II. REVIEW OF LITERATURE

The *Pratylenchus* species rank as the second most important plant parasitic nematode after *Meloidogyne*. About forty species of *Pratylenchus* have been found to parasitise arable agricultural crop plants around the world (Singh and Gill, 1986). They are mostly migratory endoparasites inhabiting the cortex of the roots. They stay inside the root and feed externally on root cortical cells. After the death of the cell on which they feed, they migrate to new cells. Their feeding and migration causes extensive disruption of the cells, the typical syndrome of attack being formation of lesions that coalesce to cover larger areas. A physiologically disfunctioning root gives rise to general chlorosis, stunting and even smothering of the plant (Rao, 1992). A number of species of *Pratylenchus* are found to attack cereals (Mayne and Subramanyam, 1933; Chona and Swarup, 1960; Das, 1960; Sethi and Swarup, 1969; Siddiqui, 1964), prominent among them are *P. indicus* (Prasad and Rao, 1978) and *P. zeae* (Atkins *et al.*, 1955; Fernadez and Ortega, 1985; Ray *et al.*, 1987) that affect rice. The prevalence of *Pratylenchus* is mainly limited to upland paddies (Plowright *et al.*, 1988; Sahoo and Sahu, 1992) and dry nurseries where root knot is recalcitrant and also problematic. *Pratylenchus* as a potent parasite of rice has been less studied, least so in case of *P. zeae*. Although studies have been made on the role of *P. zeae* in other crop plant ecology and production, no work has yet been done in India in this pest in order to assess its potentiality as a pest of upland paddies, alone or in combination with other nematode pests of rice rhizosphere. The history of work done on *Pratylenchus zeae* is being presented here to have an understanding of the role of the pest in arable agriculture and upland rice in particular.

1. MORPHOLOGY AND MORPHOMETRICS

P. zeae was first described by Graham (1951) on corn in USA, the taxonomic diagnosis being from females only. Further improvement was done by Sher and Allen (1953) and by Fortuner (1976) from a neotype supplied by Graham. Its occurrence in India first denoted by Chona and Swarup (1960). Nath *et al*. (1975) reported this species on sugarcane along with a description of a single male. The morphological and morphometrical disgnostic features of *P. zeae*, as its stand till date, are enumerated as follows.

A. MORPHOLOGY

Female :

Lip with 3 annules, stylet 15-17 µm long with broad, flattened knobs, posterior uterine branch 1-1½ times as long as the vulval body diameter. Vulva-annus distance 3-4 times the length of tail, posterior half of the sub-cylindrical tail ending in small but rounded terminus tail annules over 20. Spermatozoa not seen. Four lateral incisors extending post phasmid to near terminus, intestine with post rectal sac. Male unknown or rare (Sher and Allen, 1953; Taylor and Jenkins, 1957; Williams, 1960; Yokoo, 1962; Roman and Hirschmann, 1969; Samsoen and Geraert, 1975; Fortüner, 1976). Nath et al. (1975) added further to this description; dorsal oesophageal gland opening 3-4 µm behind stylet base. Excretory pore located at about the juction of the oesophagus and intestine. Hemizonid immediately antherior to the excretory pore. Ovary outstretched with a single row of oocytes. Vulva a transverse slit, occasionally with a protruding lip. Phasmid, small pore like, located almost mid-way on tail. Tail with about 20-25 annules.

Male : (From a single male by Nath et al., 1975)

Morphologically similar to female. Testis outstretched with multiple rows of spermatocytes. Spicules arcuate dorsally, well developed with two swellings. Bursa enveloping tail tip and extending beyond the anterior end of spicules.

Juveniles :

Similar to adults except diffusing in body size and lacking reproductive parts. Tail tip of 2nd stage juvenile slightly pointed.

B. MORPHOMETRICS

The morphometrical studies on larvae, females and males of Graham (1951) and Nath *et al* (1975)are given in Table 2.

Earlier reports (Taylor and Jenkins, 1957; Tarte and Mai, 1976) indicated induced variations in length and width of body, stylet length, a, b and 'V' values in *Pratylenchus* sp. but Roman and Hirschman (1969) found that stylet length and 'V' values have the lowest coefficient of variability and hence are of diagnostic value (Olowe, 1975). Olowe and Corbett (1983) observed some variations in morphological parameters of *P. zeae* and *P. brachyurus* populations raised from a single female nematode on different host plants. Variations in Indian populations of *P. zeae* on sugarcane were ascribed to be due to geographical variations (Nath *et al.*, 1975).

