EFFECT OF ROOT-KNOT NEMATODE *Meloidogyne incognita* (Kofoid and White) Chitwood AND RENIFORM NEMATODE *Rotylenchulus reniformis* Linford and Oliveira ON COWPEA

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Effect of root-knot nematode *Meloidogyne incognita* (Kofoid and White) Chitwood. and reniform nematode *Rotylenchulus reniformis* Linford and Oliveira on cowpea" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Effect of root-knot nematode *Meloidogyne incognita* (Kofoid and White) Chitwood and reniform nematode *Rotylenchulus reniformis* Linford and Oliveira on cowpea is a record of research work done independently by SMT. N. AMITHA under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

INTRODUCTION

Nematodes "a wonder group among the animal kingdom" pose one of the aggravating pest problems in Agriculture. The presence of host plants in abundance and the conducive climatic conditions of our country have been instrumental in stimulating the development of nematodes after causing heavy crop losses.

Cowpea (*Vigna unguiculata* L. walp) is an ancient crop now grown as a pulse, as a vegetable or for fodder throughout the tropics and subtropics. In India its seed production for human use is probably the greatest (Steele, 1976) and in Kerala this crop covers more than 75 per cent of the area under pulses.

Of the several constraints in the productivity of this crop, pests and diseases have a leading role. Plant parasitic nematodes are invariably found in the soil around the roots of cowpea plants. The important parasitic forms identified are *Meloidogyne* spp., *Heterodera* spp., *Pratylenchus* spp., *Telotylenchus* spp. and *Rotylenchulus reniformis* and they cause heavy loss in yield regularly (Yadav, 1986).

In Kerala root-knot nematode (*Meloidogyne incognita* (Kofoid and White) chitwood) and reniform nematode

(*Rotylenchulus reniformis* (Linford and Oliveira) have gained considerable importance among the phytonematodes as pest of cowpea. Though the pathogenicity and damage potential of these nematodes have been studied by earlier workers on the different crops (Singh 1975; Gaur and Prasad, 1980; Raut and Sethi, 1980; Naganathan, 1984). The information available on pathogenicity of these nematodes to cowpea and on the relative importance of the two nematodes is very meagre.

Hence detailed studies were carried out during 1986-88 for assessing the extent of damage caused by *M. incognita* and *R. reniformis* to cowpea individually and in combination.

Review of Literature

1. REVIEW OF LITERATURE

The root-knot nematode (*Meloidogyne incognita* (Kofoid and White) Chit wood) and reniform nematode (*Rotylenchulus reniformis* Linford and Oliveira) occur in polyspecific communities in the same soil and root samples. The pathogenicity and threshold levels of these nematodes on various crops have been studied. Information on the interaction of these nematodes cohabiting on some hosts are also available. A brief review on these aspects relating to the nematodes is presented below.

1.1 Crop loss caused by the nematodes

1.1.1 *M. incognita*

In solanaceous vegetables like chillies, brinjal and tomato Sen (1958) reported a crop loss of 70 per cent solely due to the attack of root-knot nematode. Chidambaranathan and Rangaswamy (1965) observed considerable reduction in shoot, root and plant weight in these crops. Birat (1968) observed galled roots, marked shortening of tap roots and significant loss in root, shoot and fruit weight in bhindi when inoculated with root-knot nematode.

In a field experiment, Mayol and Bergeson (1970) observed 75 per cent reduction in weight of foliage and 48 per cent reduction in root weight of tomato when inoculated with *M. incognita*. Yield losses upto 85.3 per cent and 39.9 per cent have been reported in tomato plants inoculated with *M. incognita* at the time of planting and flowering respectively (Ducusin and Davide, 1972).

Pathogenicity test made by Castillo and Bulang (1974) in celery seedlings with *Meloidogyne Spp.* showed significant reduction in top weight and root weight with high gall ratings.

Barker *et al.* (1976) reported a yield loss of 50 to 85 per cent in tomato grown in the coastal plains due to the infection of root-knot nematode, whereas in the mountaneous regions of North carolina it was 20 to 30 per cent. Ogunfowora (1977) opined that *M. incognita* caused 10 per cent yield loss in tomato whereas Olthof and Potter (1977) reported that the yield was reduced by 10 per cent and 40 per cent with populations of 6120 and 27,950 larvae of *M. hapla*/kg soil respectively.

Krishnappa *et al.* (1981) found that 44.87 per cent yield loss could be attributed to root-knot nematode alone in a heavily infested field of brinjal.

The yield losses of three cultivars of chilli when inoculated with *M. incognita* were estimated to be ranged from 25 per cent to 31 per cent (Lindsey and Clayshulte, 1982). Naganathan (1984) reported a yield loss of 19.7 per cent and 61 per cent in Capsicum cv. Co-1 and tomato cv. PKM-1 respectively.

1.1.2 *R. reniformis*

According to Verma and Prasad (1969) the percentage reduction in yield of tomato varied from 0.65 to 84.19 per cent in 100 to 10,000 *R. reniformis*/pot.

Gapasin and Valdez (1979) conducted experiments to find out the reaction of sweet potato to *R. reniformis*. They reported 60.6 per cent tuber reduction in plots inoculated with 500 larvae.

1.2 Pathogenicity of the nematodes

1.2.1 *M. incognita*

Symptomatological studies were conducted by Mukherji and Sharma (1973) in *Trichosanthes dioica* infested with

M. incognita. They found that infection in young plants resulted in stunting, occasional chlorosis and reduced stand whereas in older plants the stem was found to be thin, weak and pale coloured. Root system was reduced and knots on the tap root were large and confluent.

Based on a glass house experiment conducted by Reddy (1975) in Cicer arietinum, it was reported that plants inoculated with M. incognita showed reduced growth, drying and shedding of leaves and poor pod formation.

Nadal and Bhatti (1977) opined that an inoculum level of 10,000 M. javanica/plant/pot was strongly pathogenic to brinjal. However Dhawan and Sethi (1978) reported that when brinjal seedlings were inoculated with 10, 100, 1000 or 10,000 larvae of M. incognita/kg of soil, length of shoot and roots as well as shoot weight were significantly reduced with an inoculum of 1000 larvae or more. Root weight was significantly poor at an inoculum of 10 larvae/kg of soil. Highest gall number and nematode multiplication rate were observed with 100 larvae/kg soil.

Gupta (1975) studied the pathogenicity of cowpea cv. HFC-42-1 and found a significant reduction in height and fresh shoot and root weight at 1000 or 10,000 larvae of M. javanica/500 g soil.

According to Nath et al. (1979) increased larval inoculation of M. incognita resulted in proportional decrease in plant girth, flowering, fruiting and bacterial nodulation in bengal gram. Blackening of cortical and vascular tissues below or above the feeding site was observed in some of the plants.

Srivasthava et al. (1979) studied the effect of root-knot nematode M. javanica on the growth of soybean. The results indicated that an inoculum level of 100 larvae/kg of soil significantly reduced the plant growth.

Pathogenicity of M. incognita on soybean was studied by Raut and Sethi (1980). They observed significant reduction in top growth, root length and bacterial nodulation in inoculated plants when compared with the uninoculated plants. Plants exposed to higher levels of nematode (1000 and 10,000 larvae/kg soil) exhibited chlorosis, delay in maturity and shedding of basal leaves.

According to Raut (1980) root-knot nematode adversely affected the growth of mungbean as well as hinder the rhizobial nodulation. Infested plants showed reduction in length and fresh weight of shoot and root.

Gaur and Prasad (1980) investigated the relationship between the population density of M. incognita and damage to egg plant. A population density above 1,000 second stage juveniles/plant hastened maturity of the crop. 4000 juveniles/plant caused about 80 per cent reduction in yield.

Lindsey and Clayshulte (1982) found severe stunting and yield suppression in chilli at all initial densities of M. incognita tested from 385 to 4230 eggs and larvae/500 cm^3 soil.

Seedlings of Phaseolus vulgaris cv. Roxinho inoculated with 10, 100, 1000 or 10,000 eggs of M. javanica showed significant reduction in dry stem weight at inocula at or above 1000 and fresh root weight at 10,000 (Sharma, 1982).

Bistline and Rhoades (1984) inoculated bittergourd seedlings with M. incognita and found that seedlings treated with 10,000 eggs exhibited reduced plant growth and heavy gall formation. Most of the seedlings were morbid and dead in pots infested with 20,000 or more eggs.

Sable and Darekar (1985) reported significant reduction in all growth characters of bittergourd at 500, 1000, 5000 and 10,000 *M. incognita* juveniles/plant.

Thakar *et al.* (1986) studied the effect of different inoculum levels of *M. incognita* on plant height, shoot fresh weight, root fresh weight and root-knot index in Pusa phalguni and V(16). Significant increase in root weight and root-knot index were observed with 10 or more nematodes/ plant in Pusa phalguni whereas in V(16), 1000 nematodes/ plant were required to cause any significant difference.

While studying the pathogenicity of *M. incognita* on betelvine Jagdale *et al.* (1986) observed a significantly lower number of leaves and reduced leaf size in plants inoculated with 10,000 and 50,000 larvae.

1.2.2 *R. reniformis*

Singh (1975) studied the pathogenicity of *R. reniformis* in soybean cv. Jupiter and reported significant reduction in the mean weight of roots and tops as well as in the plant height.

Gapsin and Valdez (1979) studied the reaction of sweet potato to _R. reniformis_. They observed lesions, necrosis and rotting. Tubers were cracked, deformed and smaller in size.

Singh and Khera (1979) studied the pathogenicity of _R. reniformis_ on brinjal var. Purple round. Symptoms like chlorosis, stunted growth, curling of central crown leaves, premature fall of flowers and sparsely developed roots were observed.

According to Gupta and Yadav (1980) _R. reniformis_ caused significant reduction in height as well as fresh shoot and root weight of cowpea. The normal bacterial nodulation on the root was found unaffected.

In a pot experiment, green gram cv. H 70-16 was inoculated with 10, 100, 1000 or 10,000 _R. reniformis_/pot. Plant height, fresh shoot weight, fresh root weight and number of nodules/plant were found to be reduced with increased inoculum density (Gupta and Yadav, 1982).

Sahoo and Padhi (1985) studied the pathogenicity of _R. reniformis_ on okra and reported that there was significant stunting of plant growth at the minimum density of 100 nematodes/pot/l of soil. Higher population densities resulted in reduced length and dry weight of shoot and roots. At 10,000 nematodes/l of soil, the nematode altered the root system by stunting the tap roots and causing a fibrous root system due to over crowding at the initial stage.

