PATHOGENICITY OF BURROWING NEMATODE, *RADOPHOLUS SIMILIS*, (COBB 1893) THORNE, 1949 ON BANANA

By

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THESIS

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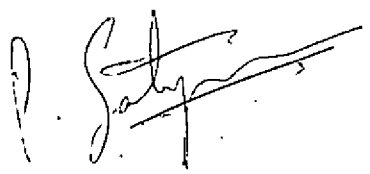
VELLAYANI, TRIVANDRUM

1982

DECLARATION

I hereby declare that this thesis entitled "Pathogenicity of burrowing nematode, Radopholus similis (Cobb 1893) Thorne 1949, on banana" 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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Vellayani,
15th September 1982.

CERTIFICATE

Certified that this thesis, entitled "Pathogenicity of burrowing nematode, Radopholus similis (Cobb 1893) Thorne 1949, on banana" is a record of research work done independently by Sri. P. Satyanarayana under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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I take this opportunity to express my thanks to Dr. P.K. Koshy, Dr. V.K. Sosamma and Dr. P. Sundara Raju, Nematology division of C.P.C.R.I., Kayamkulam, for helping me in learning the tissue culture method of nematodes.

I am grateful to my friends for their co-operation throughout the course of this study.

Finally, I express my thanks to the Kerala Agricultural University for the award of fellowship to me. I am very thankful to my parents and members of my family for their co-operation.

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INTRODUCTION

INTRODUCTION

Banana (Musa paradisiaca L.) is grown in large scale in most of the tropical countries for its valuable fruits. In India the crop is grown extensively in the states of Kerala, Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra and Orissa. In Kerala the crop is grown in an area of over 53,000 ha. with a total production of 1.7 lakh tonnes per annum.

Banana crop is attacked by several diseases and pests which substantially limit its production. Among the pests, nematodes have recently been observed to constitute a major threat to the banana production in Kerala State. The important parasitic nematodes associated with banana include, the burrowing nematode, Radopholus similis, spiral nematode, Helicotylenchus sp., root knot nematode, Meloidogyne incognita, root-lesion nematode, Pratylenchus sp., and reniform nematode, Rotylenchulus sp.

Burrowing nematode, Radopholus similis was reported on banana for the first time in 1966 by Nair et al. These nematodes cause damage, variously

referred to as root rot, blackhead disease and toppling disease. Though the occurrence of Radopholus similis was reported in 1966, investigation on this nematode on banana was not done in the state. Therefore, the extent of damage done by this nematode on banana was studied in the present investigation.

REVIEW OF LITERATURE

1. REVIEW OF LITERATURE

1.1 Distribution and diseases caused.

While investigating a disease of banana in Fiji, Cobb (1893) found a new nematode and named it as Tylenchus similis. Later Thorne (1949) renamed it as Radopholus similis and it was confirmed by Sher in 1968. He considered Radopholus similis to be indegenous to Australia and New Zealand.

It was distributed throughout the world and it was reported on pepper from Bangka islands, Indonesia (Vandervecht, 1950), from Florida on citrus (Suit and DuCharme, 1953) where it was considered as a threat spreading over 8000 acres (Birchfield, 1957). It was also reported on banana from Honduras (Stover and Fielding, 1958) from New South Wales, Australia (Blake, 1961 b), in the soils of Puerto Rico (Ayala and Roman, 1963), in Europe (Scotto La massesse, 1967) and from Srilanka on tea (Sivapalan, 1967). They were subsequently reported from many countries like, Belgium (Heugens, 1968), Mexico (Toboada and Cabellero, 1968) Rhodesia (Anon. 1969), Germany (Sturhan, 1970), Ghana (Addoh, 1971), New Guinea (Fisher et al. 1971), Costa Rica, (Tarjan, 1971), Tanzania (Ngundo and Taylor, 1973), and in Zambia (Raemackers and Patel, 1973).

O'Bannon (1977) cited that Radopholus similis was distributed throughout the world except in Israel (Minz et al. 1970) and Taiwan (Hung, 1977).

Radopholus similis was first reported in India on banana by Nair et al. (1966) and later on coconut, (Weischer, 1967; Mathen et al. 1970), arecanut (Kumar et al. 1971) turmeric and ginger (Koshy, Sosamma and Nair 1975) in Kerala.

It was found to attack banana and sugarcane (Cobb, 1893 and 1915). They cause 'pepper yellows' disease on pepper (Vanader Vecht, 1950). The 'spreading decline' disease on citrus in Florida, though known since 1928, was attributed to Radopholus similis in 1953 (Suit and Ducharme, 1953). Radopholus similis caused 'Black head toppling disease' on banana (Leach, 1958) and this disease was called by different names in different countries as 'Radopholus root rot', 'Black head', 'toppling disease' and 'decline' (Blake, 1961 b). It was also known to cause the diseases on grape fruit (Feder and Feldmesser, 1956), cardamom (D'Souza, and Kumar, 1969) and 'yellow leaf disease' on arecanut (Koshy et al. 1976).

1.2 Symptoms.

1.2.1 Above ground: In general the infested plant did not reveal any distinctive symptom of Radopholus similis attack, on

the aerial parts (Taylor, 1969). However, the Radopholus similis affected plants did not grow to its full extent and were stunted. (Suit and Du Charme, 1953; Feder and Feldmesser, 1956; Senanayaka, 1969; Decker et al. 1970; Vilsoni et al. 1976; Sundara Raju et al. 1979). Banana plants showed unthriftiness and poor anchorage (Blake, 1961 b). Premature flowering and fruiting together with general stunted appearance of young tea plants was observed (Sivapalan, 1968). Sickly appearance, production of small leaves, premature shooting of a weak banana bunch and abundant production of water suckers was observed (Fisher et al. 1971).

Plants produced fewer and smaller leaves in Radopholus similis affected citrus gardens (Suit and Du Charme, 1953). Chlorosis was observed on the leaves of affected grape fruit plants (Feder and Feldmesser, 1956). Occasionally Radopholus similis attacks leaf bases near the soil line on banana (Wehunt and Edwards, 1968). Reduction in size and number of leaves was observed by Blake, (1972). In the case of pepper, leaves turned pale yellow or whitish and hanging, and yellow leaves always curl inwards and drop (Vander Vecht, 1950; Ichinohe, 1976; Venkatesan, 1977). Top leaves withered and scorched in the case of ginger (Vilsoni et al. 1976). Scale leaves of turmeric harboured Radopholus similis (Sosamma, et al. 1979).

Collapse of the adult banana plants at the time of fruit formation was noticed (Blake, 1961 a; Decker et al. 1970; Fisher et al. 1971).

1.2.2 Below ground symptoms: The attack of Radopholus similis resulted in striking reddish brown lesions on roots (Cobb, 1915; Feder and Feldmesser, 1956; George and Martin, 1969), which often coalesced and girdled the roots (Loos, 1959, Loos and Loos 1960b; Fisher et al. 1971; Koshy et al. 1975; Venkatesan, 1977; Sundara Raju et al. 1979). Some times the lesions extend more than two and half to four inches (Loos and Loos, 1960 b) and rhizomes were also affected (Nair et al. 1966; Sosamma et al. 1979; Sundara Raju et al. 1979), due to which the length and number of roots were greatly reduced, side roots were few or absent and the lesioned roots lost their white or colourless appearance and gradually turned purplish black (Feder and Feldmesser, 1956; Loos, 1959; Loos and Loos 1960 b; Blake, 1961 a and b; Nair et al. 1966; Senanayaka, 1969; Tomerlin and O'Bannon, 1974; Koshy et al. 1975). Longitudinal cracks were noticed on the surface of the older roots (Loos and Loos, 1960 b; Blake, 1961 a; Blake, 1966).

1.3 Pathogenicity.

The pathogenicity tests, conducted on citrus showed, stunted growth with small leaves, thin foliage with dried

twigs and small fruits with extensive root destruction (Suit and DuCharme, 1953). Birchfield (1957) described the symptoms and identified Radopholus similis as a threat to citrus industry in Florida. Pathogenicity of Radopholus similis was proved on banana in the presence of Fusarium oxysporum f. Cubense(Loos (1959) and on pepper in the presence of Fusarium oxysporum (Sheela, 1978). Blake (1961 b) showed the effect of Radopholus similis on banana, he found all typical symptoms produced by the nematode, and the destruction of the plants due to its attack was observed. O'Bannon et al. (1971) found its pathogenicity on six peanut varieties. The results of inoculation experiments indicated potentiality of Radopholus similis to cause severe damage to the root system of coconut and arecanut (Koshy et al. 1975). Radopholus similis was found to cause reduction in the growth of above ground parts by 79 per cent and the root growth by 86 per cent in pepper (Venkatesan, 1977). Wehunt et al. (1978) developed the root lesion ratings 1 - 5 according to the severity of infection, size and number of lesions on the roots.

Similar pathogenicity tests were conducted on turmeric (Sosamma et al. 1979) and they found that there was reduction in the number of tillers by 18 per cent, number of leaves by 14 per cent, width of the lamina by

17 per cent, length of the lamina by 15 per cent, shoot length by 4 per cent, shoot weight by 48 per cent, number of roots by 31 per cent, maximum root length by 16 per cent, root weight by 42 per cent, number of rhizome branches by 59 per cent and rhizome weight by 76 per cent at 1,00,000 inoculum level.

Sundara Raju et al. (1979) studied pathogenicity on ginger and found 50 per cent reduction in number of tillers, 63.4 per cent in number of leaves, 39.11 per cent in shoot length, 61.54 per cent in root length, 83.1 per cent in root weight and 73.6 per cent in rhizome weight.

1.3.1 Correlation studies: A highly significant negative correlation was obtained between population of Radopholus similis and root weight (Tomerlin and O'Bannon, 1974). A positive correlation was observed between population of Radopholus similis and overall destruction of the plant (Sundara Raju et al. 1979) and a negative correlation of nematode multiplication was seen with an increase in the inoculum level (Sosamma et al. 1979).

1.3.2 Plant tolerance: The tolerance limit of banana plant was studied. A population of 1000 Radopholus similis per 100 g of banana roots was considered harmless (Guerout, 1970) and a population level of 550 Radopholus similis per 20 g of Musa root could not affect much on

banana production (Anon. 1976). Destruction of roots of pepper plants was observed at a threshold inoculum of 1000 nematodes per 1500 ml of soil or when average population per gram root raised to 2300 nematodes (Venkatesan, 1977).

1.4 Economic Importance.

1.4.1 Banana: Radopholus similis probably causes greater world-wide losses in banana yields. Bunch weight in the nematode uninfested plots ranged upto 16 lbs heavier than those from nematode infested plots. Total fruit production was upto 17,000 lbs per acre per year more from the nematode free plots than from the nematode infested plots. A reduction of yield by 66.7 to 116.7 lbs per planted rhizome was recorded (Loos and Loos 1960 b). Maas (1969) recorded a yield of 37 tonnes in 100 per cent infested plots whereas it was 73 tonnes per year in less than 30 per cent infested plants. Within 3 to 4 years of attack there was 50 per cent yield loss, about 12.5 tonnes per ha. and a tipover of the plants went upto 60 per cent of the total population. (Adam and Rodriguez, 1970).

1.4.2 Citrus: On declined trees, reduction in the fruit production varied with the age of the tree, variety, grove care and the duration of infestation. In general

the reduction in fruit yield varied from 40 to 70 per cent for oranges (DuCharme, 1968). A citrus grove planted with healthy seedlings produced 1,322 boxes of citrus per ha. whereas the seedlings infested with Radopholus similis produced only 62 boxes at the end of the 9 years (O'Bannon, 1977).

1.4.3 Pepper: Due to the attack of Radopholus similis in Bangka islands, the population of pepper vines were reduced to 2 million from 22 million (Hubert, 1957). In the fields where there was more than 50 per cent Radopholus similis infection, yield reduction approached 40 per cent (Vilsoni et al. 1976).

1.4.4 On other crops: A healthy grape fruit tree could produce 14 to 17 boxes per tree, a similarly aged, infected tree produced only 4 to 6 boxes. Infestation of Radopholus similis on grape fruit suppressed yield by 50 to 80 per cent (O'Bannon, 1977). An initial inoculum level of ten nematodes caused 35 per cent reduction in the weight of the rhizome after four months and 46 per cent at the end of the eight months in turmeric (Sosamma et al. 1979). A reduction of 73.6 per cent in rhizome weight was observed with an initial inoculum level of 10,000 nematodes over a period of 6 months in ginger (Sundara Raju et al. 1979).

1.4.5 Control of Radopholus similis / yield benefit: There was an increase of 0.8 number of leaves, and 3.7 inches in the circumference of pseudostem, over the control, when the plants were treated with 3 gal.per acre of DBCP. The plots received 25 l.t. DBCP per ha. in October and 15 l.t. per ha. in the following March, yielded 51.86 m. tonnes in the first crop and 59.4 m. tonnes in the second crop. Yield in the control plots declined from 39 m. tonnes in the first crop to 25 m. tonnes per ha. in the second crop. (Luc and Vilardebo, 1961). By injecting 5 milli litres of 0.25 milli litre of active ingradient DBCP, at the base of the pseudostem, the plants improved vegetative growth, and the weight of the bunches increased from 6.8 to 10.31 kg (Taylor, 1969). There was an increase in the yield from 30 to 60 per cent where control measures were taken (Blake, 1972). Application of 3 cc DBCP active ingredient per plant, for 6 times a year yielded 33 m. tonnes per ha. which was more than the treatment of same chemical for 3 times a year (31.7 m. tonnes) or those treated with 3 g of phenamiphos per plant for 3 times a year (30.4 m. tonnes) and the control (27.3 m. tonnes) in the experiments conducted by Melin and Vilardebo, (1976). Granular nematicides, phenamiphos, ethoprop and carbofuran, were found to be more effective than DBCP and to improve production (Vilardebo and Guerout, 1976). A seedling dip in DBCP at 1000 ppm concentration

for 15 minutes and longer, was found effective in killing all the nematodes in roots inside husk, the cheapest treatment for nematode control on coconut (Koshy and Sosamma (1979). Significant yield differences were obtained by using aldicarb, Aldoxycarb and DBCP (Figueroa, 1980).