Genetic inequality, environmental factors or interaction between both cause a wide range of morphological and biometrical variability in nematodes (Sasser, 1990). However, the stylet length, number of annules on tail and those between anus and phasmid, distance of oesophageal gland from the base of stylet knobs C, C^1 and 'V' values did not vary significantly in *Pratylenchids* (Saha and Khan, 1988) and thus can be taken as stable diagnostic characters.

2. ROOT INVASION

All stages of Pratylenchus are capable of invading host roots. All the stages of P. coffeae and P. zeae entered roots of snap dragon (Antirrhinum sp.) and corn (Southards, 1968). Second stage juveniles of P. indicus penetrated roots of rice as effectively as the other advanced stages. With the increase in time of exposure, the rate of invasion increased (Prasad, 1977). The rate of invasion by Pratylenchus sp. also varies with the host plant. Only 7 to 10% of inoculum entered roots of potato (Solanum tuberosm L.) (Hogger, 1969) while 81% invaded roots of soyabean (Glycine max L.) (Lindsey and Cairns, 1971).

Orientation of nematodes towards roots

'Species of Pratylenchus do attack all the regions of the growing roots. P. fallax was attracted towards root tips, region of root hair development and juction of lateral roots in wheat (Triticum aestivum L.) and barley (Hordeum vulgare L.). P. mulchandi fed on root lets and occasionally on root hairs or at juction of root hairs with the main root in pearl millet (Penisetum typhoides) (Nandakumar and Khera, 1973). P. indicus fed on root hairs before brousing 5-6 cells of epidermis of rice roots for penetration. More nematodes entered through the same hole through which the first nematode had gained entry into cortex of root (Rao, 1990). Most nematodes feed inside roots but a few remain partly embedded outside the root and feed into parasitically (Corbett, 1972).

3. LIFE HISTORY

Genus *Pratylenchus* usually reproduce bisexually and polyploid parthenogenetically but *P. zeae*, *P. neglectus*, *P. brachyurus* and some populations of *P. scribneri* having 2n = 21-26, 20, 30-32 and 12 or 25-26 respectively are monosexual and reproduce by mitotic parthenogenesis (Hung and Jenkins, 1969; Roman and Triantaphyllou, 1969). Eggs are laid in the cortex of the invaded roots singly and frequently. Hatching and post-embrynoic development occur inside the roots. The life cycle passes through 4 larval stages, adult male and female. The ecdysis of 1st stage larvae occur inside the egg. Only second stage larvae hatch out from eggs. The egg to egg life cycle of *Pratylenchus* spp. varies from 28-65 days depending upon the species, host, soil temperature and moisture (Roman and Hirschmann, 1969).

'Eggs of *Pratylenchus* spp., deposited in root tissue, hatch in 6-17 days dpending on the species. Development of 1st and 2nd stage juveniles takes place inside the egg (Roman and Hirschmann, 1969). Unicellular egg to pre-hatched juveniles in *P. coffeae* were found (Wehunt and Edwart, 1971) in uterus of gravid females. Eggs of *P. mulchandi* (Nandakumar and Khera, 1974) hatched in 6-10 days at 25-30°C. Eggs of *P. pratensis* developed in 15-20 days *in vivo* and 10 days *in vitro* in roots of tea (*Thea sinensis* L.) (Hastings, 1939). Fully developed J_2 stage of *P.*

indicus was observed inside egg in 5 days, eclosion occurred in 14-24 hr; total duration being 5.8 to 6.3 days (Prasad and Rao, 1982). Embryonic development is conditioned by species, host and temperature variations (Roman and Hirschmann, 1969).

P. pratensis developed in 54-65 days (Hastings, 1939) in roots of oats and barley (25-31 days in larval stages and 29-34 days from adult to larva of next generation). In corn, *P. zeae* completed development of one life cycle (larva to larva) within 35-40 days (Graham, 1951). The life cycle of *P. mulchandi* was 15-20 days from larvae to adults and 3-6 days for oviposition in agar plates containing pearl millet seedlings (Nandakumar and Khera, 1974). *P. thornei* completed one life cycle, egg to egg, in 25-29 days in roots of maize var. Ganga (Siyanand *et al.*, 1982). The post-embryonic developmental duration (larva to larva) of *P. indicus* in rice var. Bala was 33 to 34 days (Prasad and Rao, 1982). *P. penetrans* developed from larva to larva within 30-31 days in *Cryptomeria* sp. (Mamiya, 1971) and 35 days in peas (Dickerson, 1962). *P. coffeae* completed egg to egg development in 40-45 days in tea (Gadd and Loos, 1941). The duration of post-embryonic development among *Pratylenchus* sps. varies with species, host plant and temperature (Roman and Hirschmann, 1969).

