REVIEW OF LITERATURE
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2.1 ROW SPACING

The distribution pattern and population dynamics of soil nematodes in cultivated sugarcane fields is governed by changes in the agro-eco systems, where the nematodes, both parasites of the above ground or below ground plant parts, are subject to frequent change in their environment (Gaur, 1987). Raski et al. (1965) also reported that in agro eco-systems of vine yards the largest numbers of plant nematodes were found in the top 15-20 cm of the soil. However, few nematodes were found at the depths of 240 cm. The concentration of higher number of plant parasitic nematodes at top level may be closely related to the distribution of existing plant roots and rhizosphere in cultivated soils (Reddy, 1983).

Alby et al. (1983) reported that population levels of *Pratylenchus scribneri* and *Hoplolaimus galeatus* in soybean fields varies widely among plants and even from one side of the plant to another.

Population of nematodes in the sugarcane fields were also recorded to coincide with the depth of root zone from surface soil level at the base of clump (Misra and Singh, 1977). Mehta et al. (1992) had also reported that in sugarcane fields, the population of nematodes decline as the distance between the two clumps increases being maximum at 0 cm i.e. base of the clump and decreases at 25 and 45 cm, away from the base. While considering the population level at different depths 20 and 40 cm, from the surface soil level the population was noted to be maximum at top depth and gradually decreased at deeper levels.
Sharma and Sharma (1990) studied the distribution of three nematode species in the soil around palm trees in Himachal Pradesh, India and reported that the most suitable depths for the maximum population estimate of *Macroposthonia xenoplax*, *Meloidogyne incognita* and *Pratylenchus pruni* were 30, 10 and 20 cm respectively, while for horizontal distances were 30, 60 and 90 cm respectively from the trees.

### 2.2 CROP IRRIGATION

Soil moisture is an important factor in governing the population dynamics of soil nematodes. Nematodes are aquatic organisms and are entirely dependent on water for their activities. They can not feed, move, reproduce unless there is sufficient moisture level present in the soil (Wallace, 1965). Lee (1965) pointed out that the active nematodes in the soil are always in water and cannot be hydrotactic. The ability of some soil nematodes like *Heterodera rostochiensis* larvae to migrate to the wet moisture gradient is thought to be a mechanical response and are attracted to host roots against a water gradient.

Schoemaker (1968) noted that the number of *P. zeae* were positively correlated with soil moisture in sugarcane roots in Kenya. Twenty five to twenty per cent moisture was found to be optimum for the reproduction of *Rotylenchulus reniformis* on castor (Khan and Khan, 1973). Further, Rebois (1973) also reported that infection of soybean roots by *R. reniformis* was greater when the soil water content was maintained just below field capacity (7.2 to 13%). Invasion of roots by nematodes was reduced in wet (15.5 to 19%) and dry (3.4 to 5.8%) moisture conditions. On cereals, increased nematode population was observed at 14-20 per cent moisture level. However no significant differences in plant growth were observed (Upadhyay *et al.*, 1974).
Edward and Misra (1974) reported that soil moisture is essential and becomes a limiting factor for nematode occurrence and some nematodes like *Ditylenchus* require high soil moisture levels than others. Differential response of different species of nematodes to different ranges of moisture conditions was observed by Gaur and Haque (1987). They added that moisture stress to a pea crop influenced the growth of nematode population. Sweelam *et al.* (1988) reported that the reproduction of *T. semipenetrans* in sour orange was highest at 15 per cent soil moisture.

Bags of *Prunus strobus* wood chips with moisture contents of 38, 92, 169 and 217 per cent were inoculated with *Bursaphelenchus xylophilus* and incubated at 30°C to determine the effect of wood moisture on the nematode population. Population levels were recorded highest in wood chips with 38 per cent moisture content and decreased with each higher level of moisture content (Halik and Bergdahl, 1990).