Pathogenicity of reniform nematode, *R. reniformis* was investigated by Mishra and Padhi (1985) on french bean. The nematode produced significant pathogenic effect at 1000 nematodes/pot by causing 35.0, 36.9, 54.2 and 35.9 per cent reduction in respect of shoot length, root length, shoot and root dry weight over control.

Mahapatra and Padhi (1986) studied the pathogenicity of *R. reniformis* on Bengalgram and they found that the lowest inoculum level that significantly reduced the plant growth was 500 nematodes/kg soil. With increased inoculum level, the plants showed pathogenic symptoms like yellowing of leaves, stunted growth and brownish discolouration of roots.

1.3 Economic thresholds of the nematodes

1.3.1 *M. incognita*

Ogunfowora (1977) reported drastic reduction in the yield of tomato when inoculated with 20,000 *M. incognita*. He concluded that suitable measures for the control of *M. incognita* should be undertaken if the preplant population in the field is at or above 2000 larvae/l of soil.

Nath *et al.* (1979) reported that an inoculum of 100 *M. incognita* larvae was the damaging threshold in Bengalgram.

In the studies conducted by Raut and Sethi (1980) an initial level of 1000 *M. incognita* larvae or above/kg of soil were found to be the damaging threshold in soybean.

Raut (1980) observed that 1000 larvae of *M. incognita*/500 g of soil was the marginal threshold level for producing measurable effect on the length and fresh weight of shoot in mungbean.

DiVito *et al.* (1981) reported that the tolerance limit of tomato was 4 eggs and juveniles of *M. incognita*/ml of soil.

DiVito *et al.* (1983) suggested a tolerance limit of 3.3 eggs and juveniles of *M. incognita*/ml of soil for tomato variety Roma VF and 0.77 for IAS-1. However Ekanayake and Divito (1984) fixed this tolerance limit as 4 eggs and juveniles of *M. incognita*/ml of soil for cv. UC-105 J and IAS-1. Mani and Sethi (1984) reported a progressive decrease in plant growth of chickpea cv. Pusa 209 with increase in inoculum of *M. incognita*. Two larvae/g was found to be the damaging threshold level.

Sakhuja and Sethi (1986) reported a damaging threshold level of one egg of *M. incognita*/cm^3 in groundnut. DiVito *et al.* (1986) came to the conclusion that a tolerance limit of 0.054 and 0.74 eggs and juveniles of *M. incognita*/cm^3 of soil caused economic damage to chilli and brinjal respectively. Cantosaenz and Brodie (1986) observed that the damage threshold density of *M. incognita* was 5 eggs/g of soil for potato.

1.3.2 *R. reniformis*

Verma and Prasad (1969) found that inoculation with a minimum of 100 nematodes/pot was sufficient to cause appreciable damage in yield of tomato whereas Dasgupta and Seshadri

(1972) observed that an inoculum of 20 R. reniformis/g of soil was the damaging level in cowpea plants.

Gupta and Yadav (1979) reported that there was significant reduction in plant weight, shoot and root weight in the treatments receiving 7000 or more nematodes/500 g of soil. Singh and Khera (1979) concluded that R. reniformis was highly pathogenic to brinjal at inoculum level of 100 or more larvae/plant.

Mishra and Gaur (1981) studied the pathogenicity of R. reniformis to mothbean and reported a significant reduction in growth at the level of one infective individual/cc of soil.

Thakar and Yadav (1985) studied the effect of R. reniformis on pegeon pea and inferred that the damaging levels for susceptible and resistant varieties were 1000 and 10,000/700 g soil respectively. According to Mishra and Padhi (1985) R. reniformis produced significant pathogenic effect on frenchbean at 1000 larvae/pot in respect of shoot and root weight. Sud et al. (1985) inoculated cotton with a logarithemic series of R. reniformis and found a significant growth reduction at 100 nematodes/1000 cc of soil 30 days after inoculation. After 60 days, 10 nematodes/1000 cc of soil caused significant growth reduction. The threshold level for damage (root weight) was 1000 females/1000 cc of soil.

1.4 Combined effect of M. incognita and R. reniformis

Rao and Prasad (1971) conducted experiments to determine the effect of M. javanica and R. reniformis on tomato and found that R. reniformis occuring alone caused greater damage than M. javanica alone or both the species together in equal densities.

Singh (1976) studied interaction of M. incognita and R. reniformis on soybean and reported that the percentage penetration of soybean seedlings by both nematodes were significantly reduced with increasing inoculum levels at 10 as well as 20 days after inoculation. In mixed species infections, significant reduction was noticed at the higher inoculum levels 20 days after inoculation. M. incognita and R. reniformis singly and in combination significantly reduced the top and root dry weight 10 weeks after inoculation. Simultaneous inoculations with M. incognita inhibited the increase of *R. reniformis* whereas the population of *M. incognita* was little affected by the presence of *R. reniformis*.

Kheir and Osman (1977) reported a drastic decrease in the reproduction rate of *M. incognita* in tomato. Its developmental rate and larval root penetration were retarded by the presence of *R. reniformis* which itself appeared unaffected by the proximity of the other nematode.

Pathological reactions of Mungbean to a combination of *R. reniformis* and *M. acrita* and to *M. acrita* alone were studied by Castello *et al.* (1978). According to them apparent difference could be seen in the top growth of non infected and infected plants. However roots of infected plants were necrotic and darkly coloured with leaf chlorosis in early days. Infested plants flowered two days earlier than non-infested plants. The nematode population increased during the experimental period to the tune of 9.7 times in the case of *R. reniformis* and 16.4 times in the case of *M. acrita*.

M. incognita and *R. reniformis* interactions on three sweet potato varieties were studied by Thomas and Clark (1981). *M. incognita* population attained the peak in August and declined in

September, regardless of R. reniformis whereas M. incognita was significantly lower with R. reniformis for both months. R. reniformis with M. incognita was significantly higher in August than R. reniformis alone but in September R. reniformis with M. incognita declined to 2615. While R. reniformis alone increased 3438.

Mishra and Gaur (1981) studied the effect of individual and concomitant inoculation with M. incognita and R. reniformis on growth of Blackgram. They discovered that both the species caused significant growth reduction at the level of one individual/cc of soil. In concomitant inoculations, the extent of growth reduction was relatively less than the individual effects.

Thomas and Clark (1985) reported that simultaneous inoculation of sweet potato with M. incognita and R. reniformis in glass house experiment resulted in reduced reproduction of R. reniformis at all inoculum levels.

Khan et al. (1985) reported that when tomato roots were given single inoculations of M. incognita and R. reniformis populations of both species increased progressively with an increase in the inoculum level. With concomitant inoculations, *R. reniformis* penetration and multiplication were unaffected by the presence of low number of *M. incognita*. When the inoculum level of *M. incognita* increased up to 100 juveniles, multiplication of both the species were affected but penetration was unaffected. With 1000 juveniles of *M. incognita*, multiplication of *R. reniformis* declined at all the inoculum levels however penetration only decreased at the initial inoculum level of 1000. At the same inoculum level, multiplication of *M. incognita* was adversely affected by an inoculum of 100 or 1000 *R. reniformis* but penetration of *M. incognita* only declined when the inoculum level of both nematodes was 1000.

Pathak *et al.* (1985) studied the effect of initial inoculum level of *M. incognita* and *R. reniformis* on pigeonpea and their inter relationship. They reported that a significant plant growth reduction could be attributed to an initial inoculum of 100 juveniles/plant/500 g of soil of either *M. incognita* or *R. reniformis*. In concomitant inoculations, root-knot formation and final population of *M. incognita* was suppressed at all levels in the presence of *R. reniformis*.

Shamim Ahamad *et al.* (1987) reported on the interaction between root-knot and reniform nematode on chilli, Both nematodes were observed to reduce the growth parameters and fruit yield significantly. *M. incognita* was more damaging than *R. reniformis*. Combined inoculations resulted in a greater damage than single inoculations, indicating the synergistic effect. The multiplication rate of *R. reniformis* was reduced in the presence of *M. incognita* especially when two species were inoculated simultaneously but not vice versa.

Materials and Methods

2. MATERIALS AND METHODS

Three series of pot culture experiments were carried out in the College of Agriculture, Vellayani, Trivandrum to study the extent of damage caused by varying population of *M. incognita*, *R. reniformis* and the combinations of these two species.

2.1 Culturing of root-knot nematode, *M. incognita*

Egg masses of *M. incognita* collected (based on perineal pattern) from the roots of coleus plants grown in field were kept in distilled water in petridishes for hatching. One day old larvae were inoculated to cowpea plants raised in denematised soil. Subculturing and multiplication was done periodically to ensure the availability of sufficient larval population for various experiments.

2.2 Culturing of reniform nematode, *R. reniformis*

Pure culture of *R. reniformis* was raised by maintaining cowpea seedlings in earthen pots containing denematised pot mixture. Larvae of *R. reniformis* were collected from the field and inoculated to the seedlings and maintained as pure cultures. Subculturing was done periodically to obtain sufficient number of nematodes for the experiment.

2.3 Raising the crop for the experiments

Cowpea was raised in cement tanks of 1.0x1.0x0.5 m size using pot mixture prepared by mixing field soil, sand and well decomposed farm yard manure in the proportion of 2:1:1 sterilised with 5 per cent formalin.

Seeds of grain type cowpea (Krishnamony) were sown at the rate of two seeds/hole at a spacing of 25 x 15 cm. Later thinning was done to maintain 20 seedlings/tank. The experimental details were as follows.

Design	:	CRD
Replications	:	3
Treatments	:	9

T1 - Check

T2 - 25 larvae/100 ml soil

T3 - 50 larvae/100 ml soil

T4 - 100 larvae/100 ml soil

T5 - 200 larvae/100 ml soil

T6 - 400 larvae/100 ml soil

T7 - 600 larvae/100 ml soil

T8 - 800 larvae/100 ml soil

T9 - 1000 larvae/100 ml soil

2.4 Inoculation of the nematodes

The nematode was inoculated 15 days after sowing. The inoculum was obtained from cultures kept in the greenhouse. Egg masses of root-knot nematode were picked from the roots of infected plants and kept on the tissue papers placed over a piece wire gauze and the latter was placed in petri-dish containing sterile water in such a way that the egg masses were just in contact with water. After 24 hours, the suspension nematodes in the sterile water contained in the petridish was collected and used as the stock inoculum. The average number of larvae/ml of suspension was counted under a binocular stereo microscope using a counting slide. Inoculation of the larvae was done by measuring the required quantity stock suspension of the nematode and pouring the same into 3 to 4 pits of 4 cm depth taken in soil around the plant. The pits were then filled with dry sterile soil. The crop was irrigated periodically in order to maintain the soil moist.

