SUMMARY
6. SUMMARY

6.1 Varietal reaction of chickpea and mungbean to the test nematodes and fungi:

Twenty four cultivars of chickpea (Annigeri, C-375, Chaffa, E-100, EC-1538, F-61, F-404, JG-62, H-355, K-4, Hima, JGC-1, JG-23, JG-24, JG-221, ICC-391WR, BG-225, ICC-3103WR, ANM-123, BG-209, ICC-202WR, BG-220, Pusa-209, K-850) and 8 cultivars of mungbean (K-851, T-44, PDM-11, PDM-54, PDM-84-139, PDM-146, 4/395, ML-137) were screened for their reaction to the root-knot nematode, *Meloidogyne incognita* and the reniform nematode, *Rotylenchulus reniformis* and also to host specific fungi such as wilt-fungus, *Fusarium oxysporum f. ciceri* (on chickpea) and root-rot fungus, *Macrophomina phaseolina* (on mungbean), using different inoculum levels. The resistance/susceptibility reaction was assessed not only on the basis of number of root-galls in case of *M. incognita*, multiplication rate in case of *R. reniformis* and root-rot index in case of *M. phaseolina*, but also on the basis of reduction in different plant growth parameters. In presence of *Rhizobium*, chickpea cultivars F-61, F-404, JG-221 and ANM-123 were found resistant to *R. reniformis* whereas ICC-3103WR and ANM-123 to *M. incognita*, and mungbean cultivars PDM-54 and PDM-84-139 to *M. incognita* and PDM-54 to *R. reniformis* showed resistant reactions. Whereas 3 cultivars of mungbean, viz.,
PDM-146, PDM-84-139 and ML-137 were rated resistant against root-rot fungus. However, none of the chickpea cultivars was found resistant to the wilt-fungus.

In case of chickpea, the wilt-fungus was found to be most damaging while the reniform nematode the least. In case of mungbean, on the other hand, pathogenic potential was observed highest with root-knot nematode and least with root-rot fungus. The inoculum level of the pathogens was found directly correlated to the extent of plant damage in terms of length and weight of plants, percent pollen fertility, pod-number, chlorophyll content, nitrate reductase activity and root-nodulation. Reproduction factor of nematode was found high at low inoculum level but reduction in growth parameters was less at low inoculum level. However, at the higher inoculum level, the reproduction factor decline sharply but plant growth was affected adversely. Number of root-galls caused by *M. incognita* increase as the inoculum level increased (Tables 1a, 2a, 3a, 12a, 13a, 14a).

The reaction of different cultivars of chickpea and mungbean to the test pathogens was also studied in absence of *Rhizobium*. It was revealed that all the test pathogens brought about greater damage to various growth parameters. Moreover, the cultivars found resistant in presence of *Rhizobium*, showed susceptibility in absence of *Rhizobium* to varying extent (Tables 1b, 2b, 3b, 12b, 13b, 14b).
6.2. Interactive effects of the test nematodes and fungi on chickpea and mungbean:

Meloidogyne incognita and Rotylenchulus reniformis with Fusarium oxysporum f. ciceri on chickpea and Macrophomina phaseolina on mungbean singly or in various combinations were found to be highly detrimental to plant growth as measured in terms of plant length, fresh as well as dry weights, pod number, chlorophyll content and root-nodulation. In single pathogenic condition, F. oxysporum f. ciceri caused highest reduction in growth parameters in case of chickpea followed by M. incognita and R. reniformis while in case of mungbean, M. incognita brought about highest reduction followed by R. reniformis and M. phaseolina. In concomitant inoculation, highest reduction in plant growth was observed with M. incognita + F. oxysporum f. ciceri and least with R. reniformis + F. oxysporum f. ciceri on chickpea. In case of mungbean on the other hand, it was maximum with nematode combination than with nematode-fungus combination and minimum being with R. reniformis and M. phaseolina. In sequential inoculations, the plant damage in chickpea was highest when M. incognita preceded the fungus and least when wilt-fungus preceded R. reniformis, whereas in case of mungbean it was maximum when M. incognita preceded R. reniformis and minimum where M. phaseolina preceded R. reniformis (Tables 4a, 15a).
The population of both the test nematodes was adversely affected in all the combinations with fungi in contrast to where nematodes were present alone. It was highest when fungus was introduced prior to the nematode and least in the reverse condition. In the multipathogenic condition, the multiplication rate was affected to the greater extent in case of *R. reniformis* than *M. incognita* on both test crops. *F. oxysporum* f. *ciceri* brought about more reduction in nematode population than *M. phaseolina*. The rate of multiplication of both the nematodes was highest when inoculated individually, more being in *M. incognita*. These nematodes were also found to be inhibitory to each other in concomitant inoculations where *R. reniformis* suffered more than *M. incognita*. This effect was more pronounced when *M. incognita* was inoculated prior to *R. reniformis*. The number of root-galls caused by *M. incognita* was also affected adversely when both the nematodes were inoculated simultaneously or sequentially (Tables 4a, 15a).

Similar experiment was also conducted in absence of *Rhizobium*. Both the test plants, exhibited less growth than in *Rhizobium* treated ones. In inoculated plants, the extent of damage in all the growth parameters was greater in comparison to treated ones (Tables 4b, 15b), however, the pathogenic as well as interactive behaviour of the test pathogens was more or less on the same pattern.
6.3 Effect of the test nematodes and fungi on different growth stages of chickpea and mungbean:

In another experiment, the extent of damage due to root-knot nematode, *M. incognita*, reniform nematode, *R. reniformis*, wilt-fungus, *F. oxysporum f. ciceri* and root-rot fungus, *M. phaseolina* singly or in various combinations were examined (in presence of *Rhizobium*) in terms of plant length, fresh as well as dry weights, chlorophyll content and root-nodulation at different growth stages (vegetative, anthesis, pre-blooming, full-blooming, post-blooming, pod-setting and pod-maturing) as well as number of anthesis buds, flower and pods, percent pollen fertility at the onset or onward reproductive stages of chickpea and mungbean. It was noted that damage was highest at pod-maturing stage and least at vegetative stage. It was also noted that concomitant inoculation with *M. incognita* and *F. oxysporum f. ciceri* on chickpea and *M. incognita* with *M. phaseolina* on mungbean caused more damage than *R. reniformis* in combination with the test fungi. Under single pathogenic condition, the plant damage was found to be maximum with *F. oxysporum f. ciceri* and minimum with *M. phaseolina* on their respective test hosts. The test fungi were also found to be inhibitory to the test nematodes. The highest reduction in nematode multiplication was noted in pod-maturing stages and least in the vegetative stage in combined inoculations with fungi. The number of root-galls were also affected on the above
pattern. As compared to *M. phaseolina*, *F. oxysporum* f. *ciceri* was found to be more detrimental to *M. incognita* and *R. reniformis* (Tables 5a, 6a, 16a, 17a).

Similar experiment was also done in absence of *Rhizobium* which showed an overall reduction in plant growth than in *Rhizobium* - treated ones. In the absence of *Rhizobium* these pathogens in various combinations (singly or concomitantly) caused greater damage to all growth parameters (Tables 5b, 6b, 16b, 17b).

6.4 **Effect of the test nematodes and fungi inoculated at different age of chickpea and mungbean:**

The test nematodes as well as the host specific fungi when inoculated singly or concomitantly at different plant age (2-8 weeks) of chickpea and mungbean, caused maximum damage with respect to plant length, fresh as well as dry weights, percent pollen fertility, pod-number, chlorophyll content and root-nodulation when they were inoculated at an early stage, i.e., after 2 weeks of seed germination and minimum when inoculated at the later phase of plant growth, i.e., after 8 weeks. The nematode multiplication was highest when inoculated along with fungi at plant age of 2-weeks. The nematode multiplication gradually decreased in plants inoculated at higher age. The multiplication of nematodes, when inoculated singly was found lowest in plants inoculated at the age of eight weeks. *Meloidogyne incognita* reproduced
better than that of *R. reniformis* on both the test crops. The number of root-galls also followed the same pattern as noticed in case of nematode population. The highest number of root-galls was recorded in plants inoculated at the age of 2-weeks and least at 8-weeks when introduced singly, but reverse condition was found in concomitant inoculation with fungi (Tables 7a, 8a, 18a, 19a).