Choudhury and Phukan (1990) observed that the rainfall had no apparent influence on the nematode population fluctuation in banana cultivation. Sundarababu and Muthukrishnan (1990) reported that *X. basiri* preferred fairly high levels of moisture in the soil. They further reported that 75-100 per cent of soil moisture favoured the multiplication of this nematode.

Dwivedi and Misra (1990) correlated the distribution pattern of *Hoplolaimus indicus, Tylenchulus filiformis* and *Tylenchorhynchus brassicae* around root zones of *Citrus sinensis* with environmental factors and observed population peaks during or just after a rainy period. They added that optimum soil temperatures
of 10°C-30°C soil moisture levels of 12-16 per cent and pH 7.2-7.6 were found suitable for the growth and development of nematodes under field conditions.

Studies on survey in Southern Italy of the species composition and densities of plant parasitic nematodes occurring in irrigation canals were made by Roccuzzo and Ciancio (1991). They reported that mainly ectoparasites like *Helicotylenchus vulgaris*, *Merlinius brevidens* and migratory endoparasites like *Pratylenchoides ritteri* and *Xiphinema index* were found at population density levels varying from 2 to 35 specimen/ml of irrigation water.

Warren and Linit (1992) correlated the population density of *B. xylophila* with moisture content in soil and suggested that nematode aggregates occur in areas of high moisture content. They concluded that the population density of the nematode increases as the moisture content of soil increases.

Steinberger and Sariq (1993) collected soil samples from the 0-10 cm depth from areas undergoing four different wetting treatments (5, 10, 15 and 20 mm of water) and from a non-irrigated control soil. They found greatest abundance of nematodes in the soil treated with 20 mm water (970 nematodes/100 g of dry soil) which was 2, 4, 5 and 14 times higher than that found in the soil treated with 15, 10, 5 and 0 mm of water respectively. They further concluded that the major trigger for changes in the nematode population and microbial biomass was diurnal fluctuation in soil moisture.

### 2.3 INTER-CROPPING AND APPLICATION OF HERBICIDES

#### 2.3.1 INTER-CROPPING
The rate of increase of a nematode population on the host plant is dependent on the density of root mass. There is an upper limit to this density to form an equilibrium density which depends on the quality and quantity of the food available as well as influence of favourable conditions on the nematodes. The decrease in densities of plant-parasitic nematodes in fields is due to the absence of good host plants (Seinhorst, 1970). Ferris and Bernard (1967) reported an increase in population levels of the genus *Pratylenchus* in soils planted with vetch where soybean was grown as inter-crop.

Economically important host of *H. avenae* are wheat, barley, maize, sorghum, rye and oat and those of *H. zeae* are maize and barley. Among other hosts are other graminaceous crop varieties of wild oats. Gill and Swarup (1971) worked on host range of cereal cyst nematodes *H. avenae* and reported *Echinochloa frumantacea, Phalaris canariensis, P. paradoxa, P. polypogon, P. monspeliensis* and *Senehiera pinnatifida* as new hosts. The last named species is the only non-graminaceous plant found to be susceptible. The nematode larvae penetrated sorghum roots but no cysts were formed. Maize was confirmed as a host for the nematode.

Suryanarayan and Mukhopadhyaya (1971) reported that number of hosts which attracts *A. tritici* were rather restricted. Wheat (*Triticum aestivum*) is generally considered to be the main host but rye (*Secale orientalis*), emmer (*Triticum dicoccon*), spelt (*Triticum spelta*) and barley (*Hordeum vulgare*) have also been reported to attract this nematode. The authors reported these crops as host crop and further added that planting of these crops in infested fields would decrease the population of *A. tritici*.
Multiple cropping in areas having long growing seasons adds organic matter to the soil, increases the cycling of nutrients and improves the soil moisture. All these practices tend to decrease the population densities of nematodes on a crop of particular genotype (Nusbaum and Barker, 1971).