3. PATHOGENICITY

A. Symptomatology and damage

Roots :

Pratylenchus is usually a migratory endoparasite of the root cortex with transitional phase of external feeding at the outset. Destruction of root cortex of dicot plants viz., citrus (Radewald et al., 1971) and orange (Huang and Chiang, 1976) was reported to be due to the infestation by P. coffeae. Similar pathogenic damage symptoms were also observed in roots of Chrysanthemum, Impatiens balsamina, tomato (Lycopersicon esculentum), red clover (Trifolium pratense), carrot (Daucus carota L.), crown vetch (Vicia sp.), pepper (Piper nigrum L.) and strawberry (Fragaria chilonensis) due to P. penetrans infestation (Race and Hutchison, 1959; Shafiee, 1962; Townshend, 1963; Cayrol, 1971).

In wheat, P. thornei caused lysis of root cortical cells (Baxter and Blake, 1968), dissolution of initials of lateral roots, thickening of outer walls of endodermis and cells in the vicinity of the endoparasite, browning of stele and decaying of cortical cells, whereas in barley it caused maximum root necrosis both in stelar and cortex regions. The stele turned brownish and roots were swollen behind the tip (Corbett, 1972). P. neglectus first fed externally on roots of barley and then became migratory endoparasites. Nematodes were observed parallel to root axis and relatively few eggs were laid either singly or scattered groups of 3-4 within a single lesion (Gould, 1974). Maize roots infested by *P. brachyrus* and *P. zeae* showed mechanical breakage of cells and necrosis of both cortical and stelar tissue with concomittant formation of cavities, mechanical damage and necrosis being more in *P. zeae* (Olowe, 1977). Stunting of root has also been reported in maize (Pall and Chand, 1971). Roots of sugarcane were thickened with fewer fine roots and round or elongated lesions by *P. zeae* infestation (Apt and Koike, 1962; Singh, 1974).

Roots of rice infested by *P. indicus* showed lesions on surface, which coalasced later. Cells in cortex and stele were necrotic. The cytoplasm of cortical cells became granular around the feeding site and the cell wall thickened. Invasion of endodermis and zig zag cavities in cortex were also found (Prasad and Rao, 1981). Roots of upland rice were severely stunted with extensive grey lesions due to infestation of *P. zeae* (Plowright *et al*., 1988).

Foliage :

Due to root damage, the aerial parts of plants showed symptoms of malnutrition and water deficiency. Trees or shrubs are rarely killed but gradually became devitalized and unproductive (Walia, 1986). Rice plants infested by

P. indicus showed yellowing or discolouration of leaves from tip downwards. The plants had stunted growth (Prasad et al., 1977).

Infestation by P. indicus in direct seeded rice resulted in death of seedlings at 40-45 days following germination (Rao and Prasad, 1977) while in growing rice crops it caused reduction in ear heads upto 33%, grain yield upto 55.5% and weight of 1000 grains upto 15.1% among six upland rice varieties (Prasad and Rao, 1978). Substantial yield losses due to P. zeae in rice were reported by Plowright et al. (1988) and Prot (1990) in Philippines. Yield losses in corn were decreased by 26% by controlling P. hexincisus(Norton and Hinz, 1976). Wheat yield increased by 15-20% by controlling P. thornei (Anonymous 1969-70). Losses ranging from 7 to 32% in rice due to P. indicus were averted by controlling this nematode (Prasad and Rao, 1978).

