5. Discussion

It is now well established that plant-parasitic nematodes cause considerable damage to economically important plants and have been firmly recognised as one of the important biological constraints for crop production. On the basis of production figures and prices of 1984, the worldwide crop losses due to nematodes in 21 crops, 15 of which are life-sustaining, were estimated by Sasser & Freckman (1987) at $77 billion annually. They further visualized that the losses would probably exceed $100 billion annually when all the world crops are considered. In case of pulse crops, the major obstacles in the way of increasing production are various diseases which are responsible for reduction and uncertainty in pulse yields (Grewal, 1983; Grewal et al., 1988). The production of pulses are greatly reduced by the diseases incited by plant-parasitic nematodes. Among important pulse crops, which stand between man and starvation (Wittwer, 1981), lentil crop is damaged by plant parasitic nematodes.

In nature plants are never subjected to a single pathogen but are exposed to multipathogenic condition (Powell, 1971a). These pathogens as well as other micro-organisms are continuously interacting to each other usually resulting in greater damage. In such situations, containing of the damage becomes rather tricky. The resistant varieties may not remain resistant in such situations or they prove resistant to one and not to another pathogen at given time. This requires screening of large varieties to different pathogenic situations for different regions. The different plant diseases can also be controlled by use of predatory fungi, oil-seed cakes and many
other agencies. These aspects have been investigated in the present study. The use of predatory fungi has great relevance to the present day need of avoidance of pollution hazards caused by chemicals. Oil-seed cakes, which are byproducts of agro-based industries, have been included in the present study to evaluate their efficiency against nematodes and fungal pathogens at a time.

A survey, conducted in lentil fields in and around Aligarh, revealed that plant-parasitic nematodes in addition to pathogenic fungi were consistently associated with the unthrifty crop growth. Among nematodes, reniform nematode occurred most frequently in the crop but in case of fungi, frequency of root-rot fungus, *Rhizoctonia solani* was high in lentil fields. The interactive effects of these pathogens on the crop has been investigated in the present study.

**Varietal reaction of lentil**

In case of lentil, varieties DPL-25, DPL-26, DPL-28, DPL-33, DPL-35, DPL-36, DPL-38, DPL-39, DPL-40, DPL-42, DPL-43, DPL-44, LH-88-8, DPL-47, LH-90-54, LH-90-57, LH-90-85, LH-90-103, LH-90-84 and LH-90-87 were screened for their reaction in terms of damage in plant length, fresh as well as dry weight, pod number, chlorophyll content and root-nodulation to different inoculum levels of the reniform nematode, *Rotylenchulus reniformis* and the root-rot fungus, *Rhizoctonia solani*. These varieties showed varying degree of susceptibility to the pathogens. In the presence of *Rhizobium*, variety LH-90-85 was found resistant to *R. reniformis*, and *R. solani*. This shows that variety LH-90-85 was resistant to both the pathogens tested. Similar studies have also been conducted by many workers to
evaluate the reaction of the varieties of pulses to plant parasitic nematodes and different pathogenic fungi (Hasan, 1983; Zote et al., 1983; Tiyagi & Alam, 1986; Sahoo et al., 1986; Tiyagi & Alam, 1987; Varshney et al., 1987; Khan and Husain, 1989; Taylor, 1990; Khan & Hosseini-Nejad, 1991; Anver & Alam, 1997; Siddiqui & Mahmood, 1998; Tiwari, 1998). In these studies, the reaction of different varieties was assessed only on the basis of disease development (e.g., root-knot development, wilt index, nematode population). Whereas, in the present study, large number of plant growth parameters have been taken into account to obtain more accurate assessment of plant reaction to the test pathogens. Moreover, all the test varieties have been screened to major pathogens of the area at a time (Tables-1a, 2a).