2.5 Observations

1. Height of the plant at 45 and 65 days after inoculation.
2. Girth of the plant at 45 and 65 days after inoculation

3. Number of leaves at 45 and 65 days after inoculation
4. Weight of shoot at last harvest (65 days after inoculation)
5. Weight of root at last harvest (65 days after inoculation)
6. Nematode population in soil at 45 and 65 days after inoculation collecting samples of 100 g soil from each pot
7. Nematode population in root at last harvest
8. Number of pods at each harvest
9. Weight of seeds processed from the pods collected at each harvest.

2.6 Assessment of the combined effect of *M. incognita* and *R. reniformis* on cowpea

The experiment was done in earthen pots of 5 kg capacity using denematised pot mixture. Initially 4 cowpea seeds were sown in a pot. Later thinning was done to maintain two seedlings/pot. The experimental details are as follows.

Design	:	CRD
Replications	:	4
Treatments	:	10

T1 - 0

T2 - 400 *M. incognita* and 400 *R. reniformis*

T3 - 200 *M. incognita* and 200 *R. reniformis*

T4 - 100 *M. incognita* and 100 *R. reniformis*

T5 - 400 *M. incognita* followed by 400 *R. reniformis* 15 days later

T6 - 200 *M. incognita* followed by 200 *R. reniformis* 15 days later

T7 - 100 *M. incognita* followed by 100 *R. reniformis* 15 days later

T8 - 400 *R. reniformis* followed by 400 *M. incognita* 15 days later

T9 - 200 *R. reniformis* followed by 200 *M. incognita* 15 days later

T10 - 100 *R. reniformis* followed by 100 *M. incognita* 15 days later

Observations were same as in the above experiment.

2.7 Estimation of Nematode population in soil

Nematodes were extracted from the soil samples adopting Cobb's decanting and Sieving technique modified by Christie and Perry (1951).

Each soil sample weighing about 100 g was transferred to a plastic basin and mixed thoroughly with 300 ml of water. Coarse particles and foreign materials were allowed to settle. The supernatent liquid was then passed through a sixty mesh sieve. The materials collected in the sieve and the sediments in the basin were discarded. The filtrate was allowed to stand for a few minutes and then decanted and passed through a 200 mesh sieve and then through 350 sieve. The fine silt and nematodes collected in these sieves were washed down and collected in a beaker with minimum quantity of water. The nematodes were extracted from the filtrate by the petridish method. The suspension was poured over a tissue paper placed over a wire gauze kept on petridish containing sterile water in such a way that the suspension was just in contact with water. This was kept undisturbed and at the end of complete recovery, the suspension in the petridish was collected and examined under a binocular microscope and the population was estimated.

2.3 Estimation of nematode population in root

The population of nematodes in the root was estimated by the technique as adopted by Hooper (1970).

2.9 Statistical analysis

The data recorded from the different experiments were subjected to statistical analysis in completely randomised design as reported by Panse and Sukhatme (1978).

Results

3. RESULTS

Pot culture experiments were conducted to study the pathogenecity of root-knot nematode and reniform nematode individually and in combination on cowpea. The results obtained are presented below. Data on the related aspects in the different experiments have been pooled in the tables for comprehensive interpretation of the results.

3.1 Height of the plant

The data on plant height recorded 45 days after inoculation and at the time of last harvest (65 days after inoculation) and the results of analysis of variance of the same are presented in table 1 and 2 and appendix I.

The average height of the plants inoculated with M. incognita larvae at varying levels after 45 days ranged from 72.5 to 94.57 cms while the height of control plant was 96.80 cm. Statistically the data did not show significant variation. The percentage decrease in height when compared to control was highest in plants inoculated with 100 larvae/100 ml soil (25.10). In other treatments it ranged from 2.80% to 16.45% only. The reduction in height did not show a definite relationship with the increasing levels of pest population.

Table 1. Effect of *M. incognita, R. reniformis* and their combinations on the height of cowpea observed at 45 days after inoculation

No. of larvae/ 100 ml soil	Plant height (cm)		% decrease over control	
	M. incognita	*R. reniformis*	*M. incognita*	*R. reniformis*
0	96.80	29.67	-	-
25	94.57	27.00	2.30	8.99
50	83.40	25.67	13.84	13.48
100	72.50	27.67	25.10	6.74
200	80.88	25.00	16.45	15.74
400	85.57	24.00	11.60	19.11
600	91.40	26.33	5.57	11.26
800	91.00	29.33	5.99	11.15
1000	94.03	26.00	2.86	12.37
	N.S	N.S		

	Plant height (cm)	% decrease over control
0	90.50	-
100 M + 100 R	68.50	24.31
100 M followed by 100 R	85.00	6.08
100 R followed by 100 M	85.25	8.01
200 M + 200 R	64.00	29.28
200 M followed by 200 R	81.50	9.94
200 R followed by 200 M	75.00	17.13
400 M + 400 R	51.25	43.37
400 M followed by 400 R	57.25	36.74
400 R followed by 400 M	76.00	16.02
	N.S	

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

Table 2. Effect of M. incognita and R. reniformis and their combinations on the height of cowpea observed at 65 days after inoculation

No. of larvae/ 100 ml soil	Plant height (cm)		% decrease over control	
	M. incognita	R. reniformis	M. incognita	R. reniformis
0	102.00	50.00	-	-
25	94.78	46.33	7.07	7.34
50	90.93	30.33	10.85	39.34
100	86.25	38.33	15.44	23.34
200	79.81	30.33	21.75	39.34
400	83.29	36.00	18.34	28.00
600	86.25	33.33	15.44	33.34
800	86.25	34.67	15.44	30.66
1000	87.34	41.00	14.37	18.00
C.D	N.S	3.46		

	Plant height (cm)	% decrease over control
0	98.25	-
100 M + 100 R	74.25	24.43
100 M followed by 100 R	89.75	8.65
100 R followed by 100 M	92.75	5.59
200 M + 200 R	68.00	30.78
200 M followed by 200 R	69.50	29.26
200 R followed by 200 M	90.00	8.39
400 M + 400 R	52.50	46.56
400 M followed by 400 R	66.00	32.82
400 R followed by 400 M	87.13	11.32
CD	14.07	

M = Meloidogyne incognita R = Rotylenchulus reniformis

The varying levels of *R. reniformis* population inoculated to the plants also did not cause statistically significant variations in plant height. The mean height ranged from 24 to 29.33 cm in treatments while in control the height was 29.67 cm. The maximum percentage reduction in height (19.11) was observed in plants inoculated with 400 larvae/100 ml soil. In other treatments the reduction ranged from 6.74 to 15.74 per cent.

When *M. incognita* and *R. reniformis* were inoculated in combination and in sequence also the data on height of plants did not show significant variations. The plant height in pots inoculated with 400 larvae/100 ml soil of both genera simultaneously was 51.25 cm while in treatments in which 400 larvae of *M. incognita* was inoculated followed by *R. reniformis* (400) the height was 57.25 cm. When the treatments were given in the reverse sequence, the mean height was 76 cm. At the lower level of 200 larvae/treatment also, the simultaneous inoculation of the two nematodes reduced the plant height (64 cm) more than when *M. incognita* was inoculated first (81.5 cm) or after inoculating *R. reniformis* (75 cm). Treatments involving the lowest levels of nematode population also showed that the simultaneous inoculation was more injurious (height 68.5 cm) than sequential inoculation of the nematodes (height 85 and 85.25 cm). The percentage reduction in height ranged from 24.31 to 43.37 in pots in which the nematodes were inoculated simultaneously while in the sequential inoculation the reduction ranged from 6.08 to 17.13 per cent only.

The height of the plant inoculated with *M. incognita* larvae at varying levels observed 65 days after inoculation ranged from 79.81 to 94.78 cm while the mean height of control plant was 102 cm. The percentage decrease in height when compared to control was highest in plants inoculated with 200 larvae/100 ml of soil (21.75). In the other treatments it ranged from 7.07 to 18.34. The reduction in height did not show a definite relationship with the increasing levels of nematodes inoculated. Among the treatments, there was no significant difference in the height of plants. Significant difference in plant height could be seen at 65 days after inoculation with *R. reniformis*. Here, the plants inoculated with 50 and 200 larvae/100 ml soil gave maximum reduction in height (30.33 cm). In remaining treatments the plant height ranged from 33.33 to 46.33 cm. The percentage decrease of height when compared to control was highest in plants inoculated with 50 or 200 larvae/100 ml soil (39.34) and in rest of the treatments it ranged from 7.34 to 33.34.

When the two nematodes were inoculated in combination, a significant difference in height could be seen 65 days after inoculation. The height ranged from 52.50 to 92.75 cm as against 98.25 cm in control plants.

The plant height in pots inoculated with 400 larvae/100 ml soil of both nematodes simultaneously was 52.50, while in treatments in which 400 larvae of *M. incognita* followed by *R. reniformis* were inoculated, the mean height recorded was 66 cm. When the sequence was reversed, the mean plant height was 87.13 cm. At the lower level of 200 larvae/treatment also the simultaneous inoculation of two nematodes reduced the plant height (68 cm) more than when *M. incognita* was inoculated first (69.50) or after inoculating *R. reniformis* (90.00). The lowest level of treatment (100) revealed that combined inoculation was more injurious (74.25 cm) than nematode inoculation in sequence (89.75 and 92.75 cm). The percentage reduction in height in treatments compared to control ranged from 24.43 to

46.56 in pots in which the nematodes were inoculated simultaneously while in sequential inoculation it ranged from 5.59 to 32.82 percent.