1.5 Population Dynamics.

1.5.1 In monoxenic culture: In monoxenic cultures on citrus, the rate of reproduction during first life cycle of 19 days was arithmetic, thereafter became geometric for 36 days, then population increased at decreased rate due to population density factors (Du Charme, and Price, 1966).

1.5.2 Seasonal variation: Dry season was unfavourable for the development of Radopholus similis on banana (Melin and Vilardebo, 1973; Vilardebo, 1976). But high population levels were observed in the period of short rain showers occuring during drier months (Jaramillo and Figueroa, 1976). Rainy season was favourable for its multiplication (Vilardebo, 1976). However, population density was lowered after heavy rainfall in banana plantations (Jimenez, M.F. 1972; Jimenez Q.M.F. 1972). Lowest population density was found between June to July (Du Charme and Suit, 1968), minimum was in March (Melin and Vilardebo, 1973; Vilardebo, 1976) and continued to

be low upto August (Shafiee and Mendez, 1975; Anon. 1979). Highest populations were found during September to November (Koshy et al. 1975) and October to December (Du Charme and Suit, 1968; Vilardebo, 1976).

1.5.3. In relation to plant growth: Growing period of banana plant favoured development of population (Jaramillo and Figuroa, 1974; Vilardebo, 1976) and most favoured during flowering and just after flowering of banana. (Melin and Vilardebo, 1973; Vilardebo, 1976).

1.5.4 In relation to soil temperature: Optimum temperature for root invasion was 24°C and minimum and maximum were 12°C and 29.5°C to 32.5°C respectively. Mean soil temperature at 15 cm depth were within the limits for growth and reproduction of Radopholus similis but at times exceeded them making unfavourable for its multiplication (Du Charme, 1969). Soil temperature below 30 cm depth had no important role (Jimenez, M.F. 1972; Jimenez, Q.M.F. 1972; Shafiee and Mendez, 1975).

1.6 Histopathology.

Radopholus similis were found to enter actively growing root tips in the region of cell elongation and root hair production. Roots were penetrated by the lysis of successive cells (Du Charme, 1959; Loos and Loos, 1960 b; O'Bannon et al. 1967; Vilsoni et al. 1976).

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They bore into the parenchymatous cells in the cortex turning them necrotic and brown to black in colour (Vander Vecht, 1950; Blake 1966; Taylor 1969; Vilsoni et al. 1976; Venkatesan, 1977). On the young coconut roots small reddish brown elongate lesions were produced, but on the older roots the lesions were seen clearly only when the hypodermis (functional epidermis) was peeled off (Koshy et al. 1975). Both adults and larvae took up e feeding position between parenchyma cells in the cortex, one to four cells beneath the epidermis. The presence of these nematodes caused contiguous cells to separate. From an inter cellular position nematode inserted its stylet through the primary cell wall, depressed the cytoplasm and caused it to invaginate around the stylet tip. Invasion of the stele by Radopholus similis on banana root was not observed (Blake, 1966). But by the action of secondary organisms like Fusarium oxysporium f. cubense invasion and necrosis extended upto stele in banana roots (Loos, 1959). As the nematode progressed through the root, tunnels and cavities were formed in the cortex and stele through the passage of endodermis, as a result the phloem and cambium ring was often destroyed in the case of citrus. (DuCharme, 1959; O'Bannon, et al. 1967).

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1.6.1 Cellular changes: Within 12 hours of entering the cortex, the size of the nucleus and nucleolus in the cells surrounding the point of invasion was significantly increased and a clear halo like area appeared to separate the nucleolus from nucleus. Afterwards nucleus was disintegrated (Blake, 1966; O'Bannon et al. 1967). Cytoplasm was contracted from the cell walls, and they were found ruptured, forming cavities (DuCharme, 1959; Blake, 1966; Vilsoniet al. 1976) which later coalesce (Blake, 1966). Hyperplasia and hypertrophy were rare in banana roots (Blake, 1966), but were observed along with tumour formation from the pericycle (DuCharme, 1959) and along with wound gum formation (O'Bannon et al. 1967) in the case of citrus roots.

MATERIALS AND METHODS

2. MATERIALS AND METHODS

I A pot culture experiment on banana, variety Nenthran, using concrete pots was conducted to study the type and extent of damage done by the burrowing nematode, Radopholus similis on the crop, at the College of Agriculture, Vellayani. Randomised Blocks Design was followed with 5 replications and the following 16 treatments.

1.	T_1	-	Control - no nematode.		
2.	T_2	-	1,000	nematodes inoculated	45 DAP*
3.	T_3	-	1,000	" "	90 DAP
4.	T_4	-	1,000	" "	135 DAP
5.	T_5	-	1,000	" "	180 DAP
6.	T_6	-	1,000	" "	225 DAP
7.	T_7	-	10,000	" "	45 DAP
8.	T_8	-	10,000	" "	90 DAP
9.	T_9	-	10,000	" "	135 DAP
10.	T_{10}	-	10,000	" "	180 DAP
11.	T_{11}	-	10,000	" "	225 DAP
12.	T_{12}	-	1,00,000	" "	45 DAP
13.	T_{13}	-	1,00,000	" "	90 DAP
14.	T_{14}	-	1,00,000	" "	135 DAP
15.	T_{15}	-	1,00,000	" "	180 DAP
16.	T_{16}	-	1,00,000	" "	225 DAP

* DAP - Days after planting.

2.1 Preparation of pot mixture and sterilization.

Sieved field soil, sand and sieved well decomposed farm yard manure were mixed in the ratio 3:1:1 and were filled into eighty concrete pots of size 1 x 1 x 1 m to a depth of 80 cm. The pot mixture was sterilised using methyl bromide at the rate of 450 g per tonne of mixture.

2.2 Selection and sterilization of suckers.

Eighty, healthy and uniform size suckers of banana variety Nenthran, were selected and sterilized by dipping in a bordeaux mixture - DBCP paste (made by mixing 1 kg hydrated lime, 1 kg copper suphate, 65 ml of 70 per cent DBCP and 23 litres of water, Loos and Loos, 1960 a) after paring. Suckers were planted in the pots containing sterilized pot mixture, as soon as the paste had dried.

2.3 Raising and maintenance of pure cultures of Radopholus similis.

Radopholus similis was collected from the infested banana plants in the Instructional Farm of the College of Agriculture, Vellayani, and was multiplied and maintained on (i) banana plants raised in pots containing sterilized pot mixture and (ii) tissue culture method (O'Bannon and Taylor (1968).

2.3.1 (1) Banana plant culture: Sterilized banana suckers of Nenthran variety were planted in the pots containing

sterilized pot mixture. When the plants got established, they were inoculated with pure cultures of Radopholus similis and were allowed to grow. Sufficient numbers of banana plants were maintained to obtain necessary Radopholus similis population. The nematodes were collected from roots taken from these banana plants using the methods of Tarjan (1960) into sterile water. The nematode suspension thus obtained were used for inoculation on the experimental banana plants.

2.3.2 (ii) Tissue culture method:

2.3.2.1 Materials used: Pure culture of axenic nematodes, Mercuric chloride, Streptocycline, Ethyl alcohol, centrifuge, syringe with needle, forceps, 100 ml conical flasks, agar agar, carrots, safety razor blades, sterile water, sterilized cotton and butter paper.

2.3.2.2. Preparation of callus tissue: Healthy and fresh carrots were selected and washed repeatedly in the sterile water to remove dust. Under the laminar flow, it was dipped in 98 per cent ethyl alcohol. After showing over a flame, they were parred and sliced into discs of 8 to 10 mm thickness, and were inserted into sterile 100 mm conical flasks containing 40 ml of 1 per cent sterilized solidified agar. The flasks were plugged with sterilised cotton. They were left for 3 to 5 days to develop callus tissue on the carrot bits.

2.3.2.3 Inoculation of callus tissue: Pure suspension of Radopholus similis collected from banana plant cultures were poured into sterile centrifuge tubes and centrifuged for 1 minute at 3000 rpm. Supernatent water was poured out and 2 ml of 0.1 per cent mercuric chloride was added, centrifuged and again poured out. The sediment was washed with sterile water and centrifuged thrice for 15 seconds each. Two ml of 0.1 per cent streptocyclin solution in sterile water was added to the washed nematode suspension in the centrifuge tube and centrifuged for one minute. Streptocyclin was also washed out with sterile water, three times on centrifuge as above. The nematode suspension was taken out with sterilized syringe and inoculated directly on callus tissue developed on the carrot discs under the laminar flow. Flasks containing carrot discs were covered with butter paper and kept at 24°C in the incubator.

2.3.2.4 Sub culturing: Discolouration of the carrot discs was taken as a sign of multiplication of nematodes. Browning of carrot bits developed in about 35 days. Then the subculturing was done under laminar flow. The carrot bit was taken out with sterilized forceps and cut into 4 to 5 pieces with sterile blades and each small piece was inserted in to other sterile flasks containing the callus developed carrot discs,

prepared as described. Nematodes which had come out of the carrot disc were washed out with sterile water and the same was also injected into the sub culture flasks. These flasks were kept at 24°C in the incubator. This process was repeated to get sufficient nematode population. The callus tissues from the sub cultures were cut into small bits and put over a wire guaze containing tissue paper over a petridish with sterile water. The nematodes collected in the water and the suspension was used for inoculation.

2.4 Inoculation.

Nematode suspension of same age were collected from both the above cultures in sterile water. After estimating the nematode numbers aliquots of nematode suspensions were prepared to get 1,000, 10,000 and 1,00,000 larvae. Eight holes were made in the soil around the pseudostem upto the root zone and the respective nematode suspension was poured into the holes equally, on the corresponding treatment, on 45, 90, 135, 180 and 225 days after planting. Holes were covered immediately and light irrigation was given.

The plants were maintained giving all the recommended agronomic practices (Package of Practices recommendations, K.A.U. 1980). Out of the five replications, three were used to observe monthly build up of nematode population and the rest were not distrubed till harvest.

2.5 Observations taken.

The following observations were taken on the experimental plants.

2.5.1 Height of the plant: Length of the pseudostem from the surface of the soil to the fork of newly emerged leaf was taken on 45, 90, 135, 180, 225 days after planting and at flowering.

2.5.2 Girth of the pseudostem: Girth of the pseudostem was measured 6 inches above the soil level on 45, 90, 135, 180, 225 days after planting and at flowering.

2.5.3 Number of leaves: Total number of leaves on the plant at the time of observation were counted on 45, 90, 135, 180, 225 days after planting and at flowering.

2.5.4 Nematode population till harvest: Composite soil sample and root sample were collected from each plant at monthly intervals from the date of inoculation. Nematode population in 100 ml of soil was extracted by modified method of Cobb's decanting and sieving technique (Christie and Perry, 1951) and counted.

Nematode population in one g root was estimated by putting bits of roots on wire guaze containing tissue paper over a petridish with water. The nematodes were estimated at 24 hours interval till no more nematodes were obtained. Nematode population was also estimated from one g of affected rhizome by taking composite sample, after harvest.

2.5.5 Yield at harvest: Weight of bunch cut at the first bract, number of hands, and total number of fingers in each bunch were recorded.

2.5.6 Weight of the corm: The corm was lifted out without damaging the roots and weighed. Then nematode affected portion of the corm was chopped and weighed separately.

2.5.7 Weight of the roots: All the roots were cut of their base and weighed.

2.5.8 Length of the roots: Length of 25 roots, selected at random from each corm was measured and average was taken.

2.5.9 Root lesion ratings: All the roots were divided into 5 groups according to its severity of infection, Rating of 1 to 5 as per Wehunt et al. (1978) was followed:

1. no lesions.
2. slight infection - few lesions of 1 mm or less in diameter.
3. moderate infection - many lesions of 1 mm or less or a few lesions larger than 1 mm in diameter.
4. Severe infection - many lesions larger than 1 mm in diameter, a few coalesced into area greater than 1 cm in diameter.

5. very severe infection - many lesions 1 cm in diameter, some coalesced into lesions greater than 5 cm and the root almost destructed.

Numbers of roots under each group were counted.

II. Histopathology.

Roots of the experimental banana plants showing lesions of various stages were cut and fixed in F.A.A. The fixed roots were then processed for microtomy using safranin and fast green stain (Johansen, 1940). The sections were examined under microscope and photo-micrographs were taken.

RESULTS

3 RESULTS

An experiment on banana variety Nenthran was laid out with 16 treatments and 5 replications. Different biometric observations like height of the plants, number of leaves and girth of the pseudostem were compared to study the pathogenic effect of Radopholus similis on the crop. The results are presented below.

3.1 Height of the plants.

3.1.1 45 DAP: The height of the plants were measured on 45 DAP and the result is presented in Table 1 and Appendix I. The height ranged from 68.8 to 69.4 cm. and was not significantly different as no treatment was given until 45 DAP.

3.1.2 90 DAP: The height of the plants was again measured on 90 DAP and the result is presented in Table 1, Fig.1a and Appendix I. All the plants grew to a height of around 119 cm.

