REVIEW OF LITERATURE
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The focal theme of the present thesis is to control plant-parasitic nematodes with organic amendments of soil. As has been pointed out in the preceding chapter, organic amendments and interculture of antagonistic crop plants are highly promising non-chemical strategies for the control of plant-parasitic nematodes. These aspects have been reviewed here in this chapter.

ORGANIC AMENDMENTS:

Addition of organic matter into soil is a practice almost as old as agriculture for improvement of soil fertility and crop yield. However, beneficial effects of organic amendments with respect to suppression of plant pathogens including nematodes have been recognized in the recent past. Linford et al. (1938) were the first to observe reduction in root-knot incidence caused by *Meloidogyne* spp. on cowpea (*Vigna unguiculata* L.), when soil was amended with chopped pineapple (*Ananas comosus* L.) leaves. Further studies on these aspects were, however, hampered due to the development of many highly effective fumigant nematicides during 1940's and 1950's particularly in industrially developed countries. As a result of recent discoveries about environmental and health problems associated with the use of nematicidal chemicals, alternative strategies for the nematode control started receiving attention of nematologists the world over. A brief review with respect to nematode control with different organic amendments is given below.
Green Manuring:

Although green manuring with legumes had been a traditional practice with Indian farmers in order to improve organic matter and fertility status of the soil, it has also been found to suppress populations of plant-parasitic nematodes. Linford et al. (1938) demonstrated that the incidence of root-knot could be significantly reduced by incorporating chopped pineapple leaves into the soil @ 50-200 tons/acre. Duddington and Duthoit (1960) and Duddington et al. (1961) found reduction of cereal-root-eelworm with the incorporation of chopped cabbage (*Brassica oleraceae capitata* L.) leaves (@ 680 g/0.61 m²) into the infested soil. Hutchinson et al. (1960) noticed that population of some plant-parasitic nematodes, e.g., *Hoplolaimus*, *Tylenchorhynchus* and *Pratylenchus* spp. were significantly lower in soil where pieces of pumpkin (*Cucurbita pepo* L.) were allowed to rot compared with the rest of soil. Patel and Desai (1964) tested 5 crops for green manuring in root-knot (*Meloidogyne* spp.) infested soil, and found *Meliolotus alba* var. *annua* and *Sorghum vulgare* highly effective in reducing root-knot development. Singh (1965) used chopped leaves of karanj (*Pongamia pinnata* L.) and noted that they were responsible for suppression of root-knot intensity. Application of alfalfa (*Medicago sativa*) green manure in root-knot infested field was found to be good nematode suppressant (Mankau, 1968). Efficacy of green crop manure for reducing strawberry stem nematode in soil was observed by Andreeva (1975).

Recently, bahiagrass (*Paspalum notatum*) has been reported in the management of root-knot and cyst nematodes in soybean (Rodriguez-
Kabana et al., 1988, 1989) and M. arenaria on peanut (Dickson and Hewlett, 1989). Hackney & Dickerson (1975) noted population of M. incognita were significantly fewer from marigold than from tomato, and aborted giant cells and females were frequently observed in roots of marigold.

**Dry Crop-Residues:**

Several plant-parts such as root and shoot are left into the field after harvest and ploughed; these additives after decomposition resulted in suppressing many plant-parasitic nematodes. Johnson (1959, 1962, 1963, 1971, 1972) observed that every type of crop-residues were effective in suppressing plant-parasitic nematodes. In a study Johnson et al. (1967) demonstrated that when mature dried residues of lespedeza, alfalfa, oats and flax were incorporated into soil infested with Meloidogyne incognita, the incidence of root-knot of tomato (Lycopersicon esculentum) was significantly suppressed. Similar observations have been reported by Miller and Wihreim (1966) and Patrick and Toussoum (1965). Mountain and Elliott (1962) found effective control of Pratylenchus penetrans by ploughing rye straw into infested soil under fallow during summer, and this control was as effective as fumigation with DD mixture. Reduction in Tylenchulus semipenetrans by soil amendment with cotton waste, lucerne pellets, and lucerne has been reported by Mankau and Minteer (1962). Rice straw at 9.0 or 17.9 t/ha has been found to reduce populations of Belonolaimus longicaudatus and other plant-parasitic nematodes (Tomerlin and Smart, 1969).
Agro-industrial By-products:

Oilcakes: Oilcakes are generally rich in manurial ingredients such as nitrogen, phosphorus and potash. Application of oilcakes into the soil takes about 1-2 weeks for decomposition. They have been found more effective in moist soils than in dry soils. Oilcakes of castor (Ricinus communis L.), groundnut (Arachis hypogaea L.), cottonseed (Gossypium herbaceum L.), mustard (Brassica juncea (L) Czern. & Coss.), mahuva (Madhuca indica J.F. Gmel.), linseed (Linum usitatissimum L.), sesame (Sesamum indicum L.), neem (Azadirachta indica A. Juss.) and karanj (Pongamia pinnata L.) have been extensively used for the control of a number of plant-parasitic nematodes, however, oilcakes of cotton, groundnut, mustard, sesame, linseed etc., being chiefly used as cattle feed, may not be economical and feasible as soil amendment in nematode control.

Lear (1959) has reported a significant reduction in root-knot nematode (Meloidogyne javanica) and sugar-beet nematode (Heterodera schachtii) populations as well as root galling of tomato when the soil was amended with castor pomace. In a similar treatment also, Mankau and Minteer (1962), and Mankau (1963) have found the reduction of citrus nematode (Tylenchulus semipenetrans) and root-knot nematode (M. javanica). In India during the last two decades, a number of plant nematologists have carried out experiments on the efficacy of oilcakes for controlling nematodes on tomato (Lycopersicon esculentum Mill.), eggplant (Solanum melongena L.), okra (Abelmoschus esculentus (L). Moench.) and chilli (Capsicum annuum L.) (Singh, 1965; Singh and Sitaramaiah, 1966, 1971a; Goswami and Swarup, 1971; Srivastava et al.,
Singh and Sitaramaiah (1966) claimed that the root-knot on tomatoes grown after okra, can be checked by residual effects of oilcakes in same field without further amendments. Similar results were also observed by Alam et al. (1977b). Ismail et al. (1976) reported that all oilcakes tested were equally effective on different varieties of tomato against a number of plant-parasitic nematodes. Alam et al. (1977b) pointed out that oilcakes of castor, mustard, neem, and groundnut and two nematicides, viz., DD and Nemagon were equally effective against the population of Hoplolaimus indicus, Tylenchorhynchus brassicae, Tylenchus filiformis and M. incognita on tomato, potato (Solanum tuberosum L.) and radish (Raphanus sativus L.). Alam (1976) showed in a comparative study, that the oilcakes were equally effective in two different seasons of India, summer and winter, and also in two different soil types, one with high organic content and pH at 8.4 and another with low organic content and pH at 7.7. Khan et al. (1976a) and Alam et al. (1977a) reported that oilcakes were also effective for the control of plant-parasitic nematodes on perennial plants e.g., grevia, papaya, pomegranate, mango, blackberry, lemon, bougainvillaea and rose. In another study Alam (1990b) observed a similar effect of oilcakes on plant-parasitic nematodes in nurseries of many annual crops.

Nematodes associated with cereals and legumes were reduced by oilcakes on mung and wheat (Prasad et al., 1972, Mishra and Prasad, 1974), on paddy (Mathur and Prasad, 1973) and on wheat (Sharma et al., 1981).
It has been demonstrated that a combination of oilcakes and nematicide were more effective in reducing nematodes and increased plant growth than either of them alone (Bhattacharya and Goswami, 1988). Sawdust in combination with oilcakes gave better reduction in nematode population as well as better growth of plants (Kushwaha et al., 1983). However, Singh et al. (1986) reported that sawdust alone was more effective in reducing nematode population but resulted in phytotoxicity.

The toxicity of filtrate from the soil amended with neem cake and castor cake to M. incognita increased up to 3 weeks of decomposition, where it was maximum, then decreased by 6th week. Moreover, castor cake was more toxic at 4th week than neem cake (Goswami and Vijaylakshmi, 1987). Several other studies have recognized the toxicity of water soluble fractions of oiled and deoiled cakes on different plant-parasitic nematodes (Khan et al., 1966, 1974b; Rao and Prasad, 1969; Deshmukh and Prasad, 1969; Sitaramaiah et al., 1974; Pillai et al., 1974; Bhatnagar et al., 1978; Alam et al., 1982; Husain et al., 1984).

Singh et al. (1980) and Vijaylakshmi and Goswami (1986) have pointed out the efficacy of oilcakes as seed dressing in reducing the intensity of root-knot.