3.2 Girth of the plant

As far as the plant girth is concerned, a significant difference was observed in various treatments at 45 and 65 days after inoculation of *M. incognita* (Tables 3 and 4 and Appendix I). The girth of the plants at varying levels of *M. incognita* population ranged from 2.06 to 2.36 cm. The average girth of the control plant was 2.45 cm. The plants inoculated with 600 larvae/100 ml soil gave maximum reduction in girth (2.06 cm) as against 2.45 cm in control plants. This was on par with the girth of plants inoculated with 300, 400, 200 and 100 larvae/100 ml soil (2.15 cm to 2.22 cm). The percentage decrease of girth was highest in plants inoculated with 600 larvae/100 ml soil (15.92). The percentage decrease in the remaining treatments ranged from 3.67 to 12.24.

The varying levels of *R. reniformis* inoculated on plants did not cause any statistical variations in plant girth at 45th day after inoculation. The mean girth of

Table 3. Effect of *M. incognita*, *R. reniformis* and their combinations on the girth of cowpea observed at 45 days after inoculation

No. of larvae/ 100 ml soil	Plant girth (cm)		% decrease over control	
	M. incognita	*R. reniformis*	*M. incognita*	*R. reniformis*
0	2.45	2.36	-	-
25	2.36	2.15	3.67	8.89
50	2.33	2.14	4.89	9.32
100	2.22	2.13	9.39	9.75
200	2.16	2.20	11.84	6.78
400	2.15	2.11	12.24	10.59
600	2.06	2.23	15.92	5.51
800	2.19	2.29	10.37	2.97
1000	2.20	2.25	10.20	4.66
CD	0.20	N.S		

No. of larvae/ 100 ml soil	Plant girth (cm)	% decrease over control
0	2.53	-
100 M + 100 R	2.48	1.98
100 M followed by 100 R	2.45	3.16
100 R followed by 100 M	2.48	1.98
200 M + 200 R	2.28	9.88
200 M followed by 200 R	2.40	5.14
200 R followed by 200 M	2.28	9.88
400 M + 400 R	2.23	11.86
400 M followed by 400 R	2.28	9.88
400 R followed by 400 M	2.20	13.04
CD	0.18	

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

Table 4. Effect of *M. incognita*, *R. reniformis* and their combinations on the girth of cowpea observed at 65 days after inoculation

No. of larvae/ 100 ml soil	Plant girth (cm) *M. incognita*	Plant girth (cm) *R. reniformis*	% decrease over control *M. incognita*	% decrease over control *R. reniformis*
0	2.52	2.45	-	-
25	2.36	2.32	6.35	5.31
50	2.20	2.33	12.69	4.89
100	2.13	2.20	15.48	10.20
200	2.06	2.16	18.25	11.84
400	2.09	2.24	17.06	8.57
600	2.12	2.21	15.87	9.79
800	2.20	2.18	12.69	11.02
1000	2.29	2.29	9.13	6.53
CD	0.14	0.13		

No. of larvae/ 100 ml soil	Plant girth (cm)	% decrease over control
0	2.88	-
100 M + 100 R	2.60	9.72
100 M followed by 100 R	2.60	9.72
100 R followed by 100 M	2.80	2.78
200 M + 200 R	2.53	12.15
200 M followed by 200 R	2.45	14.93
200 R followed by 200 M	2.55	11.45
400 M + 400 R	2.50	13.19
400 M followed by 400 R	2.30	20.14
400 R followed by 400 M	2.53	12.15
CD	0.12	

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

plants inoculated with the nematode ranged from 2.11 to 2.29 cm as against 2.36 cm in control plants. The maximum reduction compared to control was noticed in plants inoculated with 400 larvae/100 ml soil (10.59 per cent).

Inoculation of *M. incognita* and *R. reniformis* in combination resulted in significant variation in the girth of plants. Inoculation of 400 R. reniformis followed by 400 *M. incognita* 15 days later reduced the plant girth to the level of 2.20 cm as against 2.53 cm of control plants. The other treatments at this level of larval population were also on par. At 200 larvae/100 ml soil the simultaneous inoculation and the inoculation of *R. reniformis* followed by *M. incognita* showed the same reduction in girth while the reduction was significantly less in the inoculation of *M. incognita* followed by *R. reniformis*. At the level of 100 larvae/100 ml soil the three combinations did not show statistically significant variation in plant girth. The percentage reduction in girth ranged from 1.98 to 11.86 when nematodes were inoculated simultaneously while in sequential inoculation the reduction ranged from 1.98 to 13.04.

At 65 days after inoculation (Table 4) maximum reduction in girth was observed in plants inoculated with 200 larvae/100 ml soil (2.06 cm). It was on par with the inoculations of 800, 600, 400, 100 and 50 larvae/100 ml soil. The girth ranged from 2.09 to 2.20 cm. The levels of 25 and 1000 larvae were on par. The percentage decrease of girth over control was highest in plants inoculated with 200 larvae/100 ml soil (18.25). In other treatments it ranged from 6.35 to 17.06 per cent.

The effect of R. *reniformis* on plant girth 65 days after inoculation also showed statistically significant variations. Inoculation of 200 larvae/100 ml soil showed the maximum reduction in girth (2.16 cm) as against 2.45 cm in control plant. This was on par with the inoculations of 1000, 800, 600, 400 and 100 nematodes/100 ml soil. The girth of plants inoculated with 50 and 25 larvae/100 ml soil were on par (2.33 and 2.32 cm). The percentage decrease of girth over control ranged from 4.89 to 11.84. It was highest in plants inoculated with 200 larvae/100 ml soil (11.84).

When the two nematodes were inoculated in combination the data showed significant variations. At 400 population level the least girth was recorded in plants inoculated with 400 *M. incognita* followed by 400 *R. reniformis* (2.30 cm). The reverse inoculation reduced the girth to 2.53 cm which was on par with the simultaneous inoculation of the nematodes (2.50 cm). The girth of plants inoculated with 200 *M. incognita* followed by 200 *R. reniformis* was reduced to 2.45 cm. This was on par with the reverse sequence and simultaneous inoculation (2.55 cm and 2.53 cm). Here the combined inoculation and the sequential inoculation were equally injurious to the plants. The percentage reduction in girth in treatments compared to control ranged from 9.72 to 13.19 in pots where the nematodes were inoculated simultaneously while in sequential inoculation the reduction ranged from 2.78 to 20.14 per cent.

3.3 Number of leaves

The data relating to the number of leaves observed 45 and 65 days after inoculation are furnished in tables 5 and 6 respectively. The results of analysis of variance are presented in appendix I.

The number of leaves observed 45 days after inoculation of *M. incognita* at varying levels ranged from 11.68 to

Table 5. Effect of *M. incognita*, *R. reniformis* and their combinations on the number of leaves of cowpea observed at 45 days after inoculation

No. of larvae/ 100 ml soil	No. of leaves *M. incognita*	No. of leaves *R. reniformis*	% decrease over control *M. incognita*	% decrease over control *R. reniformis*
0	17.84	14.33	-	-
25	17.38	11.33	2.58	20.94
50	15.58	10.00	12.67	30.22
100	11.70	8.33	34.42	41.87
200	11.68	8.17	34.53	42.99
400	13.33	7.83	25.28	45.36
600	14.09	8.50	21.02	40.68
800	13.92	9.67	21.97	32.52
1000	13.79	10.00	22.70	30.22
CD	3.58	2.96		

	No. of leaves	% decrease over control
0	25.00	-
100 M + 100 R	21.50	14.00
100 M followed by 100 R	22.75	9.00
100 R followed by 100 M	24.00	4.00
200 M + 200 R	19.75	21.00
200 M followed by 200 R	22.00	12.00
200 R followed by 200 M	21.25	14.00
400 M + 400 R	19.00	24.00
400 M followed by 400 R	18.75	25.00
400 R followed by 400 M	18.50	26.00
CD	N.S	

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

Table 6. Effect of *M. incognita*, *R. reniformis* and their combinations on the number of leaves of cowpea observed at 65 days after inoculation

No. of larvae/ 100 ml soil	No. of leaves		% decrease over control	
	M. incognita	*R. reniformis*	*M. incognita*	*R. reniformis*
0	18.88	15.33	-	-
25	18.05	14.33	4.39	6.52
50	16.22	11.67	14.09	23.87
100	15.54	10.00	17.69	34.77
200	12.38	9.67	34.43	36.92
400	13.88	8.00	26.48	47.81
600	14.30	9.33	24.26	39.14
800	14.88	11.33	21.19	26.09
1000	15.33	13.33	17.74	13.05
CD	2.56	3.89		

0	25.00	-
100 M + 100 R	23.75	5.00
100 M followed by 100 R	24.25	3.00
100 R followed by 100 M	24.25	3.00
200 M + 200 R	22.50	10.00
200 M followed by 200 R	22.25	11.00
200 R followed by 200 M	24.00	4.00
400 M + 400 R	19.50	22.00
400 M followed by 400 R	14.75	41.00
400 R followed by 400 M	22.75	9.00
CD	3.66	

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

17.38 while the number in control was 17.84. The plants inoculated with 200 larvae/100 ml soil produced the lowest number of leaves (11.68). All other treatments with the exception of 25 and 50 larvae/100 ml soil were found to be on par. The percentage decrease of number of leaves when compared to control ranged from 2.58 to 34.42.

The different levels of R. reniformis also showed statistically significant variation in the number of leaves. The effect of R. reniformis observed 45 days after inoculation indicated that 400 larvae/100 ml soil resulted in the lowest number of leaves (7.83). In general the leaf production ranged from 7.83 to 11.33 in different treatments while in control it was 14.33. The maximum percentage decrease over control was observed in plants inoculated with 400 larvae/100 ml soil (45.36). This was found to be on par with all other treatments except 25 larvae/100 ml soil. The percentage reduction over control ranged from 20.94 to 45.36.

When M. incognita and R. reniformis were inoculated in combination and in sequence, the result did not show any statistically significant variations. The number of leaves in pots inoculated with 400 larvae of *R. reniformis* followed by 400 larvae of *M. incognita* was 18.50 and in the treatments with the reverse sequence it was 18.75. In simultaneous inoculation it was 19.0. The treatment effect was not statistically differing from that of control.

The number of leaves observed 65 days after inoculation showed significant variations. The plants inoculated with 200 larvae of *M. incognita*/100 ml soil recorded a significantly low number of leaves (12.38) closely followed by 400 larvae/100 ml soil (13.88). These two treatments were found on par with 600 and 800 larvae/100 ml soil. The percentage reduction ranged from 4.39 to 34.43. There was a steady decrease in the number of leaves up to 200 larvae/100 ml soil followed by a gradual increase (from 12.38 to 15.33).