The height of the plants treated on 45 DAP with 1000, 10,000 and 1,00,000 nematodes was 118.6, 118.8 and 119 cm respectively, showing a reduction of 0.67, 0.5 and 0.335 per cent over control though was not significant.

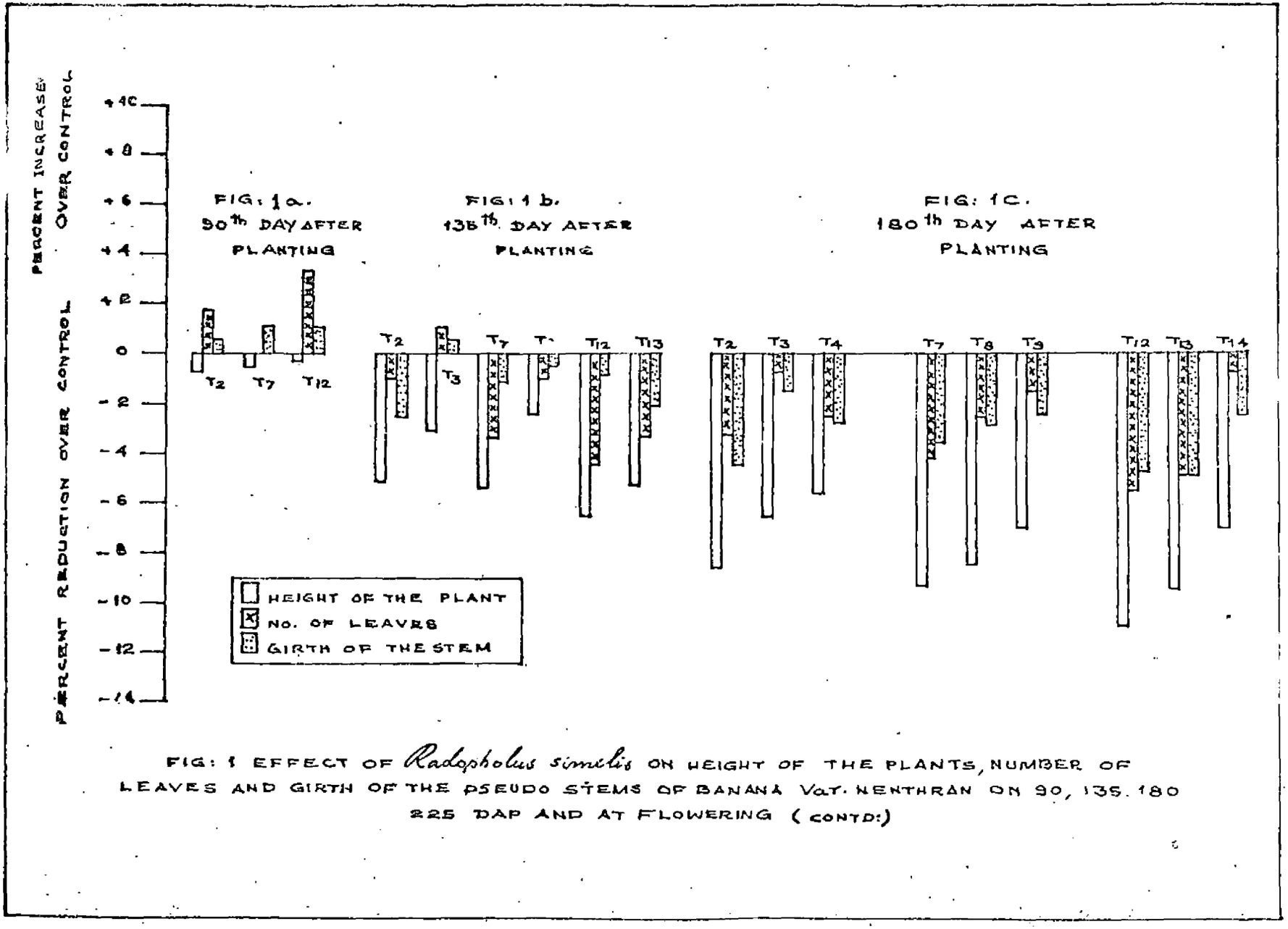

FIG: 1 EFFECT OF *Radopholus similis* ON HEIGHT OF THE PLANTS, NUMBER OF LEAVES AND GIRTH OF THE PSEUDO STEMS OF BANANA Var. NENTHRAN ON 90, 135. 180 225 DAP AND AT FLOWERING (CONTD:)

3.1.3 135 DAP: The height of the plants on 135 DAP are presented in Table 1 Fig. 1b and Appendix I. The height of the plants inoculated on 45 DAP with 1,000, 10,000 and 1,00,000 nematodes were 151.2, 149.6 and 148 cm respectively with a reduction of 4.55, 5.55 and 6.57 per cent over the control which was statistically significant.

The height of the plants treated with 1000 and 10,000 nematodes on 90 DAP were 153.4 and 154.8 cm which were on par with the control plants, eventhough there was a reduction of 3.16 and 2.27 per cent respectively, where as the mean height of the plants treated with 1,00,000 nematodes 90 DAP was 149.8 which was significantly shorter by 5.3 per cent over control. The reduction of these plants was greater than the plants inoculated with 1,000 nematodes on 45 DAP. The same trend was observed throughout the period after 135th day onwards.

3.1.4 180 DAP: The height of the plants treated with 1,000, 10,000 and 1,00,000 nematodes on 45 DAP were 180.8, 179.6 and 176 cm respectively with a reduction of 8.78, 9.38 and 11.2 per cent respectively (Table 1, Fig. 1c and Appendix I). The plants treated on 90 DAP with 1,000, 10,000 and 1,00,000 nematodes had a height of 184.8, 181. and 178.8 cm. respectively.

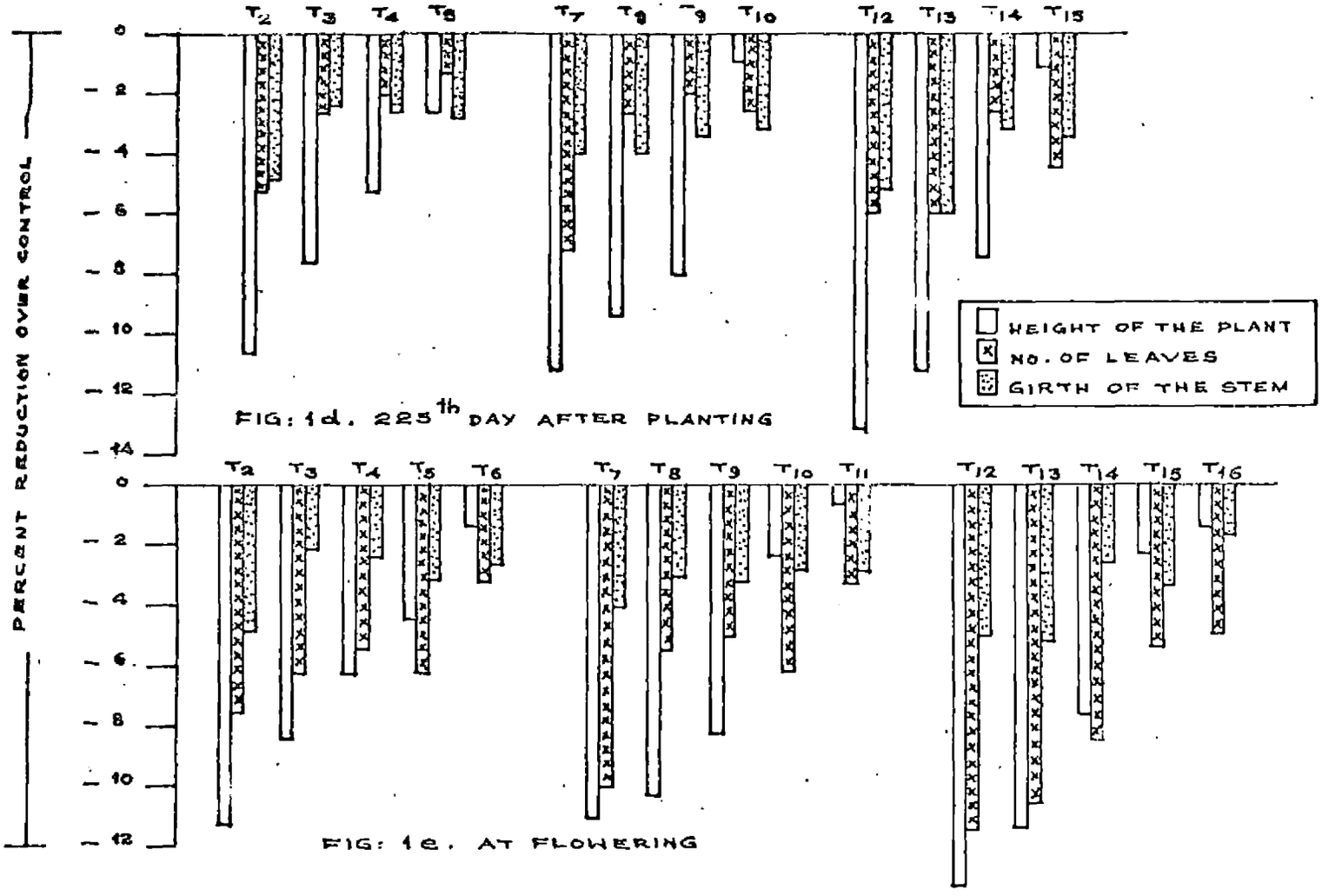

FIG: 1d. 225th DAY AFTER PLANTING

FIG: 1e. AT FLOWERING

(CONTN:) FIG: 1. EFFECT OF *Radopholus similis* ON HEIGHT OF THE PLANTS, NUMBER OF LEAVES AND GIRTH OF THE PSEUDO STEMS OF BANANA Var. NENTHRAN ON 90, 135, 180, 225 DAP AND AT FLOWERING

Which was significantly less than the control plants by 6.76, 8.68 and 9.79 per cent respectively. The height of the plants treated on 135 DAP with 1,000 nematodes was 187 cm with 5.65 per cent reduction and those inoculated with 10,000 and 1,00,000 was 184.2 cm with 7.06 per cent reduction over control, a significant reduction.

3.1.5 225 DAP: The height of the plants on 225 DAP are presented in Table 1 Fig. 1d and Appendix I. The height of the plants treated on 45 DAP with 1,000, 10,000 and 1,00,000 nematodes were 199.8, 198.6 and 194 cm. respectively with reduction of 10.48, 11.02 and 13.08 per cent over control reduction in the height of the plants treated with 1,00,000 were highly significant than all other treatments. The height of the plants treated on 90 DAP with 1,000, 10,000 and 1,00,000 were 205.8, 202 and 197.8 cm. showing a significant reduction of 7.79, 9.5 and 11.38 per cent respectively over control. The height of the plants treated on 135 DAP had a height of 211.6, 205.2 and 206.2 respectively with the 3 inoculum levels which were 5.2, 8.06 and 7.62 per cent less over control. The height of the plants treated on 180 DAP with 1,000, 10,000 and 1,00,000 nematodes were 217.2, 221.2 and 220.6 respectively which were on par with control.

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3.1.6 At flowering: As presented in the Table 1 Fig. 1e and Appendix I, all the treatments from T_2 to T_{16} were significantly shorter than the control and taller than the plants treated with 1,00,000 nematodes on 45 DAP (T_{12}) which was 203.2 cm with a reduction of 13.24 per cent over control. Plants treated with 1,00,000 nematodes on 90 DAP (T_{13}) grew to a height of 207.2 cm with a reduction of 11.53 per cent which was on par with the plants treated with 1,000, 10,000 nematodes on 45 DAP and plants treated with 10,000 nematodes on 90 DAP with a total height of 214.6, 208.6 and 210.2 cm. and with a reduction of 11.1, 10.93 and 10.25 per cent respectively. All other treatments followed the same trend as shown in Table 1. The least difference over control was found in the plants treated on 225 DAP, though they significantly differed from the control.

3.2 Number of leaves.

Number of leaves produced by the plants were counted and are presented in the Table 2 Fig.1a to 1e and Appendix II.

3.2.1 45 DAP: Up to 45 DAP, the plants produced around 6 leaves showing no significant difference among the treatments.

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3.2.2 90 DAP: The plants treated on 45 DAP produced almost equal to the control plants i.e. 12.2, 12 and 12.4 leaves in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively, where control plants produced around 12.2 leaves.

3.2.3 135 DAP: Counts on 135 DAP showed that the control plants produced 18 leaves. The plants treated on 45 DAP with 1,000, 10,000 and 1,00,000 nematodes produced 17.8, 17.4 and 17.2 leaves respectively and the plants treated on 90 DAP produced 18.2, 17.8 and 17.4 leaves respectively which were not significant.

3.2.4 180 DAP: Control plants produced 24.4 leaves upto 180 DAP but the plants inoculated on 45 DAP with 1,000, 10,000 and 1,00,000 nematodes were with 23.6, 23.4 and 23 leaves; the plants treated on 135 DAP were with 23.8, 24 and 24.2 leaves. The plants treated on 45 DAP and 90 DAP were found to be significant.

3.2.5 225 DAP: Upto 225 DAP the control plants and the untreated plants under the treatments T_6, T_{11} and T_{16} produced 30.4 leaves. But the plants treated on 45 DAP with 1,000, 10,000 and 1,00,000 nematodes produced only 28.8, 28.2 and 28.6 leaves respectively. Those inoculated on 90 DAP with 1,000, 10,000 and 1,00,000 nematodes were with 29.6, 29.6 and 28.6

leaves and the plants treated on 135 day produced 29.8, 29.8 and 29.6 leaves. The plants treated on 180 DAP produced 30, 29.6 and 29 leaves respectively.