In the above experiment, the overall growth was more in plants raised from bacterised seeds than those from non-bacterised seeds. The test pathogens thus caused greater damage in absence of *Rhizobium* (Tables 7b, 8b, 18a, 19a).

6.5 Efficacy of oil-seed cakes/nematicides against the test nematodes and fungi on chickpea and mungbean:

In a pot study, efficacy of some oil-seed cakes (neem, castor, mustard, duán) and nematicides (aldicarb, carbofuran, dimethoate) was assessed against *M. incognita* and *R. reniformis* singly or in combination with *F. oxysporum f. ciceri* on chickpea and *M. phaseolina* on mungbean. Among nematicides, dimethoate was found to be highly efficacious followed by aldicarb and carbofuran in limiting the detrimental effects of the pathogens. While among different organic amendments neem cake gave maximum degree of control of the pathogens followed by castor, mustard and duán cakes. In general oil-seed cakes were found to be equally effective as the nematicides. The different treatments were found to be
more efficacious to *R. reniformis* than *M. incognita*. As a consequence, plant growth parameters such as plant length, fresh weight, percent pollen fertility, pod number, chlorophyll content and root-nodulation improved excepting in case of dimethoate, where some phytotoxicity was observed (Tables 9a, 10a, 20a, 21a). A similar experiment was also done in the absence of *Rhizobium* (unbacterised seeds), here in this case the overall growth of plants was less, both in pathogen inoculated as well as uninoculated plants (Tables 9b, 10b, 20b, 21b).

6.6 Effect of oil-seed cakes/nematicides in combination with ploughing on nematodes and fungi on chickpea:

The efficacy of different oil-seed cakes (neem, castor, mustard, duan) and nematicides (aldicarb, carbofuran, dimethoate) was also evaluated against plant-parasitic nematodes and soil inhibiting fungi under field condition growing chickpea plants as first crop. All the treatments were found to be inhibitory to the populations of plant-parasitic nematodes, viz., *R. reniformis*, *Tylenchorhynchus brassicae*, *Meloidogyne incognita*, *Helicotylenchus indicus*, *Hoplolaimus indicus*, *Hemicriconemoides mangiferae* and *Pratylenchus coffeae* etc. The influence of these treatments were more pronounced in the predominant species, viz., *M. incognita*, *R. reniformis* and *T. brassicae* (Tables 11b). The frequency of pathogenic fungi, viz., *Rhizoctonia solani*, *Fusarium moniliformae*, *Fusarium oxysporum f. ciceri*,
Macrophomina phaseolina, Alternaria alternata, Alternaria tenius, Sclerotium rolfsii, Botrytis cinerea, etc. also declined due to various treatments, however, on the other hand, the frequency of saprophytic fungi, viz., Aspergillus niger, A. flavus, A. flavipes, A. terreus, Cunninghamella echinulata, Cladosporium herbarum, etc. improved in beds treated with oil-seed cakes but slightly decreased in case of nematicide treated beds (Table 11c).

Highest inhibition in population of plant-parasitic nematodes was noted in beds treated with dimethoate followed by aldicarb, carbofuran, neem cake, castor cake, mustard cake and dúán cake. More or less similar pattern was also noted in the reduction of frequency of pathogenic fungi. Frequency of saprophytic fungi increased in beds treated with oil-seed cakes where neem cake gave the best results followed by castor, mustard and dúán cake. However, all nematicides reduced the saprophytic fungi to some extent.

Effect of various treatments on nematodes as well as on fungi was more pronounced in deep ploughed set (40 cm deep ploughing) than normal ploughing (20 cm deep ploughing).