The economic threshold in case of Pratylenchus injury is not well defined. Khan (1963) recorded that 4.7 P. zeae/g of root in sugarcane caused growth reduction. Dry weight was reduced by 9.5% and 64.8% at levels of 19 and 109 P. zeae per 50 cc soil (Tarte et al., 1977). But at levels of 1000 nematodes per plant, growth of sugarcane was significantly reduced and was inversely proportional to the increase in levels of inocula (Nath et al., 1978). Significant reduction in growth of su-babool (Leucaena *lucocephala* L.) occurred with 100 *P. zeae*/500 ml of soil (Azmi, 1984). He also observed that the length and dry weight of shoot and root, basal diameter and number of tillers of buffel grass (*Cenchrus ciliaris*) decreased with increase in the inoculum level of *P. zeae*, the significant reduction being at 1000 nematodes per 500 ml soil (Azmi, 1988). This was also confirmed in *Penisetum pedicillatum* (Azmi, 1989). Growth reducton in sorghum at levels of 1500 *P. zeae* per 20 cm dia pot soil (Bee-Rodriguez and ayala, 1977) or 600 *P. zeae* per seedling (Motalaote *et al*., 1987) was also reported. In green gram (*Phaseolus mungo* L.) while germination of seed was reduced at 3000 or more of *P. zeae* per 500 ml soil, growth of the plant was adversely affected even at an initial level of 500 nematodes per 500 ml soil (Walia and Seshadri, 1986). With the increase in levels of inocula of *P. indicus* in rice, from 0, 5, 50 and 500 (F:M = 4:1), there was a corresponding significant reduction in yield. For every 100 nematodes in the roots, there was a reduction of 1.05% in grain yield (Rao, 1990). An initial population of 600 and 3000 *P. zeae* per 100 ml soil reduced significantly the rate of growth of upland rice. The number of tillers, panicles and spikelets were markedly reduced with maximum population density at harvest (Plowright *et al*., 1988).

5. CONCOMITTANT PATHOGENICITY

Arable soil is a polycommunal environment with many organisms living in parasitic, symbiotic or other associations. In the nematode communities, the interactions may be competitive, additive, synergistic or substractive, modified for different plants, cultural and environmental conditions. Such interactions may be physical or functionally mediated through the host plant (Sikora *et al.*, 1972).

In red clover (*Trifolium* spp.) penetration of *Meloidogyne incognita* and *P. penetrans* into the roots was unaffected at an inoculum ratio of 10:50 while at 50: 200, penetration by *M. incognita* was significantly reduced (Turner and Chapman, 1972). This concomittant inoculations also caused decrease in fecundity of *P. penetrans* (Chapman and Turner, 1975). Prior to invasion, *M. incognita* suppressed penetration of *P. brachyurus* in roots of tomato, whereas in alfalfa and tobacco, there was no interaction (Gay and Bird, 1973). Penetration of *P. penetrans* in tomato was, however, reduced in combination with *M. incognita* (Estores and Chen, 1972). *P. penetrans* interacted with *M. incognita acrita* caused reduction in root knot index in corn (Graham, 1951). In concomittant inoculation the population of *P. brachyrus* was suppressed in susceptible varieties of tobacco (*Nicotiana tabacum* L.) but in some varieties, the population of M. incognita was reduced (Johnson and Nusbaum, 1970). Townshend (1973) showed that the size of final population of P. penetrans is governed by the inoculum densities of nematodes. Ingress of P. penetrans and P. minyus was higher at lower densities and lower at higher densities for food and competition. Earlier, Tyler (1933) reported that the quantity of initial inoculum that penetrates roots governs the size of final population.

Primitive host parasites relationships are usually less competitive than the more specialised relationships (Johnson and Nusbaum, 1970). Meloidogyne spp. was suppressed by P. major on pine apple (Guerout, 1968) and P. brachyurus on cotton (Gay and Bird, 1973). Pratylenchus sp. are more competitive than M. incognita in tobacco (Graham et al., 1964). Sedentary endoparasites like M. elugye altered the physiological condition of host. However, M. incognita and P. penetrans were mutually suppressive (Estores and Chen, 1972). Reproduction of P. brachyurus on tobacco was stimulated by M. incognita (Johnson and Nusbaum, 1970) and that of P. penetrans by M. naasi on creeping bent grass (Sikora et al., 1972). In the present studies with P. zeae and M. graminicola, the former is a vagrant cell feeder and the later is sedentary. Upland rice soil conditions favour their dual prevalence and invasion into roots of rice.

The growth of red clover was reduced when M. hapla was present either singly or in combination with P. penetrans (Amousu and Tayler, 1974). when tobacco seedlings were inoculated with 600 M. incognita or P. brachyurus, or in combination, the combined inoculum reduced plant growth more severely than either nematode inoculated separately. In the concomittant inoculations, M. incognita was dominant(Ogbuji, 1978). Combined inoculation of 1000 Quinisulcius acutus and 500 P. zeae per 15 cm dia pot resulted in greatest suppression of growth of sorghum than either nematode incoulated alone. Population density of both nematodes was significantly less when combined than alone but the reproduction of P. zeae was greater than Q. acutus (Cuaremza -Teran and Trevathan, 1985).