3.2.6 At flowering: The total number of leaves produced by individual plants upto flowering was observed and are presented in Table 2. Fig. 1e and Appendix II. The control plants produced 36.2 leaves and the plants treated with 1,000, 10,000 nematodes on 225 DAP produced 35 leaves. The least number of 32 leaves were produced by the plants treated on 45 DAP with 1,00,000 nematodes.

3.3 Girth of the pseudostem.

Girth of the pseudostem was measured on 45, 90, 135, 180, 225 DAP and at the time of flowering and are presented in the Table 3, Fig. 1a to 1e and Appendix III.

3.3.1 45 DAP: On 45 DAP when there was no treatment, all the plants grew the girth around 20 to 21 cm and were not significantly different.

3.3.2 90 and 135 DAP: On 90 and 135 DAP, all the plants had a girth of around 36, 42 cm respectively without any significant difference.

3.3.3 180 DAP: On 180 DAP control plants had a girth of 47.4 cm. Where as the T_2, T_7 and T_{12}, the plants treated on 45 DAP with 1,000, 10,000 and 1,00,000 nematodes had only 45.3, 45.6 and 45.1 cm respectively. Plants inoculated with 1,000, 10,000 and 1,00,000 nematodes on

90 DAP had a girth of 46.6, 46 and 45 cm respectively. The plants treated on 135 DAP with 1,000, 10,000 and 1,00,000 nematodes measured 46.1, 46.2 and 46.2 cm respectively.

3.3.4 225 DAP: The control plants were having the pseudostems measuring 50.6 cm, where as the plants treated on 45 DAP with 1,000, 10,000 and 1,00,000 were only with 48.1, 48.6 and 48 cm respectively and the plants treated on 90 DAP were with 49.4, 48.6, 47.6 cm. Similar trend was observed in the case of the plants treated on 135 DAP and 180 DAP.

3.3.5 At flowering: The final girth of the stems of control plants was 52.5 cm on par with the plants treated on 225 DAP which measured 52.2, 51.9 and 51.6 cm inoculated with 1,000, 10,000 and 1,00,000 nematodes respectively. The girth of the stem reduced proportionately in the other treatments according to their inoculum levels and period of infestation as shown in the Table 3. The plants treated on 45 DAP with 1,000, 10,000 and 1,00,000 nematodes had a girth of the stem 49.9, 50.4 and 49.9 cm respectively and the least measured plants were in the treatment given on 90 DAP with 1,00,000 nematodes which had 49.8 cm girth.

3.4 Duration of flowering.

Number of days from planting to flowering was counted and presented in the Table 4 Fig. 2a, 3a and 4a and Appendix IV. The plants under the treatment 1,00,000 on 45 DAP (T_{12}) flowered earlier than all other treatments i.e. on 241 DAP followed by the plants inoculated with 10,000 nematodes on 45 DAP (T_7) after 247 days. The other treatments flowered as follows. Plants treated with 1,00,000 nematodes on 90 DAP (T_{13}) after 251 days; 1,000 nematodes on 45 DAP (T_2) after 252 days; 1,00,000 nematodes on 135 DAP (T_{14}) after 259 days; 1,000 and 10,000 nematodes on 90 DAP (T_3 and T_8) after 260 days; 10,000 nematodes on 135 DAP (T_9) after 269 days; 1,000 nematodes on 135 DAP (T_4) after 273 days; 1,00,000, 10,000 and 1,000 nematodes on 180 DAP flowered after 276, 281 and 284 days respectively. The plants treated on 225 DAP with 1,00,000, 10,000 and 1,000 nematodes flowered after 290, 292 and 295 days. The control plants flowered 298 days after planting.

3.5 Yield.

The weight of the bunches of plants under various treatments were shown in the Table 4, fig. 2a, 3a and 4a and Appendix IV. The control plants yielded the maximum of 3.8 kg followed by the plants treated with 1,000 nematodes (T_6) with 3.4 kg; with 10,000 nematodes (T_{11}) with 3.1 kg; with 1,00,000 nematodes (T_{16}) on

225 DAP with 2.9 kg yield. Plants inoculated with 1,000 nematodes on 180 DAP (T_5) yielded 2.88 kg. Both treatments T_4 and T_{10} which were inoculated with 1,000 nematodes on 135 DAP and 10,000 nematodes on 180 DAP respectively, yielded 2.8 kg. The plants under T_{15} inoculated with 1,00,000 nematodes on 180 DAP produced bunches weighing 2.78 kg and the plants treated with 1,000 nematodes on 90 DAP (T_3) produced 2.76 kg bunches. The plants treated on 135 DAP with 10,000 nematodes (T_9) had yielded 2.72 kg and 2.69 kg with 1,00,000 nematodes (T_{14}). The plants inoculated with 10,000 nematodes on 90 DAP (T_8) yielded 2.66 kg and the plants inoculated with 1,00,000 on the same day (T_{13}) yielded 2.45 kg. Those plants which were treated on 45 DAP with 1,000 (T_2), 10,000 (T_7) and with 1,00,000 (T_{12}) nematodes yielded 2.44, 2.43 and 2.4 kg respectively.

3.6 Number of hands per bunch

The mean number of hands per bunch under different treatments are given in the Table 4 Fig.2a, 3a and 4a and Appendix V. Control plants produced more number of hands i.e. 3.2. Treatment 6 (1,000 nematodes on 225 DAP) produced 3 hands on an average, followed by T_2 (1,000 nematodes on 45 DAP), T_{10} (10,000 nematodes on 180 DAP), T_{11} (10,000 nematodes on 225 DAP), T_{13}

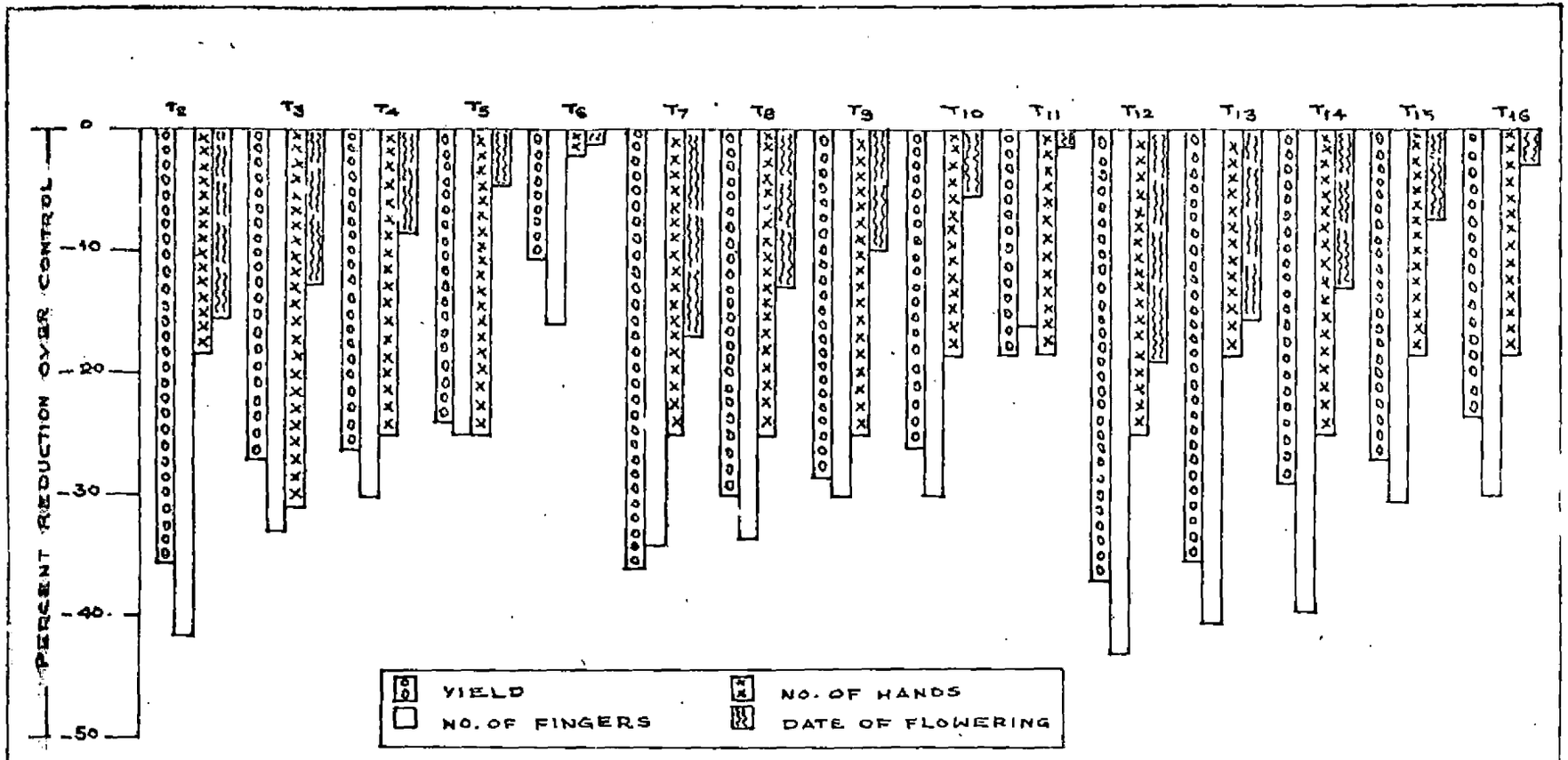

FIG: 2a. EFFECT OF *Radopholus similis* ON YIELD COMPONENTS OF BANANA Var. NENTHRAN INOCULATED ON 45, 90, 135, 180 AND 225 DAP WITH 1000, 10,000 AND 1,00,000 NEMATODES

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(1,00,000 nematodes 90 DAP), T_{15} (1,00,000 nematodes on 180 DAP) and T_{16} (1,00,000 nematodes on 225 DAP) with 2.6 hands per bunch. Treatments 4 and 5 (1,000 nematodes on 135 and 180 DAP respectively), T_7, T_8, T_9 (10,000 nematodes on 45, 90 and 135 DAP), T_{12} and T_{14} (1,00,000 nematodes on 45 and 135 DAP) produced 2.4 hands followed by T_3 (1,000 nematodes on 90 DAP) with 2.2 hands.

3.7 Number of Fingers.

The number of fingers in each bunch were counted, their mean numbers and percentage reduction over control are presented in the Table 4, Fig. 2a, 3a and 4a and Appendix IV. The control plants produced an average of 22.2 fingers. T_6 and T_{11} (1,000 and 10,000 nematodes applied on 225 DAP respectively) had 18.6 fingers; T_5 (1,000 nematodes on 180 DAP) had 16.6 and the T_4, T_{10}, and T_{16} (1000 nematodes on 135 DAP, 10,000 nematodes on 180 DAP and 1,00,000 nematodes on 225 DAP respectively) had 15.6 fingers. The plants under T_9 and T_{15} (10,000 nematodes on 135 DAP and 1,00,000 nematodes on 180 DAP respectively) had 15.4 fingers. The plants treated on 90 DAP with 1,000 nematode (T_3) and with 10,000 nematodes (T_8) had 14.8 fingers. T_7 (10,000 nematodes on 45 DAP) produced 14.6 fingers and T_{14} (1,00,000 nematodes on 135 DAP) had 13.4; T_{13} (1,00,000 nematodes on 90 DAP) had 13.2 fingers. T_2 (1,000 nematodes

on 45 DAP) had 13 fingers. The plants treated with 1,00,000 nematodes on 45 DAP had the least number of 12.6 fingers.

3.8 Weight of the Corm.

The weight of the corm with roots was taken at the time of harvest and are presented in the Table 4 Fig. 2b, 3b, 4b and Appendix IV. The maximum weight of the corm was recorded in T_6 (1,000 nematodes inoculated on 225 DAP) i.e. 5.39 kg. which was statistically on par with the control plants which produced corm weighting 5.09 kg, followed by T_{16} (1,00,000 nematodes on 225 DAP) with 4.98 kg; T_{11}(1,00,000 nematodes on 225 DAP) with 4.88 kg; T_{15} (1,00,000 nematodes on 180 DAP) with 4.38; T_5 (1,000 nematodes on 180 DAP) with 4.28; T_{10} (10,000 nematodes on 180 DAP) with 4.1 kg; T_4 (1,000 nematodes on 135 DAP) with 4.06 kg; T_{14} (1,00,000 nematodes on 135 DAP) with 3.99 kg; T_9 (10,000 nematodes on 135 DAP) with 3.95 kg; T_8 (10,000 nematodes on 90 DAP) with 3.74kg; T_3(1,000 nematodes on 90 DAP) with 3.65 kg; T_2 (1,000 nematodes on 45 DAP) with 3.47 kg; T_7 (10,000 nematodes on 45 DAP) with 3.26 kg; T_{13} (1,00,000 nematodes on 90 DAP) with 3.2 kg. Least weighing corm was produced by T_{12} (1,00,000 nematodes on 45 DAP) with 2.81 kg.