The plant damage due to the test pathogens increased with increasing inoculum level. More damage was caused by R. solani than R. reniformis. Similar results have also been reported by Anver & Alam (1997), Rao & Krishnappa (1998), Siddiqui & Mahmood (1998). The reduction in plant growth may be due to physiological and structural aberrations caused by the pathogens.

Significant reduction was also observed in the photosynthetic pigment, e.g., chlorophyll content, due to these pathogens. Decrease in chlorophyll content in infected plants, adversely affect the photosynthesis, which in turn, impede development of plants in terms of reduced plant weight, number of flowers and delayed flowering, ultimately resulting in reduced yields (Melakeberhan et al., 1985). Moreover the nematode invasion is known to bring a change in the concentration of the nutrient elements in plants such as Fe, Zn, Cu,
Mn and F, etc., which play a vital role for constituents of plants, e.g., Fe and Mn in the photosynthetic pigment (Devlin & Witham, 1986). Change in the concentration of these nutrient elements in plants, even to small extent, appear to have a profound impact on host physiology, which in tern appears to be the major cause in limiting the growth of the host plant and cause imbalance in the translocation process (Melakeberhan et al., 1985; Tiyagi et al., 1986).

The reduction in number of nodules in test plant seems to be more due to nutritional interference particularly carbohydrates or physiological changes (Bopaiah et al., 1976a; Taha & Raski, 1969) or anatomical changes (Balasubramanian, 1971) brought about by nematode-infection of plants rather than secretion of hydrolytic and oxidative enzymes (Barker et al., 1972) or competitive phenomenon between rhizobia and nematodes (Epps & Chambers, 1962; Malek & Jenkins, 1964) or interference of juveniles with the establishment of rhizobia (Hussaini & Seshadri, 1975).

The reduction in these parameters seems to be responsible for reduced plant growth as also the pod numbers. The reduction in pod number may also be due to reduced food supply to the fertile branches (Tiyagi & Alam, 1989, 1990) and to the deficiency of mineral nutrition (Melakeberhan et al., 1985; Wallace, 1974).

The rate of multiplication of nematode was adversely affected by increasing inoculum levels. Such observations have also been given out by several workers (Nath et al., 1979; Fazal et al., 1994; Ahmad & Alam, 1998). The reason for the reduction in nematode multiplication with increasing inoculum levels may be due to
competition for food and space (Triantaphyllou, 1960; Davide & Triantaphyllou, 1967).

In another experiment, where seeds of lentil were not treated with *Rhizobium* (Tables-1b, 2b), plant growth characters (length, fresh weight, dry weight pod number and chlorophyll content) in both test pathogens-inoculated and uninoculated plants were reduced as compared with those in *Rhizobium*-treated set. This appears to be due to the increase in multiplication of nematode and root-rot index in absence of *Rhizobium*. It can possibly be assigned to the reduced resistance against invading pathogens in less vigorously growing host plants. These findings are in agreement with those of Orellana *et al.* (1976), Bopaiah *et al.* (1976a) and Tu (1980).

**Influence of antagonistic fungi on plant growth, nematode and fungi in pots:**

In general, *R. solani* infection caused greater reduction in plant growth and nodulation of majority of the varieties than caused by the infection of *R. reniformis*.

In the pot study, influence of antagonistic fungi (*Paecilomyces lilacinus, Trichoderma viride, Aspergillus niger, Verticillium chlamydosporium and Arthrobotrys oligospora*) was evaluated against *R. reniformis* singly or in combination with *R. solani* on lentil plants. The results of the experiments (Tables-3a, b; 4a, b; 5a, b; 6a, b; 7a, b) clearly shows that the test pathogens caused significant damage to the host. Different combinations of nematode and fungus brought about further reduction in plant growth parameters. Thus, fungus, *R. solani* appeared to have played an important role in
elevating the disease development even with the other pathogen like *R. reniformis*. It was also observed that different treatment with antagonistic fungi have effectively contained the pathogenic effects. Highest inhibitory effects was found with *P. lilacinus* followed by *T. viride, A. niger, V. chlamydosporium* and *A. oligospora*. This show that the antagonistic fungi were equally effective against both the test pathogens on host plant.