Sawdust: It has limited scope to be used as a manure but it has been suggested for nematode control. Singh et al. (1967) and Singh and Sitaramaiah (1967, 1971a,b) applied sawdust in field planted with okra and eggplant, and Srivastava et al. (1971) in tomato and
eggplant; they observed significant reduction in the intensity of galls on those crops. Similarly, several other studies have pointed out on the use of sawdust in nematode control (Miller and Edgington, 1962; Ducusin and Davide, 1972; Mishra and Prasad, 1974; Bora and Phukan 1983; Singh et al., 1986, 1987). Besides diminishing the nematode populations, phytotoxic effects of sawdust have been identified by Singh et al. (1967). Conversely, sawdust were used with other combinations like oilcakes, nematicides, sugar-cane bagasse, urea, and cowdung. Since it is deficient in nitrogen, it is not favoured as a soil amendment. Therefore, it has been suggested (Singh et al., 1967) that it should be supplemented with nitrogenous fertilizers.

Mian and Rodriguez-Kabana (1982) have claimed that nematode-control properties of soil amendments are directly related with N content or inversely related with C:N ratio. But in case of sawdust it was noted by Alam (1976) that it is not the C:N ratio but the C content, or in other words the amount of sawdust has direct correlation with the extent of nematode control. However, in other report, Rodriguez-Kabana et al. (1987) expressed the opinion that the effectiveness of a given organic matter depends on its chemical composition and the types of microorganisms that develop during its decomposition. This view of Rodriguez-Kabana et al. (1987), in a way, fully supports the findings of Siddiqui and Alam (1990b) as the neem sawdust was more effective than mango sawdust at same C:N ratios.

Cellulosic Waste: In paper industry large quantities of hemicellulosic wastes are generated following alkaline and bisulfite treatments of
wood to release the cellulose. The hemicellulosic wastes are disposed off as an economic manure. Miller and Edgington (1962) reported effects of soil amendments with paper on meadow nematodes and subsequent Verticillium wilt of tomato. In a similar treatment, Miller et al. (1968) found reduced larval emergence as well as root invasion in eggplant by Heterodera tabacum. Huebner et al. (1983) found that addition of chopped paper into soil reduced the populations of Pratylenchus penetrans. Culbreath et al. (1985) demonstrated that addition of ligno-hemicellulosic materials to soil amended with chitin can increase the effectiveness of chitin against nematodes and avoid some of the deleterious effects of chitin when applied at high levels (1.0% w/w).

Sugar-cane Bagasse: When sugar-cane bagasse was applied at 4000 kg/ha before planting tomatoes there was 22% reduction in root galling, while 100-150 days after planting the reduction was 90% in the number of Meloidogyne spp. (Sikora et al., 1973). Rodriguez-Kabana and King (1980) concluded that the application of mixtures of blackstrap molasses with urea resulted improved control of M. arenaria.

Other Biological Wastes:

Chitin: Most interesting among the nitrogenous amendments that stimulate a specialized soil-microflora are those containing a specialized chitin or similar mucopolysaccharides. The addition of chitin into soil results in the stimulation of a microflora capable of decomposing the polymer into chitobiose and N-acetyl-glucosamine.
(Mitchell and Alexander, 1961; Muzzarelli, 1977; Rodriguez-Kabana et al., 1983). Chitin amendments result in very sharp increase in chitinase activities associated with stimulation of the chitin decomposing microflora (Culbreath et al., 1985; Mian et al., 1982; Rodriguez-Kabana et al., 1983). Chitin amendment to soil has proved effective for control of plant-parasitic nematodes (Mankau and Das, 1969; Mian et al., 1982; Godoy et al., 1983b; Rodriguez-Kabana et al., 1984). More important, with some exceptions, a relationship has been demonstrated to exist between chitinolytic ability of fungi and their capacity to destroy nematode eggs (Godoy et al., 1983b; Rodriguez-Kabana et al., 1984). Several fungal species isolated from soil treated with chitin are able to decompose the polymer and are known colonizers of eggs of Meloidogyne spp., or Heterodera glycines (Godoy et al., 1983a).

Effects of chitin amendments on nematodes may last several months, sufficient time must be allowed after addition of amendments for populations of the specialized organism to develop to levels adequate for effective nematode control. It is not unusual to obtain little or no nematode control in crops soon after chitin amendments are applied to soil, whereas good control occurs in the second crop following harvest of the first. This phenomenon was well established in a recent study by Rodriguez-Kabana et al. (1987) on root-knot nematode M. arenaria.