Barker et al. (1982) studied populations of nematodes in soybean and tobacco plots. They recorded that soybean was a very poor host for the nematode Criconemella ornata. However, greatest number of plant parasitic nematodes were noted in soybean. During the growth of tobacco, declining number of nematodes were recorded. Of all plant-parasitic nematodes, the spiral nematode, Helicotylenchus was the most abundant and most prevalent in soybean.

Interplanting of certain non-host and antagonistic crops need to be exploited for managing nematode problem. Jain et al. (1990) who further reported the influence of inter-cropping on the incidence of root-knot nematode, M. javanica in brinjal. They noted that when brinjal was intercropped with garlic, Tagetes erecta or resistant tomato cv. SL-120 the population of M. javanica was reduced compared with control. Naganathan et al. (1988) also led the same view and reported that the population of Radopholus similis and Pratylenchus coffeae on banana roots were significantly reduced by growing antagonistic crops such as tagetes, lucerne, Sun hemp or coriander as intercrops for four months.

Intercropping marigold with mulberry at 15, 30 and 45 cm distances in field trials reduced in the number of galls of M. incognita by 78.77, 75.84 and 73.74% respectively and the number of egg masses/g of root were reduced by 60.32, 54.62 and 35.76% respectively (Govindiah et al. 1991). Increase in the population of plant-parasitic nematodes mainly, M. incognita on potato was significantly arrested when
mustard (*Brassica* *funaea*) was also grown with potatoes in alternate rows (Akhtar and Alam, 1991).

### 2.3.2 APPLICATION OF HERBICIDES

Influence of herbicides on the nematode population has been studied by many authors in different crops. Herbicides are applied in sugarcane fields to control weeds as well as other herbs. Consequently reduction in the nematode population in the absence of weeds was recorded. This is because some weeds are favourable hosts for some nematode species. Besides this, some chemical herbicides also have low nematicidal value and may help in reducing the nematode population (Schmitt *et al.*, 1983).

Presence of weeds in fields, with non-host crop or fallow obviates efficacy of such practices since these unwanted plants often act as alternate host for plant-parasitic nematodes including the pest species. Various monocot and dicot weeds invariably infest the fields at high densities per unit area, thus supporting or even increasing the population of most parasitic species. (Gaur and Hague, 1986).

Baruch *et al.*, (1988) observed that the population densities of plant parasitic nematodes were higher in plots with more weeds. The presence of weeds encouraged the population build up of *H. indicus*, *P. zeae* and *R. reniformis* which may have been supported by only specific weeds. Further they reported that there was no direct long term effect of herbicides used on nematodes, but their use to reduce weed populations may help in keeping down the populations of plant parasitic nematodes.
Dubaj and Jenser (1990) found eighteen weed plants to be hosts for *Meloidogyne hapla* on sandy soil in the Danube-Tisza–mid region in Hungary. *Convolvulus arvensis, Galinsoga parviflora, Oxalis corniculata, Portulaca oleracea* and *Solanum nigrum* were the most heavily infested weeds. Six species were new hosts for *M. hapla*. These plants provide the means of survival for population of the nematode which are sources of infection of cultivated plants.

Sholwer *et al.*, (1990) reported that only *Criconemella* and non-parasitic nematodes were favoured by weed growth and weeds did not appear to act as reservoirs to other phytophagous species. But a controversial view was reported by Anwar *et al.*, (1992). They added that, weeds constitute a natural alternate host for soil dwelling nematodes. Many species of nematodes can survive in the field if sufficient weeds host are present between susceptible crop seasons. They found that the population density of *Helicotylenchus* spp. was higher on weeds collected from banana cultivation which form adequate host for the nematode.

Yeates *et al.* (1993) studied the relationship between nematodes, soil microbial biomass and weed management strategies and asparagus cropping system. They reported that the response of nematode taxa to weed management practices like sawdust mulching, repeated spring-summer cultivation, hand hoeing and two herbicide treatments were very variable, but given the range of life history strategies within tropic groups, responses followed a predictable pattern.