The favourable influence of antagonistic fungi for the control of the *R. reniformis* and *R. solani* on lentil was density dependent i.e. with the increase in the inoculum level of antagonistic fungi there were increasing improvement of plant growth and decrease in nematode population. Inoculum level (1.0g per pot) of antagonistic fungi gave the best results for reducing plant damage caused either by the individual pathogen caused by their interaction (Tables-3a, b; 4a, b; 5a,b; 6a,b; 7a,b). These results support many earlier findings where antagonistic fungi have been reported to be highly deleterious to nematode and fungus (Ahmad & Alam, 1997; Rao et al., 1998; Parveen *et al.*, 1998; Duponnois *et al.*, 1998; Fatemy, 1999; Viaene & Abawi, 2000) on other crops.

As a consequence of reduction in pathogenic effects, plant growth (length, fresh as well as dry weight, pod numbers, root-nodulation and chlorophyll content) of lentil improved in all treatments. The improvement in root-nodulation as well as in photosynthetic pigment could be due to direct effect of different treatments or indirectly through control of the pathogens. In any way, improved root-nodulation as well as leaf pigmentation might have, in turn, helped the plants for their luxurient growth.

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It is reported that antagonistic fungi are capable of parasitising nematode eggs and destroying the embryo. It also grow within the developing females resulting in their death (Jatala et al., 1979). Jatala et al. (1979, 1980, 1981), Viaene & Abawi (2000) used antagonistic fungi for control of *M. incognita*, *M. hapla* and *Globodera pallida* on potatoes and lettuce both in the laboratory and under field conditions. They reported that this fungus consistently and efficiently reduced the populations of both the test pathogens resulting in an improved yield. Furthermore, some other species of *Paecilomyces* (eg. *P. marguandii* and *P. variotii*, Barinier) and *Pseudoeirotium ovale* stolk have also been shown to be capable of destroying eggs, juveniles and adults of several nematode species (Lysek, 1966; Godoy et al., 1983; Anver & Alam, 1997).

Antagonistic fungi effectively reduced reniform nematode population by killing females, reducing their fecundity and parasitizing egg masses (Tables-3a,b; 4a,b; 5a,b; 6a,b; 7a,b). Earlier reports that the hatched out juveniles become incapacitated in the presence of fungal hyphae indicate a primary, diffusible toxic effect rendering them subsequently vulnerable to colonization. It has been reported that fungal penetration in the egg-shell takes place by mechanical rupturing of the vitelline layer through a narrow tube-like hyphal extension (Morgan-Jones et al., 1984). It is also possible that partial disintegration of vitelline layer may also be due to exoenzyme production by the fungal hyphae, possibly involving the presence of translocable, physiologically disorganizing factor, such as diffusible toxic metabolites. This disruption not only predisposes the egg to fungal infection by physical weakening of the shell, but, also
increases permeability, thus facilitating inward passage of fungal metabolites both toxic and enzymatic. This exopathic effect might be enough to abort the reproductive process. Once a fungal hypha enters an egg, enzymatic dissolution of the chitin layer takes place (Okafor, 1967). It has been reported that mycelial proliferation on the nematode body results in probable biosynthesis of destructive metabolites endogenously. Further, endogenous mycelial proliferation might support the lysis of egg-shell material. Later, hypae penetrate the larval cuticle. This endopathic activity of the fungus causes total degeneration of the egg contents and leads to the ultimate demise of the larvae. Efficacy of *P. fumosoroseus* on different nematodes parasitizing different crops has also been tested with fruitful results (Fatemy, 1998). *P. lilacinus* isolates from silkworm yielded oxalic, dipicolinic and succinic acids and some unidentified amino acids, as well as large amounts of D-mannitol (Domsch *et al.*, 1980). These chemicals might also be responsible for the killing of nematodes and inhibition of fungal growth. *Paecilomyces variotii* is known to produce cytotoxic agent and toxic metabolites in some food-stuffs (Domsch *et al.*, 1980).