The levels of *R. reniformis* population inoculated to the plants also showed statistically significant variations in the number of leaves. The results indicated that 400 larvae/100 ml soil resulted in the lowest number of leaves (8.00). This was on par with other treatments except 25 and 1000 larvae/100 ml soil. The percentage reduction ranged from 6.52 to 47.81.

When the two nematodes were inoculated in combination and in sequence there were significant variations in the data. The results showed that the inoculation of 400 *M. incognita* followed by 400 *R. reniformis* produced the lowest number of leaves (14.75). In the reverse sequence of inoculation and simultaneous inoculation, the results were found on par and with lower levels of inoculation the simultaneous inoculation was found less injurious when compared to the sequential inoculation of *M. incognita* and *R. reniformis*. In simultaneous inoculation, the percentage reduction ranged from 5 to 22 whereas in sequential inoculation the reduction ranged from 3 to 41 per cent.

3.4 Shoot weight

The data relating the effect of nematodes on shoot weight of cowpea are presented in table 7 and appendix I. A significant reduction was seen in the shoot weight of plants inoculated with different levels of *M. incognita*. It was minimum in plants inoculated with 600 larvae/100 ml

Table 7. Effect of M. incognita, R. reniformis and their combinations on the shoot weight of cowpea observed at 65 days after inoculation

No. of larvae/ 100 ml soil	Shoot weight (g)		% decrease over control	
	M. incognita	R. reniformis	M. incognita	R. reniformis
0	58.34	16.67	-	-
25	46.82	13.33	19.74	20.04
50	41.26	12.56	29.28	24.66
100	43.50	11.33	25.44	32.03
200	40.18	9.00	31.13	46.01
400	34.71	8.67	40.50	47.99
600	33.36	10.50	42.81	37.01
800	35.94	10.75	38.39	35.51
1000	33.42	13.00	42.72	22.02
CD	4.85	N.S		

0	51.21	
100 M + 100 R	42.25	17.49
100 M followed by 100 R	42.94	16.15
100 R followed by 100 M	46.10	9.98
200 M + 200 R	37.94	25.91
200 M followed by 200 R	35.13	31.40
200 R followed by 200 M	36.69	28.35
400 M + 400 R	34.31	33.00
400 M followed by 400 R	32.69	36.16
400 R followed by 400 M	35.13	31.40
CD	4.02	

M = Meloidogyne incognita R = Rotylenchulus reniformis

soil (33.36 g) which was also on par with the inoculations of 400, 800 and 1000 larvae/100 ml soil. The percentage reduction ranged from 19.74 (25 larvae/100 ml soil) to 42.81. (600 larvae/100 ml soil).

In the case of R. reniformis even though there was a reduction in shoot weight due to the nematode infestation, the variations were not statistically significant. The mean shoot weights ranged from 8.67 to 13.33 g in plants inoculated with varying levels of R. reniformis as against 16.67 g in control plant. The maximum percentage reduction in shoot weight (47.99) over control was observed in plants inoculated with 400 larvae/100 ml soil.

When M. incognita and R. reniformis were inoculated simultaneously and in sequence, a significant reduction was seen in the shoot weight of plants. The results suggested that plants inoculated with 400 M. incognita followed by 400 R. reniformis recorded the lowest shoot weight of 32.69 g. It was on par with simultaneous inoculation of both nematodes and inoculation of R. reniformis followed by M. incognita. At the level of 200 larvae/100 ml soil, sequential inoculation of these two nematodes reduced the shoot weight more than when both nematodes were inoculated simultaneously.

3.5 Root weight

The data on the effect of M. incognita and R. reniformis on root weight of cowpea are presented in table 8 and appendix I and a significant difference was observed in various treatments 65 days after the inoculation of M. incognita. The root weight increased in plants inoculated with M. incognita. The root weight was highest in treatment with 600 larvae/100 ml soil and it was followed by 400 larvae/100 ml soil and weights recorded were 10.66 g and 9.78 g respectively.

The varying levels of R. reniformis did not cause statistically significant variations in root weight. The mean root weights recorded ranged from 2.80 g to 3.48 g while in control the root weight was 3.80 g. The maximum percentage reduction over control in root weight was (26.32) observed in plants inoculated with 800 larvae/100 ml soil.

When these two nematodes were inoculated simultaneously and in sequence a significant variations were noticed

Table 8. Effect of *M. incognita*, *R. reniformis* and their combinations on root weight of cowpea observed at 65 days after inoculation

No. of larvae/ 100 ml soil	Root weight (g) *M. incognita*	Root weight (g) *R. reniformis*	% deviation over control *M. incognita*	% deviation over control *R. reniformis*
0	2.40	3.80	-	-
25	3.56	3.48	48.33	18.42
50	3.61	3.35	50.42	11.84
100	4.39	3.18	82.90	16.32
200	4.22	2.91	75.83	23.42
400	9.78	3.27	307.50	13.95
600	10.66	2.91	344.17	23.42
800	7.22	2.80	200.83	26.32
1000	6.06	3.05	152.50	19.74
CD	1.76	N.S		

	Root weight (g)	% deviation over control
0	4.17	-
100 M + 100 R	3.40	18.47
100 M followed by 100 R	3.60	13.67
100 R followed by 100 M	3.80	8.87
200 M + 200 R	3.31	20.62
200 M followed by 200 R	3.55	14.87
200 R followed by 200 M	3.75	10.07
400 M + 400 R	2.98	28.54
400 M followed by 400 R	3.18	23.74
400 R followed by 400 M	3.38	18.94
CD	0.50	

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

in the weight of root. The weight was minimum (2.98 g) when *M. incognita* and *R. reniformis* were inoculated simultaneously at the rate of 400 larvae/100 ml soil while in treatment in which 400 larvae of *M. incognita* followed by 400 larvae of *R. reniformis* were inoculated the root weight was 3.18 g. This was found on par with the reverse sequence of inoculation. At the level of 200 larvae combined inoculation of the two nematodes reduced the root weight (3.31 g) more than when *M. incognita* was inoculated first (3.55 g) or after inoculating *R. reniformis* (3.75 g). Treatments with the lowest levels of nematodes population (100 larvae/100 ml soil) also showed that simultaneous inoculation was more injurious than inoculating the nematodes in sequence.

3.6 Nematode population in soil

The populations of nematodes in soil examined at 45 and 65 days after inoculation are presented in table 9 and 10 and appendix I. The nematode population in soil 65 days after inoculation is represented in Fig.1. A significant increase in nematode population was seen with the increase in inoculum levels. The average population of *M. incognita* ranged from 17.61 to 196.33/100 ml soil.

Table 9. Effect of *M. incognita*, *R. reniformis* and their combinations on the population density after 45 days of inoculation

No. of larvae/ 100 ml soil	Number of Nematodes observed	
	M. incognita	*R. reniformis*
0	0	0
25	17.61	828.00
50	26.48	845.67
100	32.11	1136.87
200	48.33	881.00
400	104.66	828.00
600	125.78	1772.92
800	161.22	1870.50
1000	196.33	2909.33
CD	8.68	657.22
0	0	0
100 M + 100 R	13.07	63.21
100 M followed by 100 R	17.11	197.15
100 R followed by 100 M	9.00	182.15
200 M + 200 R	19.20	373.00
200 M followed by 200 R	28.01	237.30
200 R followed by 200 M	15.02	225.20
400 M + 400 R	31.00	402.10
400 M followed by 400 R	40.00	917.00
400 R followed by 400 M	25.00	294.00
CD	5.59	74.86

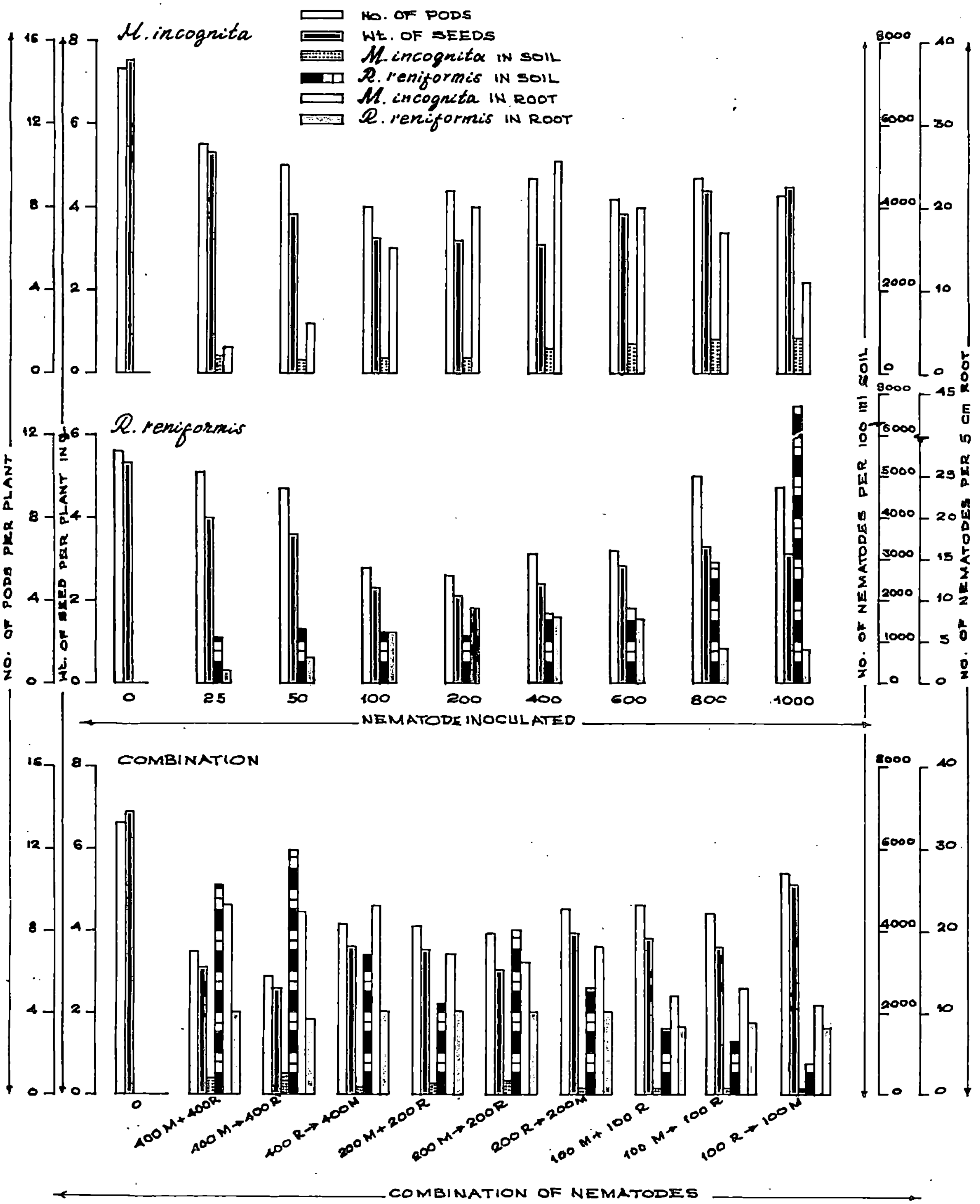
M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