Gaur and Seshadri (1986) thus concluded that since, weeds helps to increase the population of nematodes, weed management practices should be followed to reduce the nematode population and to prevent the crops from nematode attack.
Proper control of weeds is thus repeatedly advised for any method of nematode management.

2.4 BIO-FERTILIZERS

Nitrogen is the key element in agricultural production. Using of bio-fertilizers for the enrichment of soil nitrogen reduces the cost of using chemical nitrogen fertilizers, where bio-fertilizers are easily available.

Nitrogen fixation by microbes in sugarcane fields has been established (Patil and Hapse, 1981) which effectively supplement the need of nitrogen by chemical nitrogenous fertilizers. Bio-fertilizers are known to increase the yields of a sugarcane crop. Srinivasan and Naidu (1987) tested the sugarcane yields by applying *Rhizobium*, *Azospirillum* and *Azotobacter*. They found that all bio-fertilizers tested resulted in increased yield of the sugarcane crop compared to control. Among the three, *Rhizobium* and *Azospirillum* were more efficient than *Azotobacter*. In sugarcane fields, 30 to 35 per cent of N/ha could be saved with only bio-fertilizer application (Singh et al. 1985). However, no detailed work was done on the interaction of bio-fertilizers and nematodes. Knowing the efficacy of bio-fertilizers the application in sugarcane fields is on the increase and hence there is a need to study the relationship between the biofertilizers and plant parasitic nematodes.

2.5 TRASH MULCHING

Trash mulching in sugarcane helps crop growth by keeping down weeds, conserving moisture and aggregating soil particles in case of excessively sandy soils (Parthasarathy, 1972).
Increasing fertility and granulation of soil particles in sandy soils with trash blanketting in sugarcane fields has been reported (Anon, 1958). It was further added that trash blanketting suppresses the growth of weeds, increases organic matter content of soil and controls the attack of shoot borer.

Govindaiah et al. (1989) reported that mulching with Pongamia pinnata leaves was found to be superior over neem (Azadirachta indica) leaves in controlling M. incognita and increasing growth of mulberry. They added that the number of root-knots and egg masses of M. incognita were found to be a minimum, i.e., 1.95 - 3.05 and 3.25 - 5.00/g root respectively in Pongamia and neem, but maximum in the control (33.95 - 63.05/g root weight).

2.6 INORGANIC AND ORGANIC NEMATICIDES

Inorganic and organic amendments of soil possess nematicidal properties invitro and invivo (Singh and Sitaramaiah, 1973). Various chemical nemiticides have been tested on different crops. Varaprasad and Mathur (1980) reported that carbofuran (a@1 kg a.i/ha, aldicarb sulfone (a@2 kg a.i/ha and carbofuran (a@2 kg a.i/ha were effective in respective order in reducing M. incognita population on sugarbeet and improving its plant growth. Carbofuran @1 kg a.i/ha appeared to be economical as the required chemical for the seed treatment was 400 g/20 kg of seed which was sufficient to sow one hectare. Amin et al. (1992) also reported that the nematicides, aldicarb and oxamyl effectively reduced nematode population, number of galls and egg mass in tomato roots. Although slight decrease in nematode population was obtained with trifluralin and sulphur, carbofuran and diaziminos showed high population exceeded control. The efficiency of nematicides, viz., D-D, 1,3-D, DBCP, phorate, fensulfothion and dimethoate against some important plant-parasitic nematodes were tested and
significant suppression of population of all the nematodes to varying degrees around roots of tomato, eggplant, chilli, okra, cabbage, cauliflower and tablebeet was reported by Alam et al. (1981).

Amarananda and Krishnappa (1992) tested three chemicals viz., carbofuran, prophos and phorate for their effect on growth of sunflower and development of nematode, *Meloidogyne incognita*. Among the three chemicals tested, phorate at 6 kg a.i/ha applied seven days before nematode inoculation recorded maximum growth of the host plant. However, prophos at 4 kg a.i/ha applied seven days before inoculation was effective in reducing the nematode population.