In the present findings antagonistic fungi not only reduced the intensity of *R. reniformis* infection, but it also showed antagonistic effect against *R. solani* (Tables-3a,b; 4a,b; 5a,b; 6a,b; 7a,b). Some toxic metabolites and/or enzymes released by antagonistic fungi might have inhibited the growth of *R. solani*. *P. lilacinus* is reported to produce β (1-3) glucanase (Domsch *et al.*, 1980) and chitinase (Okafor, 1967) extracellularly which are key enzymes in the lysis of fungal cell walls (Mitchell and Alexander, 1963). *Rhizoctonia solani*
belongs to homobasidiomycetes, the walls of which are mostly composed of glucans with only about 6-8% chitin (Bartinickin-Garcia, 1973). It, therefore, seems that β (1-3) glucanase is more important in the degradation of cell walls of R. solani. Arai et al. (1973) isolated leucostatin and lilacin, two water soluble peptide antibiotics, from a fungus determined as Penicillium lilacinus (=Paecilomyces lilacinus), Leucostatin is active against gram-positive bacteria and many fungi.

Conclusively, I can say that antagonistic fungi such as P. lilacinus, T. viride, A. niger, V. chlamydosporium, A. oligospora are potential bio-control agent which has a number of advantages. P. lilacinus is typically a soil-borne fungus and seems to be relatively common and ubiquitous in the tropics and subtropics (Domsch et al., 1980). The capability of this species to degrade chitin has been accounted by Okafor (1967) and it is also strongly proteolytic (Janke and Holzer, 1929; Borout, 1960; Endreeva et al., 1972). There is sufficient evidence to suggest that P. lilacinus, a heavy sporulator, is strong competitor capable of successfully establishing itself in a natural soil when introduced artificially. P. lilacinus has antagonistic activity against bacteria, fungi, and nematodes.

A similar experiment was also conducted by using unbacterized seeds (Tables-3b, 4b, 5b, 6b and 7b). Here, the overall plant growth parameters (length, fresh as well as dry weight, pod number and chlorophyll content) were less than those raised from bacterized seeds. These were further decreased in plants inoculated with the test pathogens, even greater than in bacterized pathogen-inoculated plants.
This reduction has positive correlation with the increase in the multiplication of nematode and root-rot development. It may be due to reduced resistance against invading pathogens in less vigorously growing plants. These findings are in agreement with those of Orellana et al., (1976), Bopaiah et al. (1976a) and Tu (1980).

Effect of oil-seed cakes, *P. lilacinus* on plant growth, nematode and fungi in Pots

**Effect of oil-seed cakes:**

The farmers have been using organic materials for improving soil fertility since the advent of agriculture. However, it has become known only recently that these organic additives are highly effective in suppressing many plant diseases including those caused by nematodes.

In a pot study, amending the soil with oil-seed cakes (neem, castor, mahua, mustard, sesamum, soybean, groundnut, linseed, karanj, duan) has caused significant reduction in the population of plant-parasitic nematodes, viz., *Rotylenchulus reniformis, Meloidogyne incognita, Tylencorhynchus brassicae, Hoplolaimus indicus, Tylenchus filiformis, Helicotylenchus indicus, Hemicriconemoides mangiferae*, etc. on lentil (Tables-8a,b; 9a,b; 10a,b; 11a,b; 12a,b; 13a, b; 14a,b; 15a,b; 16a,b; 17a,b). These results are, in a way, in agreement with those of Lear (1959), Singh & Sitaramaiah (1970), Gour & Prasad (1970), Alam & Khan (1974) and Siddiqui (1986) with other crops.

It was also observed that different treatments with oil seed-
cakes have effectively contained the pathogenic effects. Highest inhibitory effects was found with nem-seed cake followed by castor, mahua, mustard, sesamum, soybean, groundnut, linseed, karanj and duan.

