, with reduced nematode population compared to control.

Ali (1990) reported that application of A. oligospora and organic amendment (pigeon droppings) on melons resulted in increased plant growth and reduced root galling (due to M. incognita) by 72 and 72 per cent, respectively. Meyer (1999) reported that Verticillium lecanii strains suppressed egg numbers of M. incognita (at 5000 eggs/plant) on cantaloupe melons but it did not affect the eggs embedded in root galls. They also noticed that a heat-stable substance produced by the fungus was deleterious to nematodes.

f) Control methods other than chemicals

According to Marks and Sayre (1964), the development rate of M. incognita in cucumber (C. sativus) var. Burpee hybrid increased as the potassium was increased from 2 to 156 ppm. But no such correlation with M. javanica or M. hapla.

Spraying cucumbers with maleic acid hydrazide (0.003%) or propyl gallate (0.02%) at 30ml per plant or of exposing young cucumber seedlings to ultra-violet light for 7 min improved plant growth and reduced infection caused by M. incognita in the descending order UV, maleic acid hydrazide and propyl gallate (Kozhokaru, 1972).

It is suggested that the increased plant growth following application of ethaphon or 2, 3, 5 tri endobenzoic acid (TIBA) may help to increase nematode tolerance and maleic hydrazide (MH) decreased chlorophyll-a, nitrogen content and root gall index caused by M. incognita on C. vulgaris var. Chilian black (Osman and Moursy, 1979). Application of mixtures of blackstrap molasses with urea in soil resulted in improved control of M. arenaria in squash (C. pepo) (Rodriguez Kabana and King, 1980).

Grafting fruit vegetables was very effective for controlling soil borne diseases and nematodes in water melons, cucumbers and melons in Japan (Oda, 1995).

The interactive effects of M. javanica and SO₂ were synergistic at 100 mg m⁻³ and antagonistic or additive (slightly synergistic/antagonistic) at 200 and 300 mg m⁻³ on pumpkin (C. moschata), according to Khan et al. (1995). They also observed that root galling and egg mass production were enhanced by about 11 per cent and 6 per cent at 100 mg m⁻³ and declined by 23 per cent and 24 per cent at 300 mg m⁻³, respectively.

The rate of development of M. incognita was diminished at reduced concentrations of sucrose and iron chelate whereas decreasing concentrations of vitamins and micronutrient salts increased nematode development according to McClure and Viglierchio (1966a). Oda (1999) reported that tube-grafting methods had been developed for plugs and the grafted plants were produced on watermelon, cucumber and melon to control soil-borne diseases and nematodes.

Essential oils of Carum carvi, Foeniculum vulgare, Mentha rotundifolia and M. spicata showed the highest nematicidal activity against Meloidogyne spp. juveniles according to Oka et al. 2000. They also noticed that essential oils from Origanum vulgare, O. syriacum and Coridothymus capitatus at 100 and 200 mg/kg of sandy soil reduced root galling of cucumber seedlings.

g) Integrated Nematode Management

Steam sterilization, cultivation of resistant varieties or by cultural means reduced Meloidogyne spp. on cucumber (Anonymous, 1983). Combined application of A. irregularis, manure composed of 70 per cent sea weeds and 30 per cent cattle manure, and carbofuran 5 per cent resulted in improved vigour of cucumber var. Komerone and improved yield
and decreased galling and numbers of Meloidogyne sp. in roots and soil (B’chir et al., 1983). Application of methyl bromide (40 g/m²), solar heating, phenamiphos liquid (5 cc/m³), isazofos (25 g/m²) and P. lilacinus was most effective for the control of M. javanica on cucumber (Stephan et al., 1991). Use of resistant tomato cultivars, viz., Multiset, Tomosa and cucumber cultivar TS 88122 and application of soil conditioner Clandosan® effectively controlled M. incognita (Arndt, 1994). Lamparter (1994) used soil sterilization and Basamid (dazomet) for the control of M. incognita affecting cucumber. Nasr Eslahani et al. (2000) stated that solarization, farm yard manure and their integration reduced the infection of M. javanica up to 50, 57 and 83 per cent while other plant parasitic nematodes were also reduced to 72, 75 and 86 per cent on cucumber, respectively.

CONCLUSION

In cucurbits, the work on pathogenicity and yield loss due to root-knot nematodes was scarce and in future more information should be developed in all the related cucurbit species and will be more helpful to the people who are going to cultivate this crop.

The majority of the studies on root-knot nematodes affecting cucumber have been carried out with chemicals. For curcubit cultivation use of chemicals cannot be advocated due to safety issues. Growers need to consider an alternative paradigm. So the other management practices like physical control, resistance varieties are to be developed. Even though the development of resistant varieties is a time consuming process we have to adopt it for future use. But only thing is the resistant variety should be a good yielder and which is the main key to popularize a resistant variety.

In addition, biocontrol agents should also be developed as a safety measure to control the nematodes affecting cucurbits. At present Pseudomonas fluorescens and Paecilomyces lilacinus have been used extensively for the control of nematodes in other crops. So these two biocontrol agents can also be used for effective control of root-knot nematodes in cucurbits.

Apart from advocating a single control strategy, we can go for integration of all possible control methods, which will yield reliable results. In cucurbits, the information on integrated nematode management is scarce. So the elite and reliable method of controlling nematodes on cucurbits such as biocontrol agents, organic amendments and resistant varieties can be effectively integrated.

REFERENCES