Chitin amendments were effective for control of M. incognita in tomato (Mankau and Das, 1969), reduction in incidence of Tylenchulus

As with other nitrogenous amendments, chitin amendments can be phytotoxic because of relatively narrow C:N ratio (6:4) of the polymer, however, this problem can be eliminated with additional available carbon (Culbreath *et al.*, 1985). There is also evidence that some of the phytotoxic effects caused by chitin amendments may be related to changes in soil pH (Rodriguez-Kabana, 1986).

**Bone Meal and Horn Meal:** Bone meal is chiefly used as phosphatic fertilizer. Alam *et al.* (1977c) found that the population build-up of *Hoplolaimus indicus*, *Helicotylenchus indicus*, *Rotylenchulus reniformis*, *Tylenchorhynchus brassicae*, *Tylenchus filiformis* and *Meloidogyne incognita* were effectively suppressed by the application of bone meal in 12 different crops. Similar results were also obtained by amending the soil with horn meal (Alam, 1989).

**Sewage-sludge:** Besides the importance of sewage farming from the point of view of utilization of the resource, it has also been found to be an effective method of nematode control. Heald and Burton (1968) noted organic nitrogen in the form of activated sewage-sludge more effective than ammonium nitrate for reducing the population of *Belonolaimus longicaudatus* in turf grass. Tarjan (1977) observed that when composted municipal refuse was added to soil, having seedlings
infected with *T. semipenetrans* or *P. coffeae*, plant weight increased than non-supplemented controls. Thus this amendment proved highly nematicidal (Habicht, 1975; Saka, 1978; Derrico and Maio, 1980; Coomans, 1982; Hornick *et al.*, 1984; Al-Yahya *et al.*, 1988; Duhalongsod, 1988).

**Livestock Waste:** Farmyard manure (FYM) and cattle urine have been found to reduce nematode population (Adeniji, 1977). In India, it has vast traditional use by farmers in fields. Encouraging the use of FYM probably will not only have some check on nematodes but will also reduce the dependence on fertilizers. Use of animal manure for the control of *Rotylenchulus reniformis* on *Vigna unguiculata* and cotton has been reported by Castillo (1985). Kushwaha *et al.* (1983) reported that the reduction of root-knot on tomato with the use of cattle urine is less than that obtained with urea. Bene and Taccont (1973) studied pig faeces manure and horse manure in controlling *D. dipsaci* on beans. Mankau and Minteer (1962) observed that the steer manure and chicken manure reduced the citrus nematode *Tylenchulus semipenetrans*. Poultry manure has given significant reduction of *M. incognita* population on jute (Bora and Phukan, 1983) and tomato (Chindo and Khan, 1986) and also of other nematodes (Derrico and Maio, 1980).

**MIXED-CROPPING PRACTICE:**

Mixed-cropping, also sometimes termed as intercropping, is a form of multiple-cropping system where the mixtures of crops occupy the same place in space and time. It is well known that cropping

Several evidences have been made to confirm that mixed-cropping practices can depress nematode populations and reduce nematode damage on crops. Ogbuji (1976) and Olowe (1978) has observed that root-knot nematode problems to tomato and okra were usually more severe in mono-cropping system than in adjacent traditional mixed-cropped cultures with yam (Dioscorea spp.) and cassava (Manihot esculenta Crantz.) in Nigeria. Awoyomi (1978) also recorded significantly fewer plant-parasitic nematodes from fields growing yams and maize (Zea mays L.) when compared with monocultures of maize. Egunjobi (1984) observed that mixed-cropping of maize and grain legumes generally improved maize yield, with reduction in the population of Pratylenchus brachyurus.

Recently Abid and Maqbool (1980) recorded lower root-knot index (RKI) from tomato plants grown in field alongwith African marigold (Tagetes erecta L.) to those of plants grown alone. Yields were also improved by the mixed-cropping of Tagetes erecta is known to inhibit many plant nematodes, including Meloidogyne spp. (Tyler, 1938; Winoto, 1969; Alam et al., 1977d). Similar evidences in support of nematode control with intercropping include the findings of Siddiqui and Alam (1987a, b, 1988b). They reported that T. minuta, T. lucida and T. tenuifolia in mixed culture, significantly inhibited the
root-knot development caused by *Meloidogyne incognita* on tomato and eggplant and reduced the multiplication of *Rotylenchulus reniformis* and *Tyl倫chorhynchus brassicae* on tomato, eggplant, cabbage and cauliflower. The growth of test plants also improved.