3.9 Weight of the roots.

Weight of the total number of roots of individual plants were taken and are presented in the Table 4

Fig. 2b, 3b, 4b and Appendix IV. The roots produced by the control plants weighed maximum i.e. 608 g on an average followed by T_{11}(10,000 nematodes on 225 DAP) with 540 g; T_6 (1,000 nematodes on 225 DAP) with 525 g; T_5 (1,000 nematodes on 180 DAP) with 485 g; T_{16} (1,00,000 nematodes on 225 DAP) with 450 g; T_{10} (10,000 nematodes on 180 DAP) with 435 g; T_4 (1,000 nematodes on 135 DAP) with 420 g; T_{15} (1,00,000 nematodes on 180 DAP) with 410 g; T_8 (10,000 nematodes on 90 DAP) with 385 g; T_9 (10,000 nematodes on 135 DAP) with 375 g; T_{14} (1,00,000 nematodes on 135 DAP) with 360 g; T_3 (1,000 nematodes on 90 DAP) with 350 g; T_2(1,000 nematodes on 45 DAP) with 340 g; T_{13}(1,00,000 nematodes on 90 DAP) with 325 g; T_{12} (1,00,000 nematodes on 45 DAP) with 280 g; and T_7 (10,000 nematodes on 45 DAP) with 240 g.

3.10 Length of the root.

The mean length of the roots measured as described are given in the Table 4 Fig. 2b and Appendix IV. Control plants were found to produce longest roots i.e. 50 cm on average followed by T_6 (1,000 nematodes on 225 DAP) with 45.2 cm, T_5(1,000 nematodes on 180 DAP) with 38 cm; T_{11} (10,000 nematodes on 225 DAP) with 36 cm; T_4 (1,000 nematodes on 135 DAP) with 35.8 cm, T_{16} (1,00,000 nematodes on 225 DAP) with 35 cm; T_{10} (10,000 nematodes on 180 DAP) with 34.6 cm. The

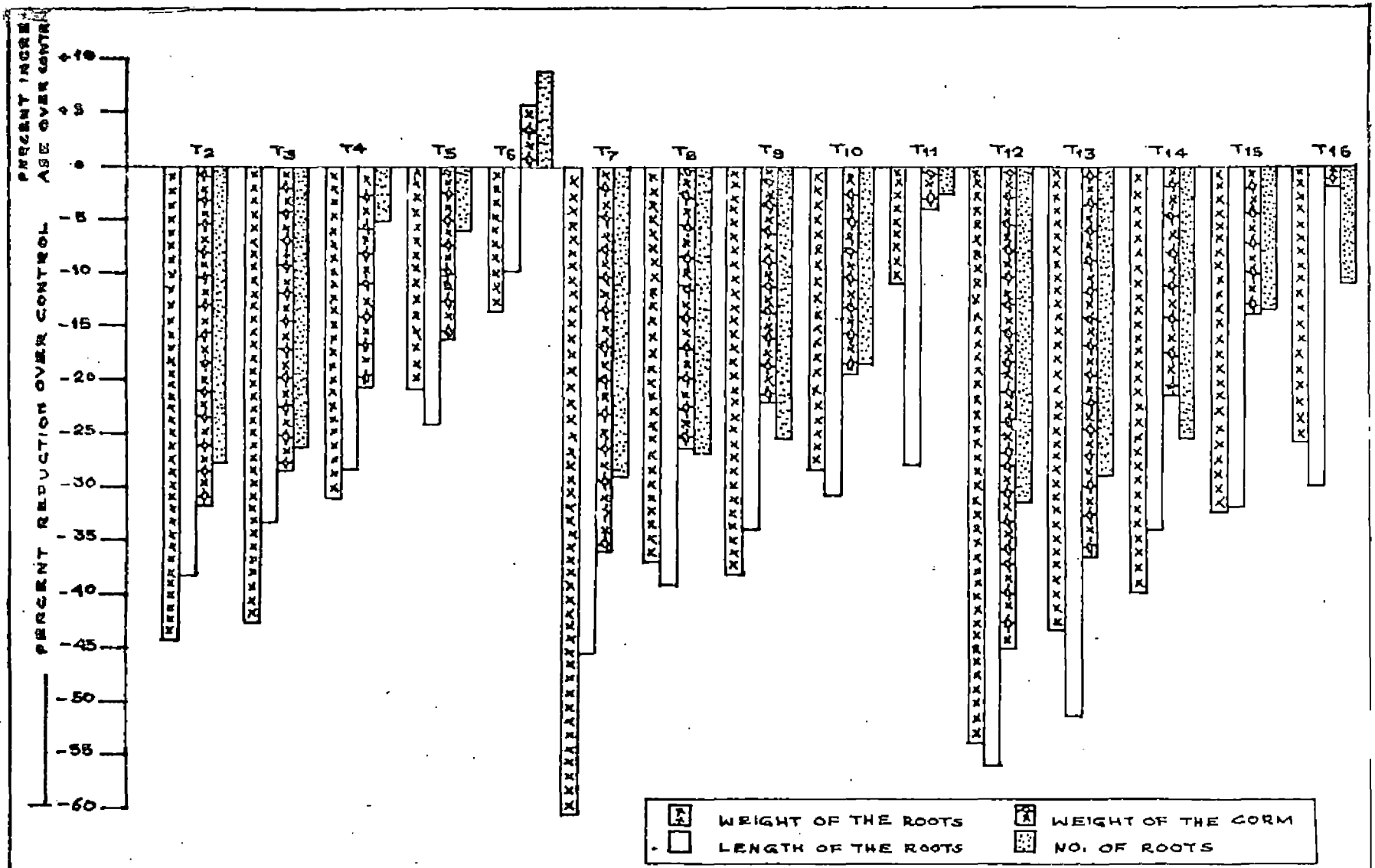

FIG: 2b. EFFECT OF *Radopholus similis* ON ROOT CHARACTERS OF BANANA VAR. NENTHRAN INOCULATED ON 45, 90, 135, 180 AND 225 DAP WITH 1000, 10,000 AND 100,000 NEMATODES

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treatments 1,00,000 and 10,000 nematodes applied on 135 DAP (T_{14} and T_9) produced 33 cm roots the treatment with 1,000 nematodes on 45 DAP (T_2) followed this with 31 cm; and T_8 (10,000 nematodes on 90 DAP) with 30.4 cm. The plants treated with 10,000 population on 45 DAP (T_7) produced 27 cm root and the plants treated with 1,00,000 nematodes on 90th DAP (T_{13}) produced the roots which measured 24.2 cm and shortest roots were found in the plants treated with 1,00,000 nematodes on 45 DAP (T_{12}) i.e. 22 cm.

3.11 Number of roots.

The total number of roots produced by each plant is presented in Table 4, Fig. 2b, 3b, 4b and Appendix IV. It was found that the plants treated with 1,000 nematodes on 225 DAP (T_6) produced more number of roots i.e.242 followed by the control plants which were found to produce 222 roots. It was followed by the plants treated with 10,000 nematodes applied on 225 DAP (T_{11}) with 216 roots; and the plants inoculated with 1,000 nematodes on 135 DAP (T_4) with 211 roots; plants treated on 180 DAP with 1,000 nematodes (T_5) produced 209 roots. The plants treated on 225 DAP with 1,00,000 nematodes (T_{16}) produced 197 roots followed by the plants inoculated with 1,00,000 nematodes on 180 DAP (T_{15}) with 192 roots; the plants treated with 10,000 nematodes on 180 DAP (T_{10}) produced 181 roots and the plants treated with

10,000 nematodes (T_9) and 1,00,000 nematodes (T_{14}) on 135 DAP produced 165 roots followed by the plants inoculated on 90 DAP (T_3) with 1,000 nematodes with 164 and 10,000 nematodes (T_8) with 162.2 roots. Those plants inoculated with 1,000 nematodes on 45 DAP (T_2) produced 162 roots and the plants treated with 10,000 nematodes on 45 DAP (T_7) and 1,00,000 nematodes on 90 DAP (T_{13}) produced only 158 roots. The plants inoculated with 1,00,000 nematodes on 45 DAP (T_{12}) could produce only 152 roots which was found to be the least number of roots.

3.12 Root lesion ratings.

The roots of individual plants were divided into five groups according to severity of its infection and are presented in Table 6.

Rating 1 having no lesions were very few except in the control plants, where all the roots were not having lesions. Plants treated with 1,000 (T_6) and 10,000 (T_{11}) nematodes on 225 DAP had 42.6 and 9 roots without any lesions. In the plants treated with 10,000 nematodes on 45 DAP (T_7) and 1,00,000 nematodes on 45 and 90 DAP (T_{12} and T_{13}), all the roots showed lesions.

Roots with slight infection comes under rating 2. The plants treated with 1,000 nematodes on 225 DAP (T_6)

was found to have more number of roots under this rating i.e. 81.2 followed by the plants treated with 1,000 nematodes on 180 DAP (T_5) with 35.8. The plants treated on 45 DAP with 1,00,000 nematodes had only 7.2 roots under this rating.

The number of roots under rating 3 with moderate infection, varied in different treatments as seen in the Table 6. Plants treated with 10,000 nematodes on 225 DAP (T_{11}) found to be having more roots under group 3 with 63.6 followed by the treatment with 10,000 nematodes on 180 DAP (T_{10}) with 54.4. All other treatments followed it as shown in the table. Least number of roots under this group was found in the treatment with 1,00,000 nematodes on 90 DAP (T_{13}) with 14.8 roots.

The number of roots affected severely were grouped under 4. The treatment with 1,00,000 nematodes on 180 DAP (T_{15})had more roots under this rating i.e. 71.8 and all other treatments followed it, least number of roots under this rating was found in the treatment with 1,000 nematodes on 45 DAP (T_2) i.e. 28.4 roots.

Very severely infected roots were under rating 5. Treatment with 1,00,000 nematodes on 90 DAP (T_{13}) had the maximum with 95.4 roots followed by the treatments with 1,00,000 nematodes on 45 DAP (T_{12}) with 91.8 roots.

Other treatments followed as seen in the Table 6. Least number of roots under this rating was in the treatment with 1,000 nematodes on 225 DAP (T_6) with 29.1 roots.

3.13 Nematode population.

Nematode population in 100 g of soil, and one g of root were taken at monthly intervals, till harvest and the results are presented in the Table 7 and 8.

The plants treated on 45 DAP with 1,000, 10,000 and 1,00,000 nematodes when observed after one month, yielded 6.6, 22.6 and 36.3 nematodes in 100 g of soil, and 4.3, 23.6 and 36.6 nematodes in 1 g of root respectively. As shown in the table, the nematode population increased with the increase in time upto the month of October, when it was 59.3, 68.3 and 88.6 in 100 g of soil and 121, 144.3 and 167.3 nematodes per gram of root in the plants inoculated with 1,000, 10,000 and 1,00,000 nematodes respectively. At the time of harvest there were 11.6, 13.6 and 16 nematodes in 100 g of soil, in the plants treated with 1,000; 10,000 and 1,00,000 nematodes respectively. Thus there was an average of 69,600 ; 81,600 ; and 96,000 nematodes per plant having 600 kg soil. In the above treatments T_2, T_7 and T_{12} the population in 1g of the root were 83.4, 94.8 and 113.4 respectively. The total root population was 38,364; 36,972 and 54,532. The grand total population consisting of total soil and root population were

1,07,964; 1,18,572 and 1,50,432 nematodes with multiplication factors 107.96, 11.86 and 1.5, in the plants inoculated with 1,000, 10,000 and 1,00,000 population respectively.

The plants treated on 90 DAP with 1,000, 10,000 and 1,00,000 nematodes when observed for nematode development after one month, showed 14.6, 22 and 30.3 nematodes in 100 g of soil, and 13.3, 18.6 and 20.3 nematodes in 1g of root respectively. As seen in the Table 7. The population was found to increase upto October, when it was 45.3, 89.6 and 72 nematodes in 100 g of soil and 119.6, 140.6 and 161.3 nematodes from 1 g of root. At the time of the harvest, the population was 10.6, 12.8 and 15.2 in 100 g of soil, which when multiplied to the total soil, the population of 63,600; 76,800 and 91,200 nematodes were obtained in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively. The population in 1 g of root and corm on an average was 81.6, 63.6 and 108 nematodes, which when multiplied to the total affected roots and rhizome, a total population of 34,680; 32,118; and 54,540 were obtained. The grand total population was 98,280; 1,08,918 and 1,45,740 nematodes, with multiplication factors 98.28, 10.89 and 1.46 in the plants treated with 1,000, 10,000 and 1,00,000 nematodes.

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The plants treated on 135 DAP after one month had 17.6, 21.3 and 34.3 nematodes per 100 g of soil, and 18.3, 26.6 and 37.6 nematodes per 1 g of root in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively. There was an increase in the population till November, in the plants treated with 1,000, 10,000 nematodes, where it was 39.3, and 42 nematodes in 100 g of soil, and 100.6, 137.3 nematodes in 1 g of root. But in the plants treated with 1,00,000 nematodes the maximum population was observed in the month of October, when it was 55.3 nematodes in 100 g of soil and 157.6 nematodes in 1 g of root. The final counts in 100 g of soil was 9.6, 11.8 and 13.8 nematodes, which when multiplied to the total soil, they were 57,600; 70,800; and 82,800 nematodes and the 1 g of root and rhizome population was found to be 53.4, 55.8 and 122.6 nematodes, which when multiplied with total affected root portion, gave the total root population of 25,632; 26,226; and 55,692 nematodes. The grand total population of nematodes were 83,232; 97,026 and 1.38,492 nematodes with multiplication factors 83.23, 9.7 and 1.39 in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively.

The plants inoculated on 180 DAP after one month had 18, 21.6 and 35.6 nematodes from 100 g of soil and 27.3, 32.3 and 64.6 nematodes from 1 g of root in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively. The population increased with the increase

Table 8. Final *Radopholus similis* population on banana.