It is well known that whenever some organic materials are added to the soil, there occurs an ecological succession or micro-organisms. Thus successive phases of biochemical degradation and succession of micro-organisms may guide the control of plant pathogens present in the soil.

Various theories have been put forward to explain the mode of action of organic amendments leading to the control of plant-parasitic nematodes, such as:

(i) Application of organic amendments may bring about changes in physical and chemical properties of soil inimical to nematodes (Ahmad et al., 1972).

(ii) Namato-toxic substances, present in the amendments are released after dissolution in water. Water soluble fractions of oil-seed cakes have been found highly toxic to plant-parasitic nematodes (Khan et al., 1974a; Rao & Prasad, 1969; Sitaramaiah et al., 1974; Alam et al., 1982) and inhibitory to larval hatching of Meloidogyne spp. (Khan et al., 1974b). Some chemicals, e.g., nimbidin, thionimone and azadirachtin from neem have been reported to be highly namaticidal and nematostatic (Khan et al., 1974b; Siddiqui, 1986).

(iii) Toxicants are produced/released during microbial decomposition of organic amendments. Alam et al. (1982) have reported that water
soluble fractions obtained after different periods of decomposition of oil-seed cakes were progressively more nemato-toxic with increase in the time of decomposition. This indicate that the more toxic chemicals are released during the course of decomposition. Eno et al. (1955), Walker et al. (1967), Hasan & Saxena (1974), Khan et al. (1974a), Sitaramaiah & Singh (1978a) and Alam et al. (1977b, c, 1978, 1979) have reported that ammonia, H₂S, fatty-acids, aldehyde, formaldehyde, amino-acids, carbohydrates are released during decomposition of organic matter. These chemicals have been found highly deleterious to plant-parasitic nematodes in vitro studies.

The metabolites of microbes which become active during decomposition of organic amendments have also shown varying degree of toxicity of nematodes. In the present study also, an increase in the frequency of saprophytic fungi has been noted. Culture filtrates of many saprophytic fungi have been found to be highly deleterious to plant-parasitic nematodes as reported by many workers (Alam et al., 1973; Khan et al., 1981; Kirmani et al., 1978).

The water soluble fractions of organic amendments as such, as well as after decomposition and the microbial metabolites thus seem to play an important role in the control of plant-parasitic nematodes. In all the probability, these toxicants, reach the soil pore spaces, which inhabit the nematodes, thus adversely affecting their population build-up (Alam, 1976).

(iv) The organic amendments also increase predaceous and parasitic activity of soil-biota (Linford, 1937; Singh & Singh, 1981).
Van der Laan (1956) had postulated that organic additives might induce some sort of resistance in plants against plant-parasitic nematodes. This was proved by later studies of Alam et al. (1977c, 1980) and Sitaramaiah & Singh (1978b). These workers reported that plants, raised in oil-seed cake amended soil, acquire some resistance against plant-parasitic nematodes. They correlated this phenomenon with the increase in the phenolic level in plant roots and proposed that this increase might have caused due to the absorption of phenolics released from the amendments during the course of decomposition.

Organic additives also release nutrients which accelerate rapid root development and overall plant growth thus helping the plant to escape nematode attack. This theory has been substantiated by the results of experiment, where the organic amendments have improved plant mass several folds (Tables-8a,b; 9a,b; 10a,b; 11a,b; 12a,b; 13a,b; 14a,b; 15a,b; 16a,b; 17a,b).

The various theories put forward to explain the mode of action of organic amendments as discussed above, may well be applicable in the present case where oil-seed cakes have significantly suppressed the population of plant-parasitic nematodes infecting lentil.