Alam et al. (1976) demonstrated that mixed-cropping of mustard and rocket-salad with wheat and barley inhibited the population build-up of plant-parasitic nematodes but these oilcrops did not improve the yield of wheat and barley.

The effects of mixed-cropping practice on the nematode population densities and on crop yield responses tend to suggest that the mixed-cropping practice has potentials for crop nematode management. There are some additional advantages in the use of mixed-cropping system in nematode control. According to Agboola and Fayemi (1971), Ogunflowora and Norman (1973), Nwosa (1981), Trenbath (1986), resource efficiency is higher for crop mixtures than for sole crops. Anthony and Willimot (1957), Evans (1960) and Grimes (1962) also suggest that mixed-cropping results in better cash returns per unit area of land than for sole cropping. Finlay (1974), Anon. (1974) and Edje (1979) similarly provided other evidences to confirm this. Most interesting fact is that mixed-cropping serve as insurance against total crop loss due to pest epidemics selective for crop species. Conclusively, mixed-cropping system, if better understood, may well provide one of the most economically feasible nematode management options that is consistent with peasant farmers in the third world.
PLAN OF WORK

Evidently, a great deal of work has been carried out on the use of organic soil-amendments particularly with oilcakes. So far not much information is available regarding soil amendment with agrowastes of some crops, even though these crops are known to be antagonistic to nematodes. Moreover, little attention has been paid to the intercropping of such crops. Hence the effect of organic amendments as such and in combination with intercropping of the antagonistic crops has been investigated in the present study. With a view to evolve cost-effective nematode control technologies, a novel method of nematode control has been worked out using a commercial product of neem *Azadirachta indica* marketed by Godrej Soaps Ltd. by the trade name 'Nimin' as a urea coating agent. Similar studies were also undertaken using oils of neem, castor, mustard and rocket-salad. Systemic activity of oilcakes and leaves of neem and castor as bare-root dip treatment against nematode was also investigated. This again proved to be highly cost-effective treatment against the nematode. The detailed programme of the study is as follows:

A. **Integrated nematode control with organic amendment/nematicide and intercropping:**

1. Effect of soil amendment with oilcakes and leaves of neem and castor and carbofuran, and intercropping of kasni/chicory (*Cichorium intybus*) with berseem/Egyptian clover (*Trifolium alexandrinum*) and rizka/lucerne, alfalfa (*Medicago sativa*) on the population of plant-parasitic nematodes and yield of the fodder crops in field.

2. **Residual effect of different treatments of the preceding experiment (No. 1) on the population of plant-parasitic nematodes and plant growth of okra (*Abelmoschus esculentus*) cv. Pusa Sawani in field.**
3. Effect of soil amendment with oilcakes and leaves of neem and castor and carbofuran, and intercropping of mustard (Brassica juncea) cv. Local with potato (Solanum tuberosum) cv. Kufri-Chandramukhi on the population of plant-parasitic nematodes and crop yield in field.

4. Residual effect of different treatments of the preceding experiment (No. 3) on the population of plant-parasitic nematodes and plant growth of okra (Abelmoschus esculentus) cv. Pusa Sawani in field.

5. Effect of soil amendment with oilcakes and leaves of neem and castor and carbofuran, and intercropping of rocket-salad (Eruca sativa) cv. Local with potato (Solanum tuberosum) cv. Kufri-Chandramukhi on population of plant-parasitic nematodes and crop yield in field.

6. Residual effect of different treatments of the preceding experiment (No. 5) on the population of plant-parasitic nematodes and plant growth of okra (Abelmoschus esculentus) cv. Pusa Sawani in field.

B. Nematode control with organic amendment:

7. Effect of soil amendment with chopped plant leaves (fresh) on the population of plant-parasitic nematodes and plant growth of tomato (Lycopersicon esculentum) cv. Pusa Ruby and chilli (Capsicum annum) cv. Pusa Jawala.


13. Effect of soil amendment with urea coated with 'Nimin' (a triterpene rich neem product) and oils of neem, castor, mustard and rocket-salad on the population of plant-parasitic nematodes and plant growth of tomato cv. Pusa Ruby and chilli cv. Pusa Jawala.

C. Nematode control with bare-root dip treatment:


D. Antinemic action of oilcake/leaf extracts and root-exudates:


18. Effect of water soluble fractions of undecomposed and decomposed oilcakes of neem and castor on the mortality and hatching of *M. incognita* in vitro.