Studies on inoculations with P. brachyurus and P. zeae in maize alone or in combination with the fungus Fusarium moniliforme showed that growth was reduced in combined inoculation signifying a synergestic effect (Jordan et al., 1987). Similar interaction was reported on maize when Tylenchorhynchus vulgaris and P. zeae or T. vulgaris and fungus, F. moniliforme were inoculated together than either oranism inoculated alone. Development of T. vulgaris was suppressed in the presence of P. zeae but the latter was not affected by T. vulgaris (Upadhyaya and Swarup, 1981). When sugarcane was inoculated with 1200 P. zeae and 1600 larvae of M. incognita, and a suspension of fungus Pythium graminicola, separately or in combination either nematode alone significantly reduced plant height, shoot circumference, shoot and leaf fresh and dry weight and root fresh weight or the fungus alone reduced only plant height. The two nematodes in combination reduced only plant height and weight of shoot and leaf, whereas all the organisms in combination were antagonistic (Valle-Lamboy and Ayala, 1980).

Competition may be more within species of similar feeding habits. Sedentary endoparasites are more competitive than ecto-endo parasites. Mechanical destruction of feeding sites or their physical occupation, induced physiological changes in roots (Eisenback and Grifin, 1987). These physiological alterations either increase or decrease the activity of the other cohabitants. Synergestic reaction may be due to an increase in susceptibility to invasion of the less pathogenic species. The more pathogenic nematodes may have the number of feeding sites reduced. Interactions may be stimulatory or neutral or detrimental to one or both species (Duncan and Ferris, 1983).

Pratylenchus sps. release glucosidases while feeding which acts on amygdalin thereby hydrolysing the compound into benzaldehyde and HCN both of which are phytotoxic (Dasgupta and Parthasarathy, 1990). Nematodes escape this phyto-toxicity by migrating away from such areas in cortex and invade fresh cells. Secretions of P. indicus increased soluble amino acids by 1.3 times and phenolics by 10.3% in roots of rice (Prasad and Rao, 1978).

6. HOST RANGE

A wide host range is a beneficial factor for survival and perpetuation of an organism. The genus Pratylenchus feeds on almost all the cultivated agricultural and horticultural crops and even on weeds and other plants growing around. Several plants, identified as hosts for P. zeae, has been enlisted (Table 1).

Among crops sugarcane (Singh, 1966), green gram (Walia, 1982), Groundnut (Singh, 1978), cotton (Vadivelu, 1991), potato (Walliulah & Bhat, 1990), tobacco (Jain and Singh, 1993) and su-babool (Azmi, 1984) are the good hosts of P. zeae.

Some cereals are also infested with P. zeae. These are sorghum (Tikiyani et al., 1969), maize (Ibrahim et al., 1988), barley (Hashmi and Hashmi,1989)and wheat (Waele and Jordan, 1988).

P. zeae occurs in the USA, Venzeula, Brazil, Ivory Coast, Cuba,Cameroon and Senegal where mostly rainfed rice is grown (Rao, 1992). This nematode was also reported in

Table 1 : Plants identified as hosts for *P. zeae*

Common name	Botanical name	Reference
1	2	3
Cereals		
Wheat	*Triticum aestivum* L.	Waele and Jordan, 1988
Barley	*Hordeum vulgare* L.	Hashmei and Hashmi, 1983
Maize	*Zea mays* L.	Kinloch and Lutrick, 1975
Rice	*Oryza sativa* L.	Samsoen and Geraert, 1975
Sorghum	*Sorghum vulgare* L.	Kinloch and Lutrick, 1975
Sugarcane	*Saccharum officinarum* L.	Nath *et al*., 1975
Oil seeds		
Groundnut	*Arachis hypogea* L.	Singh, 1978
Linseed	*Linum usitatissimum* L.	Shafshak *et al*., 1985
Sunflower	*Helianthus annus* L.	Bolton *et al*., 1989
Vegetables		
Potato	*Solanum tuberosum* L.	Walliullah and Bhat, 1990
Onion	*Allium cepa* L.	Hashmi and Hashmi, 1989
Garlic	*Allium sativum* L.	Hashmi and Hashmi, 1989
Ginger	*Zingeber officinale* Rose	Kaur *et al*., 1989

contd......