Table 10. Effect of *M. incognita*, *R. reniformis* and their combinations on the population density after 65 days of inoculation

No. of larvae/ 100 ml soil	Number of nematodes observed	
	M. incognita	*R. reniformis*
0	0	0
25	305.00	1139.00
50	298.66	1319.67
100	328.76	1292.00
200	345.67	1161.97
400	556.00	1693.17
600	688.55	1832.20
800	830.11	2879.80
1000	857.55	8721.00
CD	130.54	3115.48
0	0	0
100 M + 100 R	92.22	1656.53
100 M followed by 100 R	96.60	1343.00
100 R followed by 100 M	90.10	792.00
200 M + 200 R	205.00	2214.21
200 M followed by 200 R	336.00	4032.00
200 R followed by 200 M	93.00	2679.05
400 M + 400 R	343.18	5130.00
400 M followed by 400 R	462.00	5907.00
400 R followed by 400 M	132.00	3430.15
CD	16.64	464.54

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

FIG. 1. EFFECT OF *M. incognita*, *R. reniformis* AND THEIR COMBINATIONS ON THE YIELD OF COWPEA AND THE POPULATION DENSITY OF NEMATODES



A maximum population was recorded in pots inoculated with 1000 larvae/100 ml soil (196.33).

The varying levels of R. reniformis population inoculated to the plants also caused significant variations in population build up. The mean population of R. reniformis ranged from 828 to 2909/100 ml soil. The maximum population of 2909 was recorded in pots treated with 1000 larvae/100 ml soil.

When the two nematodes were inoculated in combination and in sequence a significant variation was seen in the population build up. Simultaneous inoculation of the nematodes at 400 larvae/100 ml soil recorded a population of 31 M. incognita and 402 R. reniformis 45 days after inoculation. Maximum population build up was recorded in the inoculation of M. incognita followed by R. reniformis (40 M. incognita and 917 R. reniformis) and in the reverse sequence of R. reniformis followed by M. incognita, the nematode population was 25 M. incognita and 294 R. reniformis/100 ml soil. The same pattern of multiplication was noticed in lower levels also.

Though at 45 days after inoculation *M. incognita* recorded a low population, a progressive increase was observed towards the later stages of the experiment. The results showed statistical variations after 65 days of inoculation. The population of *M. incognita* at different inoculum levels ranged from 298.66 to 857.55. The maximum population was recorded in pots inoculated with 1000 larvae/100 ml soil. The multiplication rate was maximum in pots inoculated with 25 larvae/100 ml soil and minimum in pots inoculated with 1000 larvae/100 ml soil.

In the case of *R. reniformis* also, the maximum population was seen in pots inoculated with 1000 larvae/100 ml soil (8721). Here also the multiplication rate was maximum in pots inoculated with 25 larvae/100 ml soil and minimum in pots inoculated with 1000 larvae/100 ml soil.

When *M. incognita* and *R. reniformis* were inoculated in different combinations, the average population of *M. incognita* ranged from 90.10 to 462.00 and *R. reniformis* ranged from 792.00 to 5907.00. The maximum population of *M. incognita* and *R. reniformis* were recorded in pots inoculated with 400 *M. incognita* followed by 400 *R. reniformis*

15 days later and minimum population of these two nematodes were observed in pots inoculated with 100 *R. reniformis* followed by 100 *M. incognita* 15 days later.

3.7 Nematode population in the root

The population of nematodes in the root observed 65 days after inoculation of nematodes are presented in table 11, Fig.1 and appendix I. The mean population of *M. incognita* in 5 cm root ranged from 3.1 to 25.9 in different treatments. The maximum nematode population of 25.9 was recorded in pots inoculated with 400 larvae/100 ml soil and the minimum in 25 larvae/100 ml soil. The number of nematodes in pots with 1000 larvae/100 ml soil recorded only 11.2 nematodes in 5 cm root. There was a gradual increase in number of nematodes in pots inoculated with 400 larvae/100 ml soil while the treatments having higher levels of nematodes showed lower population in roots.

In *R. reniformis* also significant variation were noticed at different levels of inoculation. Here the maximum mean population of 8.9 was recorded in plants inoculated with 200 larvae/100 ml soil and the minimum 1.5 in plants inoculated with 25 larvae/100 ml soil. Gradual

Table 11. Effect of M. incognita, R. reniformis and their combinations on the population of nematodes in the root

No. of larvae/ 100 ml soil	Number of nematodes observed in 5 cm of root	
	M. incognita	R. reniformis
0	0	0
25	3.1	1.5
50	5.9	2.9
100	15.7	6.7
200	20.1	8.9
400	25.9	8.6
600	19.2	7.9
800	17.21	4.1
1000	11.2	4.0
CD	4.13	0.09
0	0	0
100 M + 100 R	12.7	7.9
100 M followed by 100 R	13.6	8.4
100 R followed by 100 M	11.1	8.1
200 M + 200 R	17.3	9.9
200 M followed by 200 R	16.7	9.8
200 R followed by 200 M	18.2	10
400 M + 400 R	23.2	10
400 M followed by 400 R	22.9	9.6
400 R followed by 400 M	23.7	10.2
CD	0.74	0.652

M = Meloidogyne incognita   R = Rotylenchulus reniformis

increase in the root population was noticed upto the inoculum level of 200 larvae/100 ml soil and at higher levels there was a decrease in root population.

When M. incognita and R. reniformis were inoculated simultaneously and in sequence, significant variation in root population was noticed. In pots inoculated with 400 R. reniformis followed by 400 M. incognita/100 ml soil recorded a maximum root population of 23.7 M. incognita and 10.2 R. reniformis in 5 cm root after 65 days of inoculation. This was on par with reverse sequence of inoculation and also with the simultaneous inoculation of the nematodes at 400 larvae/100 ml soil. The minimum population of the two nematodes was recorded in treatment with 100 R. reniformis followed by 100 M. incognita/100 ml soil (11.1 and 8.1).

3.8 Yield (Number of pods)

The data on yield and the results of analysis of variance of the same are presented in table 12 and appendix I. The number of pods obtained from plants inoculated with M. incognita larvae at varying levels of ranged from 7.94 to 10.87 and the number of pods in control plant was

Table 12. Effect of *M. incognita*, *R. reniformis* and their combinations on the number of pods of cowpea

Number of larvae/ 100 ml soil	Number of pods		% decrease over control	
	M. incognita	*R. reniformis*	*M. incognita*	*R. reniformis*
0	14.67	11.33	-	-
25	10.87	10.33	25.90	8.83
50	10.13	9.50	30.95	16.15
100	7.94	5.67	45.88	49.96
200	8.70	5.33	40.72	52.96
400	9.35	6.33	36.26	44.13
600	8.29	6.50	43.49	42.63
800	9.46	10.00	35.51	11.74
1000	8.70	9.50	40.70	16.15
CD	2.27	1.68		
0	13.25		-	
100 M + 100 R	9.25		30.19	
100 M followed by 100 R	8.75		33.96	
100 R followed by 100 M	11.75		11.32	
200 M + 200 R	8.25		37.74	
200 M followed by 200 R	7.75		41.51	
200 R followed by 200 M	9.00		32.08	
400 M + 400 R	7.00		47.17	
400 M followed by 400 R	5.75		56.60	
400 R followed by 400 M	8.25		37.74	
CD	1.53			

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

14.67. The lowest number of pods was in plants inoculated with 100 *M. incognita* larvae/100 ml soil (7.94). This was found on par with all other treatments except 25 larvae/ 100 ml soil. The percentage decrease in these treatments ranged from 43.49 to 25.90 (Fig.1).

The yield data showed that there was significant decrease in various treatments inoculated with *R. reniformis* also. The lowest number of pods (5.33) was recorded in plants inoculated with 200 *R. reniformis* larvae/100 ml soil. It was on par with inoculation of 100, 400 and 600 larvae/100 ml soil. The mean numbers of pods ranged from 5.33 to 10.33 while in control the number was 11.33.

The yield data also revealed that sequential inoculation of 400 *M. incognita* followed by 400 *R. reniformis* 15 days later resulted in highest reduction in number of pods (5.75). This was also on par with the simultaneous inoculation of the nematodes (7.00). At the level of 200 larvae, the sequential inoculation of *M. incognita* and *R. reniformis* reduced the number of pods (7.75) more than when *R. reniformis* was inoculated first (9.0). These two sequential inoculations were on par with the simultaneous inoculation of *M. incognita* and *R. reniformis*. Treatments involving the lowest level of nematode population (100) also showed that the sequential inoculation was more injurious than simultaneous inoculation. The percentage reduction ranged from 30.19 to 47.17 in simultaneous inoculation whereas in sequential inoculation, the reduction ranged from 11.32 to 56.60 per cent.

3.9 Yield (Seed weight)

The yield data (seed weight) with respect to the individual and combined inoculation are presented in table 13 Fig.1 and appendix I. The data showed statistically significant variations. The yield of the plant inoculated with *M. incognita* larvae at different inoculum levels ranged from 3.13 to 5.29 g while the yield in control plant was 7.57 g. The lowest yield of 3.13 g was recorded in plants inoculated with 400 *M. incognita* larvae/100 ml soil. This was on par with inoculation of 50, 100, 200 and 600 larvae of *M. incognita*/100 ml soil. The percentage decrease ranged from 30.12 to 58.65. The reductions in yield were on par from 25 to 400 larvae/100 ml soil and an increase was noticed in higher inoculum levels.