Treatments	Wt. of the Roots(g)	Wt. of the affected corm (g)	Total wt. of the affected portion (g)	Population per g (Nos.)	Total Root population (Nos)	Population in 100 g soil (Nos)	Total soil population(Nos)	Grand Total population(Nos)	Multiplication Factor
T_2	340	120	460	83.4	38,364	11.6	69,600	1,07,964	107.96
T_3	350	75	425	81.6	34,680	10.6	63,600	98,280	98,28
T_4	420	60	480	53.4	25,632	9.6	57,600	83,232	83.23
T_5	485	48	533	27.6	14,711	7.8	46,800	61,511	61.51
T_6	525	25	550	16.2	8,910	4.2	25,200	34,110	34.11
T_7	240	150	390	94.8	36,972	13.6	81,600	1,18,572	11.86
T_8	385	120	505	63.6	32,118	12.8	76,800	1,08,918	10.89
T_9	375	95	470	55.8	26,226	11.8	70.800	97,026	9.7
T_{10}	435	80	515	45	23,175	9.6	57,600	80,775	8.08
T_{11}	540	30	580	39.6	22,968	7.4	44,400	67,368	6.74
T_{12}	280	200	480	113.4	54,432	16	96,000	1,50,432	1.50
T_{13}	325	180	505	108	54,540	15.2	91.200	1,45,740	1.46
T_{14}	360	95	455	122.4	55,692	13.8	82,800	1,38,492	1.39
T_{15}	410	55	465	123.6	57,474	12.4	74,400	1,31,874	1.32
T_{16}	450	40	490	129	63,210	8.2	49,200	1,12,410	1.12

in time, upto November, when the plants were flowering, where the 100 g soil population was 38.6, 42.3 and 47.6 nematodes and the root population counts were 80.3, 114.6 and 177 nematodes per 1 g of root in the plants treated with 1,000, 10,0000 and 1,00,000 nematodes respectively. The final population counts of 100 g of soil were 7.8, 9.6 and 12.4 nematodes, which when multiplied to the total soil, the population was 46,800; 57,600 and 74,400 nematodes in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively. The final population of 1 g of root and affected rhizome was 27.6, 45 and 123.6 nematodes which when multiplied to the total affected portion, it was 14,711; 23,175; and 57,474 nematodes. The grand total population was 61,511; 80,775 and 1,31,874 nematodes with multiplication factors of 61.51, 8.08 and 1.32 in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively. The plants inoculated on 225 DAP after one month had 11.6, 14.6 and 21.6 nematodes per 100 g of soil and 1 g of root had 21.6, 30.3 and 67.3 nematodes in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively. The population increased in the month of November and reached maximum in December. Then it was 21.3, 24 and 40.3 nematodes in 100 g of soil, and the root population was 40.3, 65.6 and 174 nematodes, in the

plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively. The final population counts in the 100 g foil was 4.2, 7.4 and 8.2 nematodes, which when multiplied to the total soil, it was 25,200; 44,400 and 49,200 nematodes in the plants treated with 1,000, 10,000 and 1,00,000 nematodes respectively. The final root and rhizome population of 1 g sample was 16.2, 39.6 and 129 nematodes, which when multiplied to the total affected root portions, it was 8,910; 22,968 and 63,210 nematodes. The grand nematode population was 34,110; 67,368 and 1,12,410 nematodes with a multiplication factor 34.11, 6.74 and 1.12 in the plants treated with 1,000, 10,000 and 1,00,000 nematode population.

3.14 Effect of Nematode population and period of inoculation on plant characters.

To find the individual effect of nematode population and period of inoculation, the mean percentage reduction of different characters, under each inoculation period and under each inoculum level were compared and are presented in Table 5. Fig. 3a, 3b, 4a and 4b.

3.14.1 Duration of flowering: The effect of period of inoculation on the plants to come to flowering was found to be 17.23, 13.76, 10.4, 5.93 and 1.9 per cent less in the plants inoculated on 45, 90, 135, 180 and 225 DAP and the effect of nematodes was 8.46, 9.46 and

Table 5. Effect of Radopholus similis population and period of inoculation on yield and other components of banana.

5 a. Effect on yield

Initial inoculum level	Per cent reduction over control — No. of days after planting					Mean
	45	90	135	180	225	
1000	-35.79	-27.37	-26.32	-24.21	-10.53	-24.85
10,000	-36.05	-30	-28.42	-26.32	-18.42	-27-84
1,00,000	-36.84	-35.53	-29.21	-26.84	-23.68	-30.42
Mean	-36.23	-30.96	-27.98	-25.79	-17.54	

5 b. Effect on number of hands

Initial inoculum level	Per cent reduction over control — No. of days after planting					Mean
	45	90	135	180	225	
1000	-18.75	-31.25	-25	-25	-2.25	-20.45
10,000	-25	-25	-25	-18.75	-18.75	-22.50
1,00,000	-25	-18.75	-25	-18.75	-18.75	-21.25
Mean	-22.91	-25	-25	-20.83	-13.25	

5 c. Effect on flowering

Initial Inoculum level	Per cent reduction over control					Mean
	No. of days after planting					
	45	90	135	180	225	
1000	-15.44	-12.75	-8.39	-4.7	-1.01	-8.46
10,000	-17.11	-12.75	-9.73	-5.7	-2.01	-9.46
1,00,000	-19.13	-15.77	-13.09	-7.38	-2.68	-11.61
Mean	-17.23	-13.76	-10.4	-5.93	-1.9	

5 d. Effect on number of fingers

Initial Inoculum level	Per cent reduction over control					Mean
	No. of days after planting					
	45	90	135	180	225	
1000	-41.45	-33.3	-29.73	-25.23	-16.22	-29.19
10,000	-34.23	-33.33	-30.63	-29.73	-16.22	-28.83
1,00,000	-43.24	-40.54	-39.64	-30.63	-29.73	-36.75
Mean	-39.64	-35.73	-33.33	-28.53	-20.72	

5 d. Effect on weight of the corm

Initial inoculum level	Per cent reduction over control					Mean
	No. of days after planting					
	45	90	135	180	225	
1000	-31.83	-28.29	-20.24	-15.91	+5.89	-18.07
10,000	-35.95	-26.52	-22.39	-19.45	-4.14	-21.69
1,00,000	-44.79	-37.13	-21.61	-13.95	-2.16	-23.93
Mean	-37.52	-30.65	-21.41	-16.44	-0.14	

5 f. Effect on weight of the roots

Initial inoculum level	Per cent reduction over control					Mean
	No. of days after planting					
	45	90	135	180	225	
1000	-44.08	-42.43	-30.92	-20.23	-13.65	-30.26
10,000	-60.52	-36.67	-38.32	-28.45	-11.18	-35.13
1,00,000	-53.94	-46.54	-40.78	-32.56	-25.99	-39.96
Mean	-52.85	-41.88	-36.84	-27.08	-16.94	

5 g. Effect on length of the roots

Initial inoculum level	Per cent reduction over control					Mean
	No. of days after planting					
	45	90	135	180	225	
1000	-38	-32.8	-28.4	-24	-9.6	-25.56
10,000	-46	-39.2	-34	-30.8	-28	-35.6
1,00,000	-56	-51.6	-34	-32	-30	-40.72
Mean	-36.66	-41.2	-32.13	-28.93	-22.53	

5 h. Effect on number of roots

Initial inoculum level	Per cent reduction over control					Mean
	No. of days after planting					
	45	90	135	180	225	
1000	-27.03	-26.13	-4.96	-5.86	+9.0	-10.99
10,000	-28.83	-26.94	-25.68	-18.47	-2.70	-20.62
1,00,000	-31.53	-28.83	-25.68	-13.51	-11.26	-22.16
Mean	-28.79	-27.3	-18.77	-12.61	-1.65	

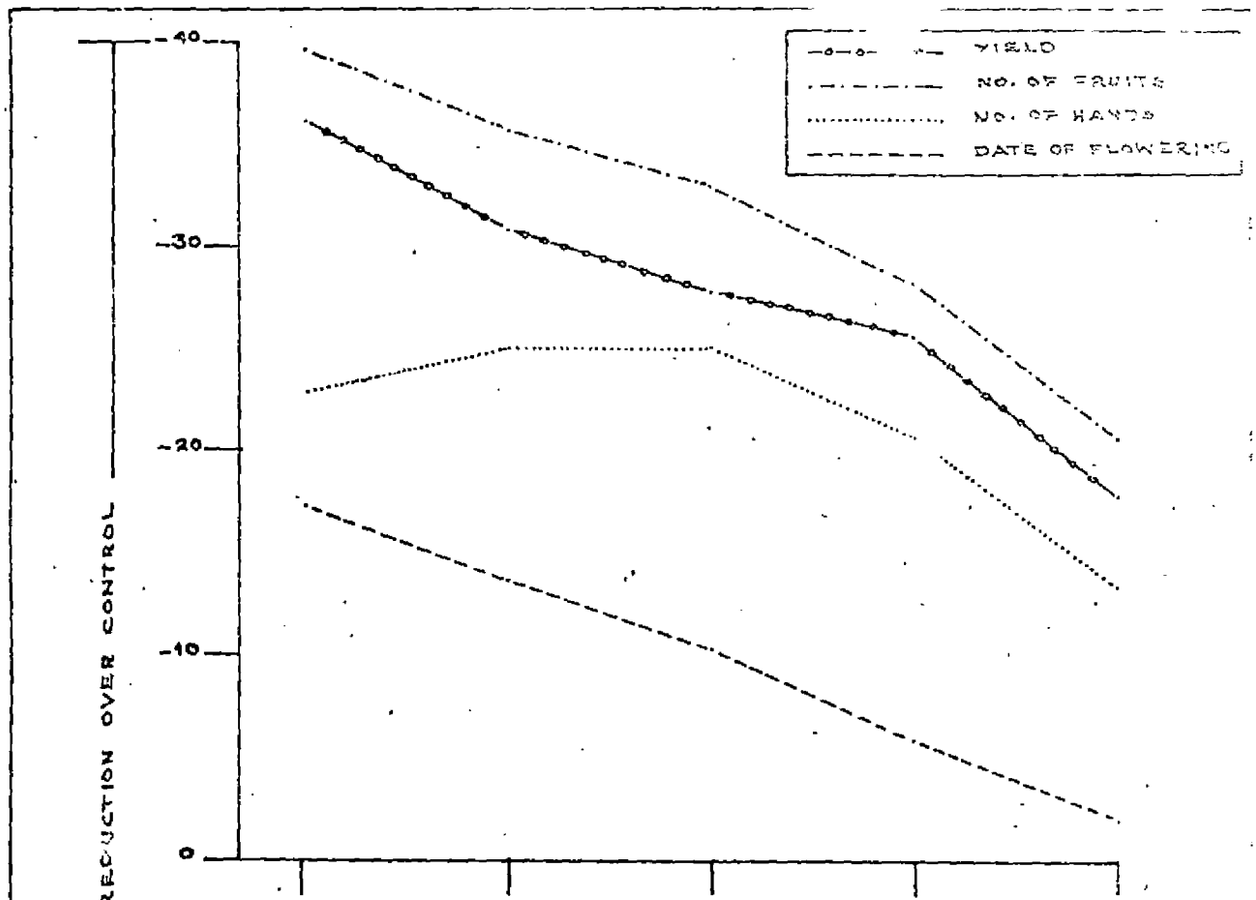

FIG: 3a. EFFECT OF PERIOD OF INOCULATION OF *Radopholus similis* ON YIELD COMPONENTS OF BANANA

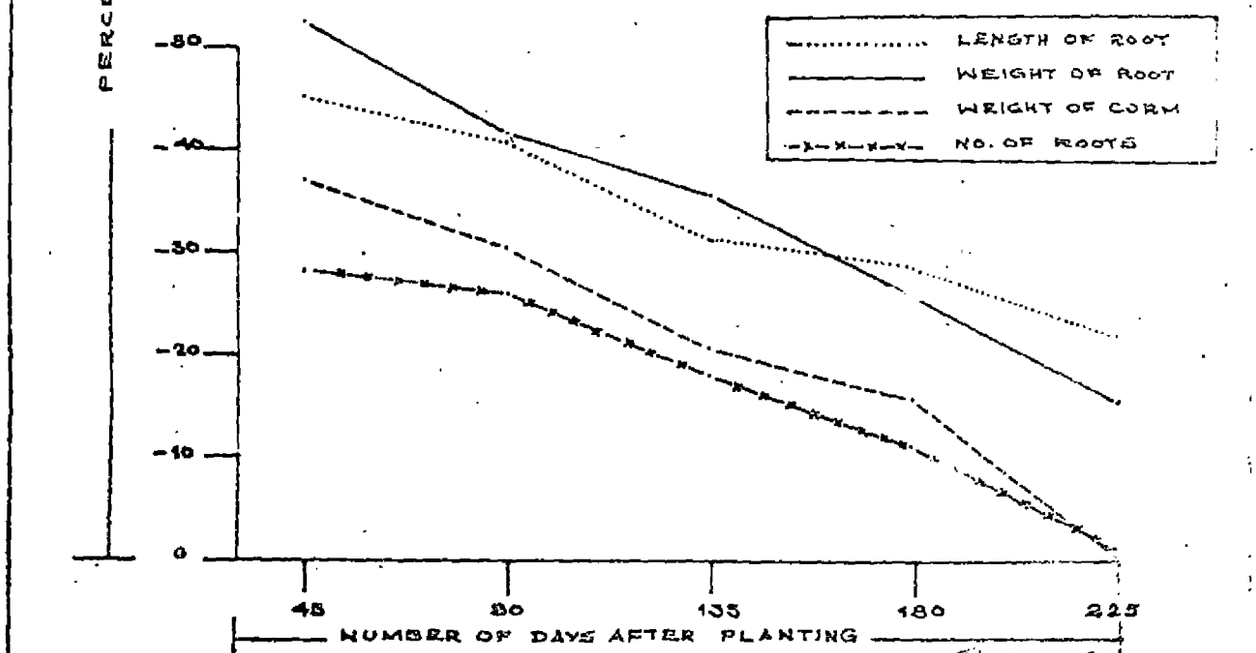

FIG: 3b. EFFECT OF PERIOD OF INOCULATION OF *Radopholus similis* ON ROOT CHARACTERS OF BANANA

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11.61 per cent less in the plants inoculated with 1,000, 10,000 and 1,00,000 nematodes respectively.