continuation of Table 1

1	2	3
Pulses		
Greengram	*Phaseolus aerius* Roxb.	Walia, 1982
Faba bean	*Vicia faba* L.	Shafshak *et al*., 1985
Soyabean	*Glycine max* Merr.	Triol. Tech. Rept., 1977
Fenugreek	*Trigonellafoeum gracecum* L.	Triol. Tech. Rept., 1977
Others		
Guava	*Psidium guajava* L.	Triol. Tech. Rept., 1987
Plantain	*Musa paradisiaca* L.	Adiko, 1988
Rose	*Rosa* sp.	Sundarababu and Vadivelu, 1989
Rubber	*Hevea brassiliensis* Mull Arg	Lordello and Veiga, 1983
Tuberose	*Polyanthus tuberosa*	Triol. Tech. Rept., 1987
Weeds and fodder crops		
Buffel grass	*Cenchrus ciliaris* L.	Azmi, 1988
Dinanath grass	*Penisetum pedicillatum* Trin.	Azmi, 1989
Goose grass	*Eleusine Indica* L.	Fernendez and Ortega, 1982
Guinea grass	*Panicum maximum* Jacq	Lordello and Mello, 1970

contd.......

continuation of Table 1

1	2	3
Para grass	*Panicum purpuraseen* Rald.	Lordello and Mello, 1970
Rice flat sedge	*Cyperus iria* L.	Fernendez and Ortega, 1982
Rhodes grass	*Chloris guyana* Kunth.	Sheperd, 1977
Subabool.	*Leucaena leucocephala* L.	Azmi, 1984
Pig weed	*Amarnanthus hybridus* L.	Jordan and Waele, 1988
Weeping love grass	*Eragrostis curvula* Beauv.	Sheperd, 1977
Crotolaria	*Crotolaria sphaerocarpa* L.	Jordan and Waele, 1988
Jimson weed	*Datura stramonium* L.	Jordan and Waele, 1988

association with deepwater and upland irrigated rice culture (Atkins *et al*., 1955; Fernadez and Ortega, 1985; Ray *et al*., 1987; Plowright, 1988).

Several weeds act as alternate hosts of *P. zeae* in upland rice field (Macdonald and Mai, 1963; Rossner, 1983; Bendixen, 1988). Amongst them *Cyperus iria*, *C. rotondus* *Eupatorium compositifolium*, *Typha domingensis*, *Eleusine indica* and *Panicum maximum* (Shepherd, 1968; Fernadez and Ortega, 1982; Gerber and Smart, 1987) were reported to be good hosts.

7. MANAGEMENT AND CONTROL

A. Effect of Organic nematodes

Therapeutic :

Use of commercial formulations of insecticides/ nematicides have been found to be effective therapeutic and prophylactic control methods for *Pratylenchus* (Willis and Thompson, 1979; Lordello *et al*., 1983 Smolik, 1987; Badra and Adesiyan, 1990). Although several nematicides have been tested, carbamates and organophosphatec chemicals were reported as very effective in controlling *P. zeae* and other nematodes (Walters, 1979; Novaretti *et al*., 1984, Sawazaki *et al*., 1987; Mohapatra and Padhi, 1988; Lewis *et al*., 1991).

Carbofuran, a systemic insecticide/ nematicide at 2g/ m row increased yields of maize by 33% by controlling *P. zeae* whereas both carbofuran and carbosulfan doubled grain yield(Walters, 1979; Lordello *et al*., 1983). Carbofuran at 200g a.i/100m and carbosulfan at 100g a.i/100m significantly reduced *P. zeae* and *P. brachyurus* at different growth stags of maize. But, the degree of control, plant density and dry matter differed with both the nematicides (McDonald *et al*., 1987). Significant reduction of *P. zeae* and *M. javanica* was obtained in sugarcane by application of carbofuran at a dose of 60kg a.i./ha soil (Novaretti *et al*., 1984) but the soil treatment with 60 kg/ha controlled nematodes upto 6 months (Novaretti and Nelli, 1985). Carbofuran, aldicarb, phorate and phenamiphos at 0.05 or 0.1g a.i 20 lit soil were effective against *P. zeae* in su-babool, all treatments gave better growth of seedlings and reduced maximum population of nematode, the best result being at higher dose (Azmi, 1988). Soil treatment with carbofuran at 4 kg a.i./ha controlled populations of *P. zeae* and increased the proportion of filled spikelets and total grain yield of rice over control (Plowright *et al*., 1988) while carbofuran or phorate at only 1 kg a.i./ha were equally effective against *P. indicus* (Prasad *et al*., 1988). Even at 0.75 kg a.i./ha, carbofuran had stimulatory effect and increased plant height of rice (Singh *et al*., 1990). Carbofuran, phorate and terbufos resulted in better production of cane by controlling P. zeae but carbofuran was superior than others in giving control upto 6 months (Novaretti and Nelli, 1985).