Table 13. Effect of *M. incognita*, *R. reniformis* and their combinations on the weight of seeds of cowpea

No. of larvae/ 100 ml soil	Weight of seed (g) *M. incognita*	Weight of seed (g) *R. reniformis*	% decrease over control *M. incognita*	% decrease over control *R. reniformis*
0	7.57	5.33	-	-
25	5.29	4.00	30.12	24.95
50	3.81	3.58	49.67	32.83
100	3.25	2.33	57.07	56.29
200	3.19	2.16	57.86	59.47
400	3.13	2.42	58.65	54.60
600	3.81	2.83	49.67	46.90
800	4.39	3.33	42.01	37.52
1000	4.51	3.17	40.42	40.53
CD	0.89	0.73		

No. of larvae/ 100 ml soil	Weight of seed (g)	% decrease over control
0	6.89	-
100 M + 100 R	3.66	46.88
100 M followed by 100 R	3.56	48.33
100 R followed by 100 M	5.10	25.98
200 M + 200 R	3.50	49.20
200 M followed by 200 R	3.05	55.73
200 R followed by 200 M	3.88	43.69
400 M + 400 R	3.06	55.59
400 M followed by 400 R	2.56	62.84
400 R followed by 400 M	3.56	48.33
CD	1.33	

M = *Meloidogyne incognita* R = *Rotylenchulus reniformis*

Regarding *R. reniformis*, 200 larvae/100 ml soil recorded the lowest yield of 2.16 g. This was on par with the inoculation of 100, 400 and 600 larvae of *R. reniformis*/ 100 ml soil. The mean yields ranged from 2.16 g to 4 g as against 5.33 g in control plants. Here also a steady decline in seed weight was recorded from 25 larvae/100 ml soil to 200 larvae/100 ml soil. In other treatments an increase in yield was recorded.

When *M. incognita* and *R. reniformis* were inoculated simultaneously and in sequence, the plants inoculated with 400 *M. incognita* followed by 400 *R. reniformis* showed the maximum reduction in seed weight (2.56 g). This was on par with the reverse sequential inoculation (3.56 g) and the simultaneous inoculation of both nematodes (3.06 g). At lower levels of 200 and 100 larvae/100 ml soil also the simultaneous inoculation was less injurious when compared to the sequential inoculation of *M. incognita* followed by *R. reniformis*.

Discussion

4. DISCUSSION

Root-knot nematode, *M. incognita* and reniform nematode, *R. reniformis* have been recognised as endemic pests of cowpea in Kerala. Detailed information on the pathogenicity of these nematodes and their combined effect are lacking. A detailed study was hence conducted and the results obtained are discussed below.

M. incognita at different levels of population ranging upto 1000 larvae/100 ml of soil did not adversely affect the plant height as observed at 45 and 65 days after inoculation (Para 3.1). In the case of *R. reniformis*, the variation in height observed at 45 days after inoculation did not show significant difference. At 65 days after inoculation there was statistically significant variation in height. Maximum reduction in height was obtained at 50 larvae and 200 larvae/100 ml soil and in treatments above 400 larvae/100 ml soil, the adverse effect on plant height was getting reduced. This agrees with the findings of Gupta and Yadav (1980) who revealed that a significant reduction in the height of cowpea was caused by the incidence of *R. reniformis*.

The simultaneous inoculation of the two nematodes was found to affect the height of the plant more adversely than when the nematodes were inoculated in sequence. The simultaneous inoculation of 400 M. incognita and 400 R. reniformis resulted in the maximum reduction in height.

The girth of the plant (Para 3.2) was significantly affected by M. incognita at different levels ranging from 25 to 1000 larvae/100 ml soil when observed at 45 and 65 days after inoculation. Maximum reduction was obtained at 45 days with 600 larvae/100 ml soil. This was on par with treatments 100 to 1000 larvae/100 ml soil. At 65 days after inoculation maximum reduction was observed in plants inoculated with 200 larvae/100 ml soil. This was on par with treatments at 50 to 800 larvae/100 ml soil. Nath et al. (1979) observed that increased larval population of M. incognita resulted in proportional decrease in plant growth in bengal gram. In the case of R. reniformis significant effect was not observed at 45 days after inoculation, but in later stages a significant difference was noticed. Maximum reduction in girth was observed in plants inoculated with 200 larvae/100 ml soil. This was also on par with 100 to 1000 larvae/100 ml soil.

Combined inoculation of nematodes had a significant influence on the girth of the plants. Sequential inoculation of the nematodes caused more damage to cowpea than simultaneous inoculation, at 45 and 65 days after inoculation. At 45 days after inoculation, sequential inoculation of _R. reniformis_ followed by _M. incognita_ caused more damage while at 65 days after inoculation, the reverse sequence, _M. incognita_ followed by _R. reniformis_ was found more destructive.

Leaf production was also adversely affected by the nematodes (Results presented in Para 3.3.). _M. incognita_ caused the maximum reduction at the inoculum level of 200 larvae/100 ml soil and this was on par with 100 to 1000 larvae/100 ml soil. After 65 days of inoculation, again maximum reduction in leaf production was seen in treatments inoculated with 200 larvae/100 ml soil. Raut _et al._ (1980) observed shedding of basal leaves of soybean at inoculum levels of 1000 to 10,000 larvae of _M. incognita_/kg of soil. Jagdale _et al._ (1986) observed a significantly lower number of leaves and reduced leaf size in betelvine inoculated with 10,000 and 50,000 larvae of _M. incognita_. In the case of _R. reniformis_, significant effect was noticed 45 and 65 days after inoculation and maximum reduction was observed at 400 larvae/100 ml soil. The treatments ranging from 50 to 1000 and 50 to 800 larvae/100 ml soil were found to be on par with 400 larvae/100 ml soil at 45 and 65 days respectively. Adverse effects of the nematode on leaf production of crops had been reported by many workers. (Singh et al., 1979, Mahapatra and Padhi, 1986).

In combined inoculation (both the simultaneous and sequential inoculation) had no significant effect at 45 days after inoculation. At 65 days after inoculation, M. incognita followed by R. reniformis sequence proved more injurious when compared to the reverse sequence and simultaneous inoculation.

The injury caused by the nematode on cowpea plant and their consequent reflection on shoot and root weight was highlighted in the present study (Para 3.4.). M. incognita caused a significant reduction in shoot weight and the maximum reduction was observed in plants inoculated with 600 larvae/100 ml soil. This was on par with the inoculation levels of 400, 800 and 1000 larvae/100 ml soil. The results observed in the present study agreed with the findings of many workers (Acosta and Ayala, 1975., Castillo et al., 1978 and Sakhuja and Sethi, 1986). R. reniformis did not have any significant influence on the weight of shoot. But significant reduction of shoot weight had been reported by earlier workers (Gupta and Yadav, 1979 and 1980).

The sequential inoculation of the nematodes, especially M. incognita followed by R. reniformis, was found to gave the highest reduction in shoot weight. Similar reduction in shoot weight was noticed by Singh (1976) in soybean infected by M. incognita and R. reniformis.

The root weight of cowpea (Para 3.5.) infected by M. incognita showed a significant increase. The formation of secondary galls must have caused this increase in weight. Johnson and Nusbaun (1970) and Jiji (1986) also recorded similar increases in the root weight of tobacco and brinjal respectively. Agreeing with the findings of various scientists (Gupta and Yadav, 1980; Singh, 1975) roots of cowpea inoculated with different levels of R. reniformis showed a decrease in weight though not significant.

In the combined inoculation simultaneous inoculation of the two nematodes caused more injury to the roots of cowpea than the sequential inoculation.

The recovery of the nematode *M. incognita* and *R. reniformis* from the soil inoculated with different levels of inoculum at 45 and 65 days after inoculation are presented in Para 3.6. Though the recovery of both the nematodes were low at 45^{th} day after inoculation, there was significant increase in the population towards the later stages indicating their successful survival and multiplication in the pots. A striking feature observed in the experiment was that the multiplication rate of the nematodes was high in treatments given low initial inoculum levels when compared to the higher levels of inoculation. Probably the competition for space and food at higher inoculum levels did not favour successful establishment of the nematodes while at lower inoculum levels the nematodes could establish better and attain reproductive stability. DiVito *et al*. (1983) observed a similar trend in the case of *M. incognita*.

In the combined inoculations, *R. reniformis* seems to have exerted an adverse effect on root-knot nematode. The multiplication rate of *M. incognita* was inhibited in the proximity of *R. reniformis*. Both nematodes thrived well when *M. incognita* was inoculated prior to *R. reniformis*.

Regarding the interaction of the two nematodes, sequential inoculation of *M. incognita* followed by *R. reniformis* increased the population of *R. reniformis*. Inoculation in the reverse sequence suppressed the increase of *R. reniformis*. The results obtained contradicts the findings of Taha and Kassab (1979) that a suppression of reniform nematode was caused by root knot nematode infestation in cowpea.

Nematode population in the root samples (Para 3.7.) increased upto the inoculum level of 400 larvae/100 ml soil in the case of *M. incognita*. Thereafter the root population showed a decreasing trend. This might be due to the intraspecific competition of the nematode which is an active endoparasite. Nadal and Bhatti (1977) had recorded the highest gall number and nematode multiplication rate at 100 larvae/kg soil. Regarding *R. reniformis*, 200 larvae/100 ml soil was found critical. Below and above that level the root population got reduced.

In the combined inoculation, reniform nematode dominated the root-knot nematode in number within the roots, thus indicating a competition between the two species in getting established inside the host tissue. Inoculation of

R. reniformis followed by M. incognita recorded a higher number of both the nematodes than when they were inoculated simultaneously. Pathak et al. (1985) reported reduced root-knot formation in the presence of R. reniformis.

The adverse effects of the nematode on the growth attributes took their toll on the yield of cowpea also (Vide para 3.8.). Initial inoculum levels of 100, 200, 400 and 600 larvae of M. incognita resulted in conspicuous decrease in yield in terms of number of pods and seed weight. The maximum loss in number of pods was observed at 100 larvae/100 ml soil and in seed weight at 400 larvae/100 ml soil. The deleterious effect of M. incognita on the yield of different vegetables like tomato, okra, brinjal, frenchbean and peas have been brought out by various scientists (Batty and Jain 1977, Krishnappa et al., 1981., Reddy, 1985). R. reniformis also caused appreciable damage in yield at the inoculum levels of 100, 200, 400 and 600 larvae/100 ml soil. An inoculum level of 200 larvae/100 ml soil proved to be the critical level both in terms of number of pods and seed weight. Pathogenic capability of the reniform nematode have been established in several vegetables (Varma and Prasad, 1969., Gapasin and Valdez, 1979, Singh and Khera 1979).