3.14.2 Yield: The total reduction irrespective of nematode population inoculated at 45 DAP was 36.23 per cent. It decreased gradually to 30.96 per cent at 90 DAP, 27.98 per cent on 135 DAP, 25.79 per cent reduction on 180 DAP and 17.54 per cent on 225 DAP inoculation. The effect of nematode population irrespective of its period of infection was 24.85 per cent for 1,000 nematodes, 27.84 per cent for 10,000 nematodes, 30.42 per cent for 1,00,000 nematodes.

3.14.3 Number of Hands: The reduction of number of hands on different periods of inoculation was 22.91 per cent on 45 DAP inoculation, 25 per cent on 90 DAP, 25 per cent on 135 DAP, 20.83 per cent on 180 DAP and 13.25 per cent on 225 DAP inoculation. The effect of nematode population alone was found to be 20.45 per cent for 1,000 nematodes, 22.5 per cent for 10,000 nematodes and 21.25 per cent for 1,00,000 nematodes.

3.14.4 Number of fingers: The effect of period of inoculation on the production of number of fingers was 39.64, 35.73, 33.33, 28.53 and 20.72 per cent reduction in the plants inoculated on 45, 90, 135, 180 and 225 DAP respectively and the effect of nematodes alone was 29.19, 28.83 and 36.75 per cent reduction for 1,000, 10,000 and 1,00,000 nematodes respectively.

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3.14.5 Weight of the corm: The effect of period of inoculation alone on weight of the corm was found to be 37.52, 30.65, 21.41, 16.44 and 0.14 per cent reduction in the plants inoculated on 45, 90, 135, 180 and 225 DAP respectively. The effect of nematodes on the corm weight was 18.07, 21.69, and 23.93 per cent reduction in the plants inoculated with 1,000, 10,000 and 1,00,000 nematodes respectively.

3.14.6 Weight of the roots: The effect of the period of inoculation on the weight of the roots was found to be 52.85, 41.88, 36.84, 27.08 and 16.94 per cent reduction in the plants inoculated on 45, 90, 135, 180 and 225 DAP respectively. The effect of nematodes alone was found to be 30.26, 35,13, 39.96 per cent reduction for 1,000, 10,000 and 1,00,000 nematodes respectively.

3.14.7 Length of the roots: The effect of the periods of inoculation on the length of the root was found to be 46.66, 41.2, 32.13, 28.93 and 22.53 per cent reduction in the plants inoculated on 45, 90, 135, 180 and 225 DAP respectively. The effect of nematodes was 25.56, 35.6 and 40.72 per cent reduction for 1,000, 10,000 and 1,00,000 nematodes respectively.

3.14.8 Number of roots: The effect of the period of inoculation on number of roots was found to be 28.79, 27.3, 18.77, 12.61 and 1.65 per cent reduction in the

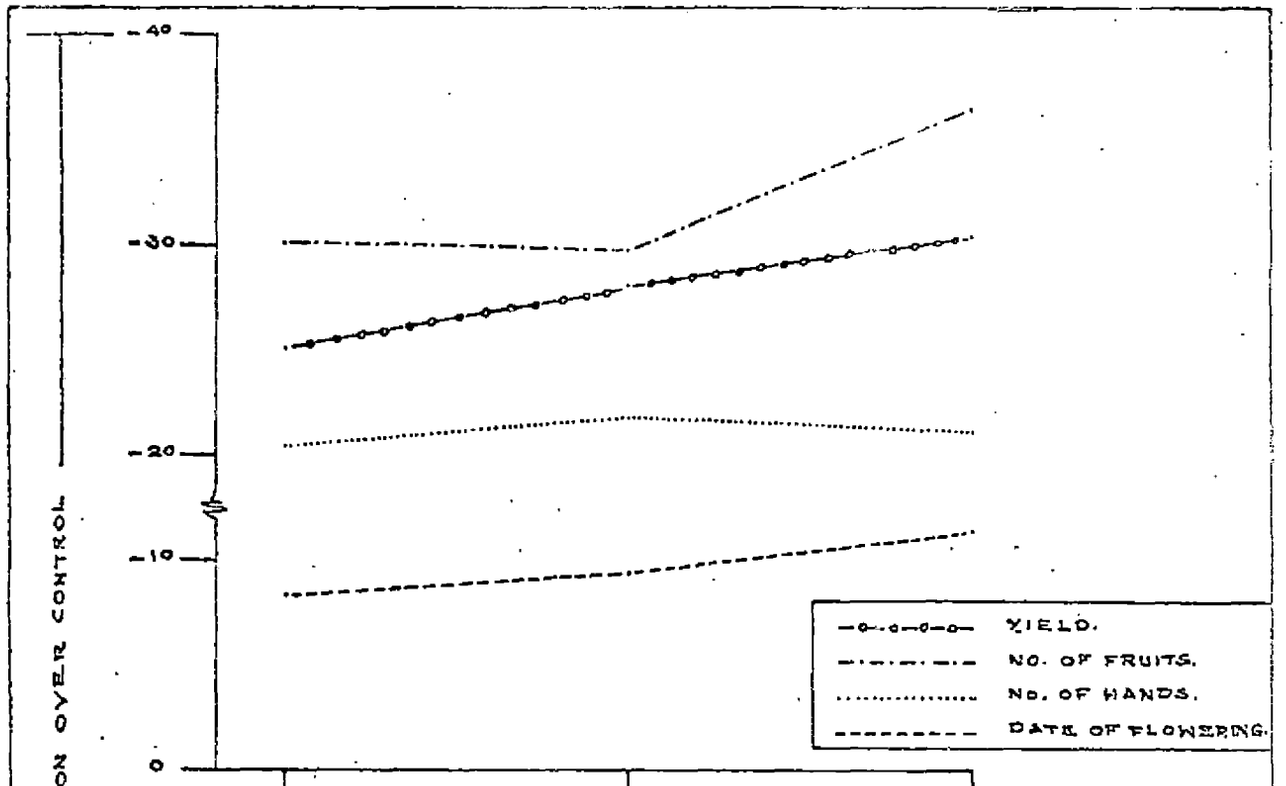

FIG. 4a. EFFECT OF NEMATODE POPULATION OF *Radopholus similis* ON YIELD COMPONENTS OF BANANA

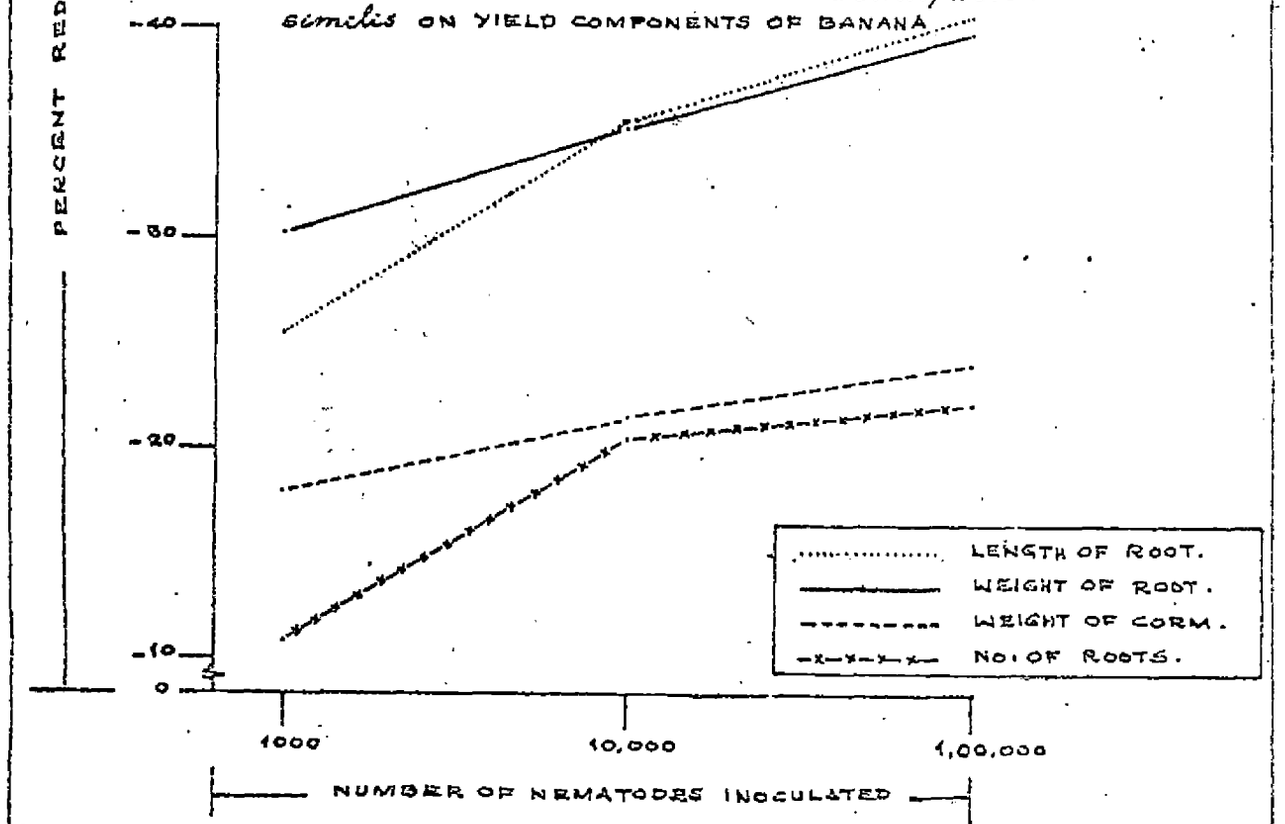

FIG. 4b. EFFECT OF NEMATODE POPULATION OF *Radopholus similis* ON ROOT CHARACTERS OF BANANA

plants inoculated on 45, 90, 135, 180 and 225 DAP respectively. The effect of nematodes was 10.99, 20.52, and 22.16 per cent reduction for 1,000, 10,000 and 1,00,000 nematodes respectively.

3.15 Histopathology.

3.15.1 Healthy root: As shown in the plate No.4a the healthy root appeared with all the tissues intact and colourless under the microscope. The epidermis was a continuous layer over the entire surface of the root consisting of single layer of cells, but in the root hairs, at the tip portion of root, uncutinized cell walls were seen. The cortex was seen as a thick layer of loosely packed parenchymatous cells with prominent nucleus, having more interspaces. The stelar portion was a solid rod like column in which the phloem and xylem vessles are seen. Pith region was separated from the cortex by endodermis, a continuous single layer of cells without inter cellular spaces.

3.15.2 Infected root: As shown in the plate 4 b and c, in the infected roots the epidermis of the root was intact except at the point of entry of the nematode where death of the cells was observed. But in the severely infected root the whole epidermis was found to be dead. In the cortex of the affected roots the cells were found to be damaged at the point of nematode feeding, which turned to reddish brown in colour. The cells walls of the affected

portion was damaged forming big cavities in the cortex. These cavities extended towards endodermis in severely infected roots. Hyperplasia and hypertrophy were not observed. Nuclei of the affected cells were found to be enlarged. In the very severely infected roots the whole cortex was found to be dead leaving only the central pith. Pith was not damaged even in the roots severely affected.

DISCUSSION

DISCUSSION

The present investigation comprises of pathogenicity and histopathology studies of the burrowing nematode Radopholus similis (Cobb, 1893) Thorne, 1949, on banana, variety Nenthran.

Though the burrowing nematode Radopholus similis was reported for first time in India on banana in 1966 from Kerala, the pathogenicity of the same has not been studied in detail. Hence the present studies on the burrowing nematode was undertaken.

The extent of damage caused by Radopholus similis on banana variety Nenthran, at three different inoculum levels was studied by using 1 cubic metre concrete pots. There was significant reduction in the growth and yield of banana plant at all the different levels tried. The effect of the nematode on 12 different plant characters was studied and the results are presented.

From Table 1, Fig. 1 a to e, Appendix I and Plate 1 a, b, c, it may be seen that the average height of the banana plant was considerably reduced due to the burrowing nematode infestation. The height of the plants on 45 DAP was 69 to 69.9 cm which did not differ significantly as there was no treatment prior to that. On 90 DAP also plants did not differ

Plate 1. Effect of Radopholus similis on the height of the banana plants.

a. Control plant

b. Plant treated with 1000 nematodes on 135 DAP

c. Plant treated with 1,00,000 nematodes on 45 DAP

Plate 1 a

Plate 1 b

Plate 1 c

significantly which grew to a height of 117.4 to 122.1 cm showing the inoculum of the nematode on 45 DAP had no influence on the plants upto 90 days. But on 135 DAP there was a significant difference in height in the plants treated on 45 and 90 DAP with 1,00,000 nematodes and with 10,000 nematodes on 45 DAP. The rest of the treated and untreated plants were on par with the control which shows that the plants treated earlier with high inoculum levels affected the normal growth of the plant. On 180 DAP the control plants as well as the untreated plants grew to a height of 198.2 cm. But there was a considerable significant reduction in the plants treated earlier with high inoculum (11.2 per cent reduction in the plants treated on 45 DAP with 1,00,000 nematodes) and the reduction was found to be less in the plants treated subsequently and with low inoculum levels, though there was also significant reduction. It shows a higher initial population and a longer period of infestation causes greater damage to the plant. On 225 DAP the control plants grew upto a height of 232.2 cm. By that time the plants inoculated earlier were at varying degrees of reduction in growth. The maximum reduction was noticed in the plants treated on 45 DAP with 1,00,000 nematodes (13.08 per cent). Varying degrees of reduction in height from 194 to 223 cm was observed in other treatments.