Combined application of carbofuran and FMC or phorate and FMC at the rate of 20% FMC and 1 kg each of the other two nematicides significantly increased the yield of pea nut (Mohapatra and Padhi, 1988). Carbofuran at 60 kg/ha and filter cake at 30 ton/ha increased yield of sugarcane about 23% by controlling P. zeae and M. javanica populations (Novaretti and Nelli, 1985).

Prophylactic :

Bare root dips in nematicidal solutions is adopted to ensure (a) clearing roots of adhering ectoparasites, (b) protecting the rhizosphere of young seedlings from parasitic nematodes, and (c)inducing resistance through translocation of nematicide into seedling and thus prevent infection and loss due to nematodes in the early growth stages of transplants. Dipping seedlings in carbosulfan, phenamiphos or FMC 35001 at 1% was recommended to ensure healthy crop growth and protection against root nematodes (Hirschmanniella sp.) in rice (Rao et al., 1986). Nemacur (Phenamiphos), phosphomidon, carbosulfan and carbofuran at 0.2% were effective as pre-inoculation and post-inoculation root dips in rice against the root knot nematode, M. graminicola (Krishna Prasad and Rao, 1976).

Most carbamates or organophosphates have more or less systemic properties, but their mode of action is through contact with the nematode (Bunt, 1987). These chemicals usually incapacitate nematodes at field concentrations and their effects may be reversible (Sitaramiah, 1990). Hence, even if mortality of nematodes was low due to the impairing of neuro-muscular activity, the rate of hatching, motility and orientation towards host, feeding and their development are affected. Ethoprop has only local systemic action against nematodes in roots. Overall, these nematicides inhibit the enzyme acetyl cholinesterase at cholenergic synapsis in the nematodes (Bunt, 1987).

As in pea (*Pisum sativum*) where carbofuran and its metabolites inhibited indole acetic oxidase, preserving plant growth hormones at critical level (lee, 1976), in rice the same mechanism may operate (Venugopal and Litsinger, 1980). Both carbamates and organo phosphates are potential inhibitory of acetyl cholinesterase in nematodes (Meinikov, 1971) and mineralise and nitrify NH_4. Also they preserve soil organisms responsible for organic mineralization (Rao *et al*., 1983).

B. Effect of botanicals (oilcakes)

Eventhough several nematicides control nematodes effectively, they do not adequately meet the needs for environmental safety. However, a form of accelerated nematicidal degradation of organophosphates and carbamates occur in treated fields. But, at the same time, repeated application may cause environmental contamination (Sultanul Haq *et. al.*, 1990). As such, organic soil amendments are being explored for management of nematodes as well as to meet the needs for environmental safety.

Oil cakes, some of which are used as feeds for animals, are a good source for soil amendment in arable lands. These are decomposable and they increase aeration, solubilization of nutrients and status of nitrogen, helping better root growth and ultimately more efficient utilization of nutrients (Badra and Elbary, 1978). Also some oil cakes are blended with synthetic fertilizers to enhance their efficacy by slow release of nitrogen (Satasivamani *et al.*, 1982). Cotton seed cake increased nitrate nitrogen, higher urease activity and pH of soil (Rodriguez Kabana, 1966).

Application of oil- cakes as organic amendments for control of several parasitic nematodes in crops has been extensively reported (Khan *et al.*, 1976; Goswamy and Vizayalaxmi, 1981, 1983; Goswamy and Meshram, 1991; Sitaramiah, 1993). Aqueous extracts of neem oil- cake (*Azadirachta indica* L.) decreased populations of *P. brachyurus* (Egunjobi and Larinde, 1975). Hatching of *M. incognita* eggs was prevented by aqueous extracts of mustard, sesame and cotton oil -cakes prepared by soaking 100 g in a litre of cold water. But, boiling extraction from mustard and cotton seed cakes, inhibited hatching more than cold extraction (Inderjit Singh _et_ _al_., 1980) indicating that higher temperatures increased active principles of extract. Black mustard seed cake contained allelisothiocynate, toxic to potato cyst nematode (_Heterodera_ _rastochensis_ Woll.) (Ellenby, 1945). Seedling root dip treatment in organic soils showed that chalmogra oil was most effective in reducing gall number in roots of tomato infested with _M._ _incognita_ followed by neem, karanj and polanga. However, at higher concentration all three oils except polanga proved effective against larval penetration and gall production (Pradhan _et_ _al_., 1989).