The reduction in the frequency of parasitic fungi was also noted in the beds amended with oil-seed cakes (Tables-8a,b; 9a,b; 10a, b; 11a,b; 12a,b; 13a,b; 14a,b; 15a,b; 16a,b; 17a,b). These amendments also supported in growth of saprophytic fungi. Similar results have been obtained by Davey & Papavizas (1959, 1960), Papavizas & Davey (1960), Papavizas (1963) and Khan et al. (1973, 1974a) with
other organic amendments. Addition of various types of organic matters have been found effective in suppressing the population of certain parasitic fungi and have controlled diseases caused by them, e.g., *Phytomatorichum* spp. (Mitchell et al., 1941); *Helminthosporium sativum* (Chinn et al., 1953), *F. solani* f. *phaseoli*, *R. solani* and *Thielaviopsis basicola* (Snyder et al., 1959), *R. solani* (Chinn & Ledinghum, 1957), *F. oxysporum* f. *cubens* (Sequeira, 1962), *F. solani* f. *phaseoli* (Toussoun et al., 1963) and *Corticium sasaki* (Dath, 1982).

Oil-seed cake amendments have also been found effective in suppressing the soil population of pathogenic fungi like *Rhizoctonia solani*, *Colletotrichum* and *Fusarium* spp. in the rhizosphere of egg plant, okra and tomato (Khan et al., 1973, 1974a), *Fusarium udum* on pea (Vasudeva et al., 1962, 1963), *F. oxysporum* f. *ciceri* on gram (Chauhan, 1960), *F. oxysporum* f. *coriander* on coriander (Srivastava & Sinha 1971), *F. udum* on pigeonpea (Singh & Singh, 1981, 1982), *Pythium* spp. on ginger (Sadananadan & Iyer, 1986), *Ganoderma lucidum* on coconut (Gunasekaran et al., 1986).

There may be several reasons for the suppression of parasitic fungi with organic amendments. Khan et al. (1974b) have found water soluble fractions of some oil-seed cakes, viz., neem, castor, mahua, mustard, sesamum, soybean, groundnut, linseed, karanj, duan, and some bitter principles of neem like nimbidin and thionimone inhibitory to the growth of *Rhizoctonia solani*, *Fusarium oxysporum*, *Helminthosporium nodulosum*, *Alternaria tenuis* and *Curvularia tuberculata*. 
Several fatty acids (Sayre et al., 1964, 1965; Patrick et al., 1965; Toussoun et al., 1968), aldehyde and ketones (Khan, 1972), amino-acids, carbohydrates, free-sulphur (Ahmad et al., 1972) are present or released during decomposition of organic amendments. Some of these have been reported to be toxic to pathogenic fungi (Sayre et al., 1965; Sayre, 1980; Khan et al., 1974b). The volatile degradation product of oil-seed cakes/meals also inhibit the population of Fusarium spp. (Zakaria et al., 1980). Fungi static effects due to amendments with degradation products of avocado trees have been reported by Wehner et al. (1982).

The suppressant effects of organic amendments on parasitic fungi may also be due to stimulation of microbial activity and biocontrol agents (Lockwood, 1960; Lloyed & Lockwood, 1966; Singh & Singh, 1981).

Thus it appears that improvement in plant growth of lentil in amended soil was due to reduction in population of plant-parasitic nematodes and frequency of pathogenic fungi (Tables-8a; 9a; 10a; 11a; 12a; 13a; 14a; 15a; 16a; 17a) and also due to their manurial effect (the test oil-seed cakes contain about 5% N). Increased microbial activity in amended soil is known to bring about unceased conversion of N to nitrate form (Schmidt, 1954; Gunner, 1963), which in tern, appears to be responsible for stimulation of nitrate reductase activity as has been shown by the present study. Plants utilize the nitrate form of nitrogen, which however, must be reduced to ammonia before incorporation into the nitrogenous compounds of plant. This reaction is mediated by enzymes, e.g., nitrate reductase. Nitrate reductase a metalloflavo protein is a substrate induced (NO\textsuperscript{3-})
enzyme (Afridi & Hewitt, 1965; Candela et al., 1957; Hageman & Flesher, 1960; Hewitt & Afridi, 1959). The application of oil-seed cakes provide more and more inducing substrate (nitrate) for the enzyme (nitrate reductase) to accelerate its activity, which results ultimately in increased metabolic activity of plants and then plant growth.