In testing of organic amendments a considerable decrease in the population of *P. brachyurus* in the micro plots receiving cocopod husk was noted and this effect was also carried over in the second crop (Egunjobi, 1977). D'Errico and Maico (1980) noted that all organic materials applied, viz., dried poultry faeces, dried poultry manure, composted oil cake, composted poultry manure significantly reduced the root-knot nematode indices on host plants.

The effectiveness of groundnut oilcake on the reduction of nematode population (*M. incognita*) in unsterilized soil than sterilized soil was reported by Bhattacharya et al. (1987). The better performance of plants in unsterilized soil over sterilized soil is attributed to loss of fertility value on autoclaving the soil. Zaki and Bhatti (1989) reported that effectiveness of castor in reducing the nematode population of *M. javanica* infecting tomato was better in fertilizer treatments than in unfertilized plots.

All the test organic amendments viz., horn meal, bone meal and oil seed cakes of mahua, castor, mustard, neem and peanut were effective in inhibiting the
root-knot development and population build-up of *Tylenchorhynochus brassicae* on their respective hosts (Alam *et al.*, 1989).

Organic amendments, press mud, farmyard manure, poultry manure, neem, coirpith and sugarcane bagasse were applied to sugarcane in the fields of India for the control of plant-parasitic nematodes. Neemcake and press mud were found to be most effective (Jonathan *et al.*, 1991).

Substantial reduction was recorded in hatchability, infectivity and development of *M. javanica* juveniles by several organic and inorganic amendments. Sheepdung and rice straw were most effective, pigeon dropping and horsesdung were intermediate and poultry droppings were least effective among the organic amendments tested. Among the inorganic amendments tested, urea and ammonium nitrate were most effective and ammonium sulphate was least effective.

Applications of multiple treatments involving organic amendments and nematicides on the tomato revealed that aldicarb and possibly oxamyl combined with pigeon droppings, poultry droppings were the best treatments in producing highly profitable plant growth where crop was infected with *R. reniformis* (Badra and Mohamed, 1979). Fensulfothion, aldicarb, DBCP and neem oilcake all are effective in reducing the population of *Radopholus similis* affecting arecanut palms (Sundararaju and Koshy, 1986).

Akhtar and Alam (1991) observed a significant suppression in the population of plant-parasitic nematodes when soil was treated with oil seed cakes and leaves of neem and castor and nematicide carbofuran. Eight oilcakes viz., neem, karanj, mustard, til, ground nut, mahua, cotton and two systematic pesticides viz.,
carbofuran and phorate were tested against lesion nematode, *Pratylenchus zeae* in rice. Treatment with oil cakes proved to be at par with the pesticides. However, treatment with oil cakes also caused increase in crop yield parameters (Sahoo and Sahu, 1994).

### 2.7 PHYSICAL PROPERTIES OF SOIL

#### 2.7.1 pH

One of the important constituent of soil environment that effects nematodes in many ways is pH of the soil solution. Burns (1971) reported that greatest number of *Pratylenchus alleni* colonized soybean roots at pH 6.0 from the silty loam soil and also stated Dorylaimoidea were greatest at both pH 6.0 and 8.0, non-stylet nematodes were recovered in greater numbers at pH 5.2 and 6.5 and was not related to alfalfa root production.

*Xiphinema basiri* and *Mylonchulus minor* were reported to be susceptible to even slightest changes in the pH, but *Hoplolaimus indicus* and *Helicotylenchus indicus* showed greater tolerance to a wide range of fluctuations (Jairajpuri et al., 1974). Malik and Jairajpuri (1984) reported that the pH range 2.0 to 3.0 of phosphate buffer proved to be highly toxic to adults and juveniles of *Xiphinema americanum*. The survival time recorded was only 20-40 seconds and the maximum period for adults and juveniles was at pH 6.0 to 6.6 both in buffer solution in tap- water. Kimpinski and Willis (1981) further reported that raising the soil pH from 5.0 to 6.9 in which alfalfa was grown increased the numbers of *P. penetrans* and greatly reduced the numbers of *P. crenatus*. The number of both nematode species were reduced significantly as soil pH was increased. The high susceptibility to the pH gradients ranging from 2.2 to 4.0
and 6.4 to 8.0 showed that nematodes cannot survive either at high acidic media or at low alkaline media. The maximum life span was noted at 5.8 to 6.0 indicating that this was optimum range (Ahmed and Jairajpuri 1982).