Combined inoculation of the nematode indicated that in terms of both number of pods and weight of seed, inoculation of *M. incognita* followed by *R. reniformis* was more injurious than the inoculation done simultaneously!

An overall appraisal of the data indicated the deblitating effect of the two nematodes, *M. incognita* and *R. reniformis* in cowpea. Initial inoculum levels of 100, 200, 400 and 600 larvae/100 ml soil of these nematodes exerted severe damaging influence on cowpea. The higher inoculum levels of 800 and 1000 larvae/100 ml soil did not show a progressive increase in crop loss probably due to the competition of nematodes for space and food especially since these nematodes are known to prefer specific feeding sites.

It is also seen from the results that the threshold levels of the nematodes will fall within the range of 100 to 600 larvae/100 ml of soil. The damaging threshold level of *M. incognita* and *R. reniformis* had been worked out by various scientists. Das Gupta and Seshadri (1972) observed that an inoculum level of 20 larvae of *R. reniformis*/g of soil was the damaging level on cowpea. Raut (1980) reported that 1000 larvae of *M. incognita*/500 g of soil was the marginal threshold level in mungbean. Cowpea appears to be more sensitive to *M. incognita*.

A complement of nematodes are generally seen in the rhizosphere of plants. The symptoms manifested in the plants are usually the outcome of their combined effect.

It was observed in the present experiment on the combined effect of *M. incognita* and *R. reniformis* that an inoculum level of 400 *M. incognita*, followed by 400 *R. reniformis* 15 days later exerted a highly deleterious effect on cowpea. Simultaneous inoculation of 400 *M. incognita* and 400 *R. reniformis* did not lag for behind in its deblitating effect. Both the plant characters and yield parameters were equally affected by these inoculum levels. Generally the symptoms manifested in nematode ravaged plants are the outcome of histopathological disorders produced in the plants by the feeding nematodes. *M. incognita* is accepted as a phloem feeder while *R. reniformis* is found to prefer the pericycle region of cowpea as its feeding site (Rasak and Evans, 1976). As indicated by the results obtained in the present experiment, these feeding activities of the nematode ultimately resulted in the disruption of the normal function of the root ie. nutrient and water uptake and translocation leading to unthriftness of the plant. Pathological reaction of different crops to a combination of root-knot and reniform nematode have been studied by several workers. (Kheir and Osman, 1977., Pathak *et al*., 1985, Shamim Ahamed *et al*., 1987). Considering the nematode population, reniform nematode dominated the root-knot nematode in combined inoculation. Similar results have been reported by Rao and Prasad (1971) and Pathak *et al*. (1985).

Despite the importance of *M. incognita* and *R. reniformis* as serious pests of cowpea, no accurate data are available on the enormity of crop losses due to them. The present investigation was an attempt to determine the damaging population levels of each nematode and the extent of crop loss at this critical level. The results indicated that the damaging population level fall in the range of 100-600 larvae/100 ml soil. The tentative effort made to study the interactive effect of the endoparasite *M. incognita* and semi endoparasite *R. reniformis* revealed a competitive interaction, with the time of inoculation and inoculum levels checking the domination of the nematodes.

Summary

SUMMARY

A series of pot culture experiments were conducted for assessing the extent of damage caused by *M. incognita* and *R. reniformis* to cowpea individually and in combination. The results obtained have been summarised below.

M. incognita and *R. reniformis* were inoculated on potted plants at population levels ranging from 0 to 1000 larvae/100 ml soil. The plant height was not affected by the treatments at 45 days after inoculation. Inoculation of 200 larvae of *R. reniformis*/100 ml soil checked the plant height significantly after 65 days of inoculation. Though *M. incognita* did not produce any significant effect individually, combination of 400 *M. incognita* and 400 *R. reniformis*/100 ml soil caused deleterious effect. Simultaneous inoculation caused more damage than sequential inoculation.

Significant difference was observed in plant girth even after 45 days of inoculation of *M. incognita* alone and in combination with *R. reniformis*. Sequential inoculation of 400 *M. incognita* followed by 400 *R. reniformis*/100 ml soil recorded significantly maximum reduction in plant girth compared to all other combinations 65 days after inoculation.

Both the nematodes affected the number of leaves at 45 and 65 days after inoculation. In concomitant inoculation, significant reduction was observed at 65 days after inoculation and it was maximum in the sequential inoculation of 400 M. *incognita* followed by 400 R. *reniformis*/100 ml soil.

Inoculation of M. *incognita* at and above 400 larvae/100 ml soil produced more deleterious effect on shoot weight of cowpea. The sequential inoculation of M. *incognita* followed by R. *reniformis* produced significantly more reduction in shoot weight, irrespective of the level of inoculum.

M. *incognita* produced significant increase in root weight whereas a non significant and marginal reduction was noticed in R. *reniformis*. The simultaneous inoculation of the two nematodes gave more significant reduction than the sequential inoculation.

Multiplication rate of both nematodes in the soil were found higher in the lower inoculum levels than in the higher inoculum levels. R. *reniformis* dominated M. *incognita* in multiplication throughout the course of experiment.

The studies revealed that 400 larvae/100 ml soil were found to be critical in *M. incognita* as well as in *R. reniformis*, below or above to this level the root population was found reduced. In concomitant inoculation, reniform nematode had an adverse effect on the multiplication of root-knot nematode and at the same time its multiplication rate was slightly increased compared to their individual effect.

In the case of number of pods, individual inoculation levels between 100 and 600 were found critical. In concomitant experiment, the sequential inoculation of *M. incognita* followed by *R. reniformis* caused more significant reduction.

Both the nematodes reduced the yield of cowpea in terms of seed weight equally. However, the levels from 100 to 600 were found more critical than others. In the combined inoculation, the yield reduction was very conspicuous in all the levels except the sequential inoculation of 100 *R. reniformis* followed by 100 *M. incognita*/100 ml soil.

Plants inoculated with 100 to 600 larvae/100 ml of soil showed maximum damage. So it can be assumed that the threshold level of the two nematodes may lie in between 100 and 600/100 ml soil.

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*Original not seen

Appendix

Appendix I

Analysis of variance of different characters

1. Effect of *M. incognita* on cowpea

(a) 45 days after inoculation

Characters	Mean squares	
	Treatment	Error
1. Plant height	185.62	195.57
2. Plant girth	0.045	0.014*
3. Number of leaves	14.466	4.371*
4. Population density in soil	14834.79	25.631**

(b) 65 days after inoculation

Characters	Treatment	Error
1. Plant height	124.207	51.990
2. Plant girth	0.067	0.006**
3. Number of leaves	12.342	2.234**
4. Shoot weight	196.912	7.991**
5. Root weight	25.283	1.063**
6. Population density in soil	242955.54	5790.34**
7. Population in root	227.3	5.82**
8. Number of pods	12.551	1.759**
9. Weight of seeds	5.946	0.268**

II. Effect of *R. reniformis* on cowpea

(a) 45 days after inoculation

1. Plant height	10.731	8.296
2. Plant girth	0.021	0.008
3. Number of leaves	12.520	2.990**
4. Population density in soil	2114816	146780**

(b) 65 days after inoculation

1. Plant height	149.648	4.074**
2. Plant girth	0.026	0.006**
3. Number of leaves	18.250	5.148*
4. Shoot weight	18.825	13.594
5. Root weight	0.307	0.154
6. Population density in soil	19505030	3298301**
7. Population density in root	31.195	0.07**
8. Number of pods	15.729	0.963**
9. Weight of seeds	2.965	0.185**

III. Combined effect of *M. incognita* and *R. reniformis* on cowpea

(a) 45 days after inoculation

1. Plant height	649.960	648.900
2. Plant girth	0.078	0.017**
3. Number of leaves	20.270	20.767

4.	Population of *R. reniformis* in soil	214478	2688.4**
5.	Population of *M. incognita* in soil	357.126	14.99**
	(b) 65 days after inoculation		
1.	Plant height	993.400	95.000**
2.	Plant girth	0.108	0.008**
3.	Number of leaves	37.770	6.420**
4.	Population of *R. reniformis* in soil	10835000	103506.33**
5.	Population of *M. incognita* in soil	70179.77	132.89**
6.	Population of *R. reniformis* in root	37.73	0.204**
7.	Population of *M. incognita* in root	205.75	0.2636**
8.	Shoot weight	145.240	10.000**
9.	Root weight	0.468	0.124**
10.	Number of pods	19.00	1.130**
11.	Weight of seeds	6.251	0.860**

EFFECT OF ROOT-KNOT NEMATODE *Meloidogyne incognita* (Kofoid and White) Chitwood AND RENIFORM NEMATODE *Rotylenchulus reniformis* Linford and Oliveira ON COWPEA

By

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ABSTRACT OF A THESIS

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ABSTRACT

Three pot culture experiments were laid out with the objectives (i) to study the effect of *M. incognita* on cowpea, (ii) to study the effect of *R. reniformis* on cowpea and (iii) to study their combined effect. The individual effects were assessed with nine population levels ranging from 0-1000 larvae/100 ml soil each replicated thrice. In the combined experiment three population levels, 100, 200 and 400 and their three combinations were tried each replicated four times.

The results indicated that at initial inoculum levels of 100, 200, 400 and 600 larvae/100 ml of soil of the two nematodes, *M. incognita* and *R. reniformis* exerted severe damaging influence on cowpea. The higher inoculum levels of 800 and 1000 larvae/100 ml soil did not show a progressive increase in crop loss. It is evident that the threshold levels of the nematodes will fall within the range of 100 to 600 larvae/100 ml soil.

In the combined inoculation of the nematodes, an inoculum level of 400 M. incognita followed by 400 *R. reniformis*/100 ml soil 15 days later exerted a highly deleterious

effect on cowpea. Simultaneous inoculation did not lag for behind in its debilitating effect.

Considering the nematode population in soil, multiplication rate of both nematodes were found higher in lower inoculum levels than in the higher inoculum levels. In the combined inoculation, reniform nematode dominated root-knot nematode. Reniform nematode had an adverse effect on the multiplication of root-knot nematode. Both nematodes thrived well when _M. incognita_ was inoculated prior to _R. reniformis_.