**Effect of *Paecilomyces lilacinus***:

*P. lilacinus* was more effective against reniform nematode than the root-rot fungus. Also, it was more effective against monopathogenic infections than against complexes.

It is reported that *P. lilacinus* is capable of parasitising nematode eggs and destroying the embryo. It also grows within the developing females resulting in their death (Jatala et al., 1979). Jatala et al. (1979, 1980, 1981), used *P. lilacinus* in Peru for controlling *M. incognita* and *Globodera pallida* on potatoes, both in the laboratory and under field conditions. They reported that this fungus consisantly and efficiently reduced the populations of both the nematodes resulting in an improved yield. Furthermore, some other species of *Paecilomyces* (e.g. *P. marquandii* and *P. variotii* Barinier) and *Pseudoeurotium ovale* stolk have also been shown to be capable of destroying eggs, Juveniles and adults of several nematode species (Lysek, 1966; Godoy et al., 1983; Anver & Alam 1997).

*P. lilacinus* effectively reduced reniform nematode population by killing females, reducing their fecundity and parasitising egg masses (Tables-8a,b; 9a,b; 10a,b; 11a,b; 12a,b; 13a,b; 14a,b; 15a,b; 16a,b;
Earlier reports that the hatched out juveniles become incapacitated in the presence of fungal hyphae indicate a primary, diffusible toxic effect rendering them subsequently vulnerable to colonization. It has been reported that fungal penetration in the egg-shell takes place by mechanical rupturing of the vitelline layer through a narrow tube-like hyphal extension (Morgan-Jones et al., 1984). It is also possible that partial disintegration of vitelline layer may also be due to exoenzyme production by the fungal hyphae, possibly involving the presence of translocable, physiologically disorganizing factor, such as diffusible toxic metabolites. This disruption not only pre-disposes the egg to fungal infection by physical weakening of the shell, but, also increases permeability, thus facilitating inward passage of fungal metabolites both toxic and enzymatic. This exopathic effect might be enough to abort the reproductive process. Once a fungal hypha enters an egg, enzymatic dissolution of the chitin layer takes place (Okafor, 1967). It has been reported that mycelial proliferation on the nematode body results in probable biosynthesis of destructive metabolites endogenously. Further, endogenous mycelial proliferation might support the lysis of egg-shell material. Later, hyphae penetrate the larval cuticle. This endopathic activity of the fungus causes total degeneration of the egg contents and leads to the ultimate demise of the larvae. Efficacy of *P. lilacinus* on different nematodes parasitising different crops has also been tested with fruitful results (Fatemy, 1998). *P. lilacinus* isolates from silkworm yielded oxalic, dipicolinic and succinic acids and some unidentified amino acids, as well as large amounts of D-mannitol (Domsch et al., 1980). These chemicals might also be
responsible for the killing of nematodes and inhibition of fungal growth. *Paecilomyces variotii* is known to produce cyto-toxic agent and toxic metabolites in some food-stuffs (Domsch *et al*., 1980).

In the present findings, *P. lilacinus* not only reduced the intensity of *R. reniformis* infection, but it also showed antagonistic effect against *R. solani* (Tables-8a,b; 9a,b; 10a,b; 11a,b; 12a,b; 13a,b; 14a,b; 15a,b; 16a,b; 17a,b). Some toxic metabolites and/or enzymes released by *P. lilacinus* might have inhibited the growth of *R. solani*. *Paecilomyces lilacinus* is reported to produce β (1-3) glucanase (Domsch *et al*., 1980) and chitinase (Okafor, 1967) extracellularly which are key enzymes in the lysis of fungal cell walls (Mitchell and Alexander, 1963). *Rhizoctonia solani* belongs to homobasidiomycetes, the walls of which are mostly composed of glucans with only about 6-8% chitin (Bartinickin-Garcia, 1973). It, therefore, seems that β(1-3) glucanase is more important in the degradation of cell walls of *R. solani*. Arai *et al.* (1973) isolated leucostatin and lilacin, two water soluble peptide antibiotics, from a fungus determined as *Penicillium lilacinus* (=*Paecilomyces lilacinus*). Leucostatin is active against gram-positive bacteria and many fungi.