Optimal pH for the activity of nematode, *Mononchus aquaticus* was proved as 5.8 (Bilgrami and Jairajpuri, 1984). It has been noted that soil pH ranging from 5.0 to 7.0 has little effect on nematodes (Reddy, 1983) probably being the optimum range of pH for this nematode. In most soils, pH ranges from 4.0 to 8.0 probably has little effect on nematode activity. Survival and pathogenicity of *Steinernema glaseri* and *S. carpocapsae* decreased only slightly as soil pH decreased from 8.0 to 4.0, but adversely affected at pH 10 (Kung et al., 1990).

2.7.2 ELECTRICAL CONDUCTIVITY (EC)

Not much work on effectiveness of different range of EC has been reported on nematode activity. The effectiveness of salts, with some exceptions was found directly proportional to the molecular weight of nematode activity (Bilgrami and Jairajpuri, 1984).

2.7.3 SOIL TEXTURE


It has been reported that most of the cyst, root-knot, lesion and stubby root (*Trichodorus* species) nematodes are found in large numbers in coarse texture sandy
soils. The stem nematode, sugar beet cyst and some species of lesion and stunt nematodes are numerous in clay soils while, the citrus nematode, occur frequently in both sandy and clay soils (Anon, 1968). Naganathan and Sivakumar (1975) observed that *P. delattrei* multiplied well in sandy clay loam and brown sandy clay loam soils having fine fractions, optimum cation exchange capacity and water holding capacity than red sandy loam.

A determinant influence of soil type on nematode multiplication was also reported by Rao and Swarup (1975). They found that in sandy loam soil, clay loam and loam soils the soil nematodes multiplied well and further reported that *H. dihystera* multiplied faster in clay loam and sandy loam soils than in loamy and sand clay.

Siswoja (1981) during survey recorded *Helicotylenchus* species, *Pratylenchus* species, *Meloidogyne* species and *Criconemoides* species from the soil samples taken from eight sugarcane factories in Java (Indonesia). Nematode population were lower in the light soils than in heavy soils. Walia (1987) noted that nematodes multiplied best in sand and sandy loam soils. This was attributed to better root development in the soil types concerned, thus supporting higher nematode population. Clay and clay loam soil had non-significant differences in maintenance of nematode population.

Variations in soil texture has been proved to affect nematode morphology and population dynamics. Das and Mukhopadhyaya (1987) reported that the body length, width, stylet, neck length, width of median bulb, shoot and root weights and population of *T. semipenetrans* were maximum in alluvial and minimum in sandy and red gravelly soil, laterite and clay texture soil behaving as intermediate.
Sundarababu and Muthukrishnan (1990) reported the influence of soil texture on *X. basiri* in red soil or sandy loam, black soil and clay loam, sand or an artificial pot mixture of red earth, sand and farmyard manure in equal proportion. Highest population were found in pots with pot mixture, followed by red soil. Choo and Kaya (1991) noted the influence of four soil textures (humus, loam, clay and sand) and the presence of maize roots on the root finding ability of the entomophilic nematodes *Heterorhabditis bacteriophora*. Nematode infection of final instar larvae of *Galleria mellonella* was affected by soil texture with the highest infection (71.1%) occurring in humus, followed by sand, loam, and clay (52.2, 41.1 and 4.5% respectively). Percentage infection was higher in humus with roots than in humus without roots, but this difference was not significant in other soil types.