Groundnut cake at 2.5 or 5% of potted soil effectively controlled _M_. _incognita_ population in _Capsium_ _annum_ and promoted growth better than mustard and til cakes (Trivedi _et_ _al_., 1978). Neem, karanj (_Pongamia_ _glabra_) and groundnut cakes were equally effective against several parasitic nematodes in different plants (Khan _et_ _al_., 1976; Gowda, 1978; Singh _et_ _al_., 1980). The efficiency of oil cakes increased when mixed with soil than when added to surface of soil (Singh _et_ _al_., 1980). The decomposing chemicals of margosa (neem) cake and saw dust applied to soil at the rate of 25 q/ha were harmful to plant roots and therefore such treatments may be applied 2-3 weeks prior to planting (Singh and Sitaramiah, 1973). The microbial decomosition of organic substances, specially the product and process of ammonification and nitrification are responsible for the decrease in nematode population. Oil cakes like margosa, castor (Ricinus communis L.), groundnut, linseed (Linum usitatissimum), mustard (Brassica campestris), mahua (Madhuca indica) etc. are effective against several species of Meloidogyne, Pratylenchus, Tylenchorhynchus, Helicotylenchus and Rotylenchus (Sitaramiah, 1990).

Neem and karanj cakes at 1 t/ha as soil amendments were effective against brown plant hopper and white backed plant 'hopper in rice (Ramaraju and Sundarababu, 1990). Cotton, gingelly (Til) and neem cakes controlled seed blight pathogen in rice and the release of toxic products devising their decomposition was implicated (Manibhushana Rao et al., 1989).

Comparative efficacy of nematicides and oil cakes against the parasitic nematodes has also been reported (Alam and Khan, 1974; Khan et al., 1976; Gowda, 1978; Singh et al., 1980). In soil and roots of tomato, nematicides like carbofuran, dimethoate and aldicarb gave significantly better control than oil cakes of castor, neem, mustard, mahua and groundnut. But growth of plant was promoted by oil cakes, the maximum growth being in mustard cake application followed by neem, groundnut, castor and mahua

(Singh *et al.*, 1980). Goswami and Meshram (1991) also observed that oil cakes were as effective as nematicides in controlling *M. incognita* in tomato but growth of the plant was better in oil cakes than nematicides. Much work has not been done on the effect of botanicals on *P. zeae*.

Mode of action :

Nematotoxic principles of oil cakes through the host plant metabolism were studied by several workers (Tomerlin and Smart, 1967; Mankau, 1963; Sitaramiah and Singh, 1978; Bhattacharya and Goswamy, 1987). Absorption of chemicals such as phenols and amino acids, released following decomposition of organic matter, through roots and increase in polyphenol oxidase activity in roots following nematode infection, together contributed for control of nematodes (Alam *et al.*, 1979, 1980; Singh *et al.*, 1980, 1985 ; Goswamy and Vijayalaxmi, 1981,1987; Goswamy and Meshram, 1991).

Other toxic compounds released into soil, following amendments included ammonia, formaldehyde as products of microbial decomposition. These are either directly toxic to nematodes or imparted resistance to plants (Walker *et al.*, 1966; Mankau, 1963; Bhattacharya and Goswamy, 1987). Several products of decomposition following soil amendments with oil cakes also increase the population of some natural enemies like saprophytic fungi. Such fungi in the rhizosphere may be partly responsible for suppressing nematodes (Khan et al., 1974, 1979).

The range of biological effects produced by the toxicants of both synthetic chemicals or organic amendments fall in (a) immediate risk to survival, (b) irreversible damage to some physiological process, (c) reversible damage, or (d) long term low frequency risks (tertogenesis, carcenogenesis or mutagenesis etc.) (Samolioff, 1987). Penetration, feeding or reproduction of nematodes in or on the plant tissues and the combined effects of direct contact and reducible attractiveness of plant as food source act on nematicidal or nematostatic principle (Bunt, 1987). With plants and plant products as nematicides, the decomposing products of these amendments are known to be toxic and can be used for effective prevention of nematode invasion. But, due to paucity of information on the active principle, mode of action is little understood. Nevertheless, it is desirable that potentiality of such plants and plant products needs to be explored .