Conclusively, I can say that *P. lilacinus* is a potential bio-control agent which has a number of advantages. *P. lilacinus* is typically a soil-borne fungus and seems to be relatively common and ubiquitous in the tropics and subtropics (Domsch *et al*., 1980). The capability of this species to degrade chitin has been accounted by Okafor (1967) and it is also strongly proteolytic (Janke and Holzer, 1929; Borout, 1960; Endreeva *et al*., 1972). There is sufficient evidence to suggest that *P. lilacinus*, a heavy sporulator, is strong
competitor capable of successfully establishing itself in a natural soil when introduced artificially. *P. lilacinus* has antagonistic activity against bacteria, fungi, and nematodes.

The application of oil-seed cakes with *P. lilacinus* caused significant reduction in nematode population (Zaki & Bhatti, 1990; Rao & Reddy, 1994; Saikia et al., 1999; Chen et al., 2000) on different crops. The neem or mustard seed-cake with *P.lilacinus* controlled *M. incognita* on brinjal (Saikia et al., 1999).

Incorporation of different oil-seed cakes, such as neem, castor, mahua, mustard, sesamum, soybean, groundnut, linseed, karanj, duan with *P. lilacinus* also brought about a decline in the frequency of pathogenic fungi like *R. solani* (Tables-8a,b; 9a,b; 10a,b; 11a,b; 12a,b; 13a,b; 14a,b; 15a,b; 16a,b; 17a,b). The results has been supported by many workers (Walia et al., 1999; Saikia et al. 1999; Chen et al. 2000).

Application of oil-seed cakes and *P. lilacinus* has resulted in improved plant growth of lentil in terms of length, fresh as well as dry weight, pod number and chlorophyll content (Tables-8a,b; 9a,b; 10a,b; 11a,b; 12a,b; 13a,b; 14a,b; 15a,b; 16a,b; 17a,b). These findings are in agreement with those of Rao & Reddy (1994) who has also reported that neem extracts are very useful for carrying biocontrol agent to the root-rhizosphere of egg plant.

**Conclusion:**

As has been observed from the present study, oil-seed cakes (neem, castor, mahua, mustard, sesamum, soybean, groundnut, linseed,
karanj, duan, and antagonistic fungus, *P. lilacinus* have alleviated the plant damage caused by *R. reniformis* and/or *R. solani* to lentil, the neem-seed cake and *P. lilacinus* being significantly effective. The test oil-seed cakes are non-edible and usually used by farmers as manures. But, in fact, they have dual role of being nematicidal in nature and fulfilling nutritional requirements of plants. Besides, these effects have longer persistence in soil making their use more economical (Singh & Sitaramaiah, 1966; Alam et al., 1977a). The *P. lilacinus* on the other hand, have the capability of parasitising the egg masses and killing the females of the nematodes, hence require supplemental nutrition in the form of fertilizers. Taking into consideration these points, oil-seed cakes are cheaper than nematicides (Alam, 1976). Moreover, use of organic additives has been advocated to be safe to the environment and health. Further research may be done to evaluate the efficacy of the organic additives against the interacting pathogens on other crops.

Substantial quantities of the test oil-seed cakes are produced in India. However, it is advisable to farmers that the oil-seed cakes should not be merely used as general manures as per their common practice but should use them selectively against problem nematode-pests damaging economically important crops, including lentil. Thus dependence on nematicides could be minimized.