As a consequence of reduction in the population of plant-parasitic nematodes and frequency of parasitic fungi, the plant growth (length as well as fresh weight, percent pollen fertility, pod number, chlorophyll content, nitrate reductase activity and root-nodulation of chickpea improved.
Moreover, there was positive correlation between the improvement in plant growth and reduction in pathogenic nematodes and fungi. Among nematicides, aldicarb was found more beneficial for plant growth followed by carbofuran and dimethoate and among oil-seed cakes, neem cake was found more beneficial for improvement in plant growth followed by castor, mustard and duán cakes (Table 11a).

The effect of different treatments also persisted even after a lapse of six months in the next growing season when mungbean was grown. The population of plant-parasitic nematodes as well as frequency of pathogenic fungi could not increase as freely as in case of untreated beds, consequently improving plant growth characters (Tables 11d, e, f). The multiplication of nematodes generally was below than the initial population of the preceding crop in all the treatments.

6.7 Effect of oil-seed cakes/nematicides in combination with ploughing on nematodes and fungi on mungbean:

The efficacy of different oil-seed cakes (neem, castor, mustard, duán) and nematicides (aldicarb, carbofuran, dimethoate) was also evaluated against plant-parasitic nematodes and soil inhabiting fungi under field condition on mungbean. All the treatments were found to be inhibitory to plant-parasitic nematodes, viz., *Hoplolaimus indicus*, *Helicotylenchus indicus*, *Tylench诺rhynchus bruxsicae*,...
Rotylenchulus reniformis, Meloidogyne incognita, Hemicriconemoides mangiferae, Pratylenchus coffeae, etc. as their populations declined significantly. The influence of these treatments were more pronounced in the predominant species, viz., M. incognita, R. reniformis, T. brassicae, Helicotylenchus indicus (Table 22b). The frequency of pathogenic fungi, e.g., Macrophomina phaseolina, Rhizoctonia solani, Phyllosticta phaseolina, F. oxysporum, Alternaria tenius, Botrytis cinerea, Sclerotium rolfsii, etc. also declined due to various treatments, however, frequency of saprophytic fungi, viz., Aspergillus niger, A. flavus, A. flavipus, A. fumigatus, Rhizopus nigricans, Mucor globosum, Cunninghamamella echinulata etc. improved in the beds treated with oil-seed cakes but slight decrease was noted in case of nematicides treated beds (Table 22c).

Highest inhibition in population of plant-parasitic nematodes was noted in beds treated with dimethoate followed by aldicarb, carbofuran, neem cake, castor cake, mustard cake and duan cake. The reduction in frequency of pathogenic fungi was also found more or less the same. Frequency of saprophytic fungi increased in beds treated with oil-seed cakes and neem cake favoured these fungi to the greatest extent followed by castor, mustard and duan cakes. However, all the nematicides reduced these fungi to some extent.

Effect of various treatments on nematodes as well as on fungi was more pronounced in the deep ploughed set (40 cm
deep ploughing) than normal ploughed one (20 cm deep ploughing).

As a consequence of the reduction in population of plant-parasitic nematodes and frequency of parasitic fungi, the plant growth (length as well as fresh weight, percent pollen fertility, pod number, chlorophyll content, nitrate reductase activity and root-nodulation) of mungbean improved. Moreover, there was positive correlation between the improvement in plant growth and reduction in pathogenic nematodes and fungi. Among nematicides, aldicarb was found to be more beneficial for plant growth followed by carbofuran and dimethoate and among oil-seed cakes, neem cake was found to be more beneficial for improvement in plant growth followed by castor, mustard and duán cakes (Table 22a).

The effect of different treatments also persisted even after a lapse of six months in the next growing season when chickpea was grown. The population of plant parasitic nematodes as well as frequency of pathogenic fungi could not increase as freely as in case of untreated beds, consequently improving plant growth characters. In this crop, the multiplication of nematodes was below the initial population of the preceding crop in all the treatments (Tables 22d, e, f).