From the final height of the plants at flowering it may be seen that the reduction was more in the plants treated on 45 DAP and the reduction was proportionate in subsequent treatments. It was also observed that reduction was more in the plants treated with 1,00,000 nematodes than 10,000 nematodes, followed by 1,000 nematodes under each period of inoculation. Inoculation on 225 DAP could reduce the height slightly. This may be due to the fact that, by 225 DAP the plants were sufficiently established to cause any appreciable damage. It may be concluded that there is a direct correlation between reduction of the height of the plants and increased inoculum levels or increased infection periods. Similar reduction in height of the plant was reported by Sosamma et al. (1979) and Sundara Raju et al. (1979), who reported a reduction in the shoot length of 4 per cent and 39 per cent in turmeric and ginger respectively.

From Table 2, Fig. 1 a to e and Appendix II, it may be seen that on 45 DAP all the plants produced 6 to 6.4 leaves which were not significantly different, as evident from the fact that all the plants were free of any pathogenic organisms. Though the nematodes were inoculated on 45 DAP, the number of leaves produced on 90 DAP were 12 to 12.4 and 135 DAP 17.2 to 18.2 were which on par with the number of

leaves produced by control plants and the untreated plants. This again shows that inoculation of nematodes on 45 DAP had no influence on the production of leaves upto 135 DAP.

On 180 DAP there was a reduction in number of leaves on the plants treated on 45 DAP with 10,000 nematodes (4.1 per cent), 1,00,000 nematodes (5.74 per cent) and on 90 DAP with 1,00,000 nematodes (4.92 per cent). Remaining all other treatments including untreated and control were on par, indicating that only higher inoculum levels and longer infestation periods could cause a slight reduction in the production of leaves. The reduction in the production of new leaves was more conspicuous by 225 DAP in the plants treated earlier. There was a reduction of 5.92 per cent in the plants treated with 1,00,000 nematodes on 45 DAP and 90 DAP, 7.24 per cent and 5.26 per cent in the plants treated with 10,000 and 1,000 nematodes on 45 DAP respectively. All other treatments and untreated plants were on par with the control plants, which produced an average total of 30.4 leaves.

The final counts of leaves taken at flowering showed that the plants treated on 225 DAP produced 35 leaves, which were on par with the control plants, with 36.2 leaves, but a slight reduction was seen in the plants treated earlier. The results show that there was increased reduction with increase in the inoculum level and the period of infestation. Maximum reduction was seen in the plants treated on 45 DAP with

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1,00,000 nematodes (T_{12}) having 32 leaves. Price (1960) found that there was an increase in the number of leaves from 11.1 to 11.9 by the nematicidal treatment which otherwise would be a loss. Sosamma et al. (1979) and Sundara Raju et al. (1979) found a reduction of 14 per cent and 63.4 per cent in the number of leaves of turneric and ginger respectively. Thus it may be concluded that there will not be much effect on the number of leaves produced due to nematode attack on banana plant.

Girth of the pseudostem six inches above the soil was taken at 45, 90, 135, 180, 225 DAP and at the time of flowering and are presented in the Table 3, Fig. 1 a to 1 e and Appendix III. It was seen that on 45 DAP the pseudostem measured 19.6 to 21.1 cm all treatments are statistically on par. On 90 DAP all the plants had girth of the stem ranging from 35.4 to 36.4 cm and on 135 DAP also this girth of the plants were 41.4 to 42.5 cm statistically on par with control plants, showing that there was not much effect on the girth of the stem by the nematode infestation till 135 DAP. On 180 DAP observation the plants treated on 45 DAP and 90 DAP with 1,00,000 nematodes (45.1 and 45 cm respectively) differ significantly from control plants (47.4 cm). This shows that with an infestation period of 135 and 180 days and an initial inoculum level of 1,00,000 the girth of the plant could be reduced. From 225 DAP

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onwards the girth of the plants showed a greater reduction in plants inoculated earlier. A reduction of 5.93 and 5.14 per cent was observed in the plants treated on 90 DAP and 45 DAP with 1,00,000 nematodes. Corresponding reduction was observed in other treatments which statistically differ from control plants having 50.6 cm girth of the pseudostem. The girth of the pseudostem taken at the time of harvest shows that there was a significant reduction on all plants except those treated on 225 DAP. It may be inferred from this that there was no effect of nematodes applied after 180 DAP on the girth of the pseudostem. This finding is in agreement with Price (1960), who reported an increase of 9.7 inches in the girth of the pseudostem treated with DBCP when compated to untreated plants.

Table 4, Fig. 2 a and Appendix IV, shows that the plants treated on 45 DAP flowered earlier than all other treatments, i.e. on 241, 247 and 252 days after planting which were inoculated with 1,00,000, 10,000 and 1,000 nematodes. The plants treated on 225 DAP flowered almost along with control plants at 290 to 298 days. The other treatments flowered in between. Thus it is seen that the diseased plants flower earlier than the healthy ones and the earliness also depends upon the severity of the disease. The nematode infection might have caused some physiological

changes in the plant to throw out premature bunch. Such early flowering was also reported by Fisher et al. (1971) on banana; Sivapalan (1971) on tea and Vilsoni et al. (1976) on ginger. From Table 5 c it can be seen that the plants inoculated on 45 DAP flowered 17 days earlier for every 100 days of flowering period of the control plants. This early flowering was not very significant in other treatments as the period of inoculation advanced and the plants inoculated on 225 DAP flowered only 1.9 days in advance for every 100 days of flowering period of the control plants. Though the plants inoculated on 135 DAP flowered 10.4 days earlier for every 100 days of flowering period of control plants, the later inoculation did not have such an early flowering effect. So the plants inoculated before 135 DAP flowered much earlier showing its effect on the flowering. As there was not much effect of different levels of inoculum on early flowering as seen from the table, it can be said that irrespective of the number of nematodes the period of infection influences more on the flowering time.

The yield of the experimental plants presented in Table 4, Fig. 2 a, Appendix IV and Plate 2 a, b, c show that yield in control plants was 3.8 kg which was significantly superior to all other treatments. The plants treated on

Plate 2. Effect of Radopholus similis on yield of banana.

a. Bunch of the control plant (1)

b. Bunch of the plant treated with 1000 nematodes on 135 DAP (2)

c. Bunch of the plant treated with 1,00,000 nematodes on 45 DAP (3)

Plate 2 a

Plate 2 b

Plate 2 c

45 DAP showed maximum reduction in the yield with 35.79 to 36.84 per cent over control plants. As there was no significant difference among the three inoculum levels on 45 DAP it may be assumed that even 1000 nematodes at this stage can cause serious damage to the plants by the time, the crop is harnested. The plants treated on 90 DAP with 1,00,000 and 10,000 nematodes produced slightly heavier bunches (2.45 and 2.66 kg respectively) but they were statistically on par with the yield of plants inoculated on 45 DAP. Plants treated with 1,000 nematodes on 90 DAP (2.76 kg), was found to be statistically on par with other treatments except those plants treated with 1,000 and 10,000 nematodes on 225 DAP and control plants. Thus even 1,000 nematodes feeding on the plants from 45 days onwards could cause significant yield reduction. The plants treated on 180 DAP yielded the bunches weighing 2.78 to 2.88 kg, showing a significant reduction overcontrol. The plants inoculated on 225 DAP produced 2.9 to 3.4 kg bunches, though they were significantly less than the control plants, they had a moderate reduction. This denotes that the nematodes could cause yield reduction upto 180 DAP and afterwards it was negligible.

When the total effect of period of inoculation was taken as presented in the Table 5 a, Fig. 3 a, the yield reduced by 36.23 per cent in plants inoculated on 45 DAP, but was 25.79 per cent on 180 DAP. The reduction in yield

was only 17.54 per cent on 225 DAP. Thus it may be seen that the effect of nematodes on the plants till 180 DAP will be more and thereafter decreasing.

When the total effect of the nematodes population was taken as shown in the Table 5 a and Fig. 4 a, there was a steep increase in the percentage reduction over control from 24.85 per cent (at 1,000 inoculum level) 27.84 per cent (at 10,000 inoculum level) to 30.42 per cent (at 1,00,000 inoculum level). Thus it can be seen that with the increase in the inoculum levels, could not produce proponderence reduction in yield and that 1,000 nematode inoculum at 45 DAP is sufficient to cause appreciable reduction in the yield of the crop. It may also be seen that the population required to cause sufficient damage, depends upon the duration of its feeding and stage of the crop. Similar reduction in the yield was observed by many workers like Loos and Loos (1960 b), Mass (1969) and Adam and Rodrignez (1970).

Though the number of hands produced by the nematode inoculated plants did not differ statistically (Table No.4 and Fig.No.2 a) the control plants produced more number of hands, an average of 3.2 hands. The plants treated with 1,000 nematodes on 225 DAP produced 3 hands and all other treatments produced 2.4 to 2.6 hands. The least number of 2.2 hands was on the plants treated with 1,000 nematodes on 45 DAP. It may be inferred that there is no much effect

of nematodes on production of number of hands in a bunch. But there is a general trend of reduction in number of hands in the severely infected plants when compared to the healthy ones. Blake (1972) also reported a reduction in number of hands in the Radopholus similis affected banana plants.

When the effect of period of inoculation was compared (Table 5 b and Fig. 3 a) it was observed that maximum reduction of 25 per cent in number of hands in the plants inoculated on 90 and 135 DAP. But the reduction in number of hands is not much in other periods of inoculation. Hence it can be assumed that the number of hands produced will not greatly be influenced by the duration of nematode infection. When the effect of nematode population was compared (Table 5 b and Fig. 4 a) the reduction was almost same at all levels of inoculations.

As shown in Table 4, Fig. 2 b the average number of fingers produced by control plants were 22.2 and the plants severely infested i.e. inoculated on 45 DAP with 1,00,000 nematodes, produced only 12.6 fingers with 43.24 per cent reduction and there was a gradual increase in the number of fingers produced, under the later treatments. The plants treated on 225 DAP with 1,000 nematodes produced 18.6 finger which was almost equal to the control plants. Though the

number of fingers produced were not significantly differing among the treatments they were less when the severity of the infection was more. The same result was obtained by Blake (1972) also.

The effect of period of inoculation is presented in Table 5 d and Fig. 3 a. It is seen that the reduction in the number of fingers was maximum on plants inoculated earlier. Plants inoculated on 45 DAP had a reduction of 39.64 per cent, where on those inoculated on 135 DAP, had 33.33 per cent reduction. The reduction in number of fingers is still less on plants inoculated later on 225 DAP only with 20.72 per cent. This shows that inoculations before 135 DAP has got much influence than the periods after 135 DAP. It is seen that the 1,000 and 10,000 population reduced the number of fingers to almost same extent (29.19 per cent and 28.83 per cent). But 1,00,000 population caused severe reduction of 36.75 per cent. Hence to cause a severe reduction in number of fruits, a nematode population of more than 10,000 is required, but even 1,000 and 10,000 nematodes can also cause appreciable reduction.

As shown in the Table 4 and Fig. 2 b, the weight of the corm was more in the treatments given to the plants on 225 DAP with 1,000 nematodes (5.39 kg), than the control (5.09). The weight of the corm was gradually decreasing

with increased population levels and increased period of infestation and it was least in the treatment given on 45 DAP with 1,00,000 nematodes (2.81 kg) with 44.79 per cent reduction over control. It was also observed that the nematode affected corm portion was also increasing in this trend. It may be inferred that when nematodes feed on the roots, they decay and their main function of nutrient absorption will not be there and as a result the growth of corm, as well as the whole plant will be affected. Apart from this when there was increase in the population, they migrate to feed on the corm which will also get decayed and cause reduction in weight of corm. This was also established by many other workers like Loos and Loos (1960 b) who found the lesions extending upto 2.5 inches deep into the rhizome; Wehunt et al. (1965) and Nair et al. (1966) found the nematode attacking the corm. Sosamma and Sundara Raju (1979) individually found a reduction of 73.6 per cent in the weight of the rhizome in ginger and 76 per cent in turmeric. It is shown in Plate 3 c.

The reduction was maximum in the plants treated on 45 DAP (37.5 per cent) and it declined to 16.44 per cent in the plants treated on 180 DAP. It may only 0.14 per cent in the plants treated on 225 DAP which shows that the inoculation

upto 180 DAP has got its effect on the reduction on the weight of the corm as there was ample time for nematodes to feed and cause damage. But the plants which had already matured by the inoculation time of 225 DAP, there was no significant reduction and even increase over control plants was observed at lower inoculum levels. The reduction was less in the case of 1,000 nematodes (18.07 per cent) and increased with the increased inoculum levels (23.93 per cent at 1,00,000 population) which indicates a direct proportion of the reduction in corm weight to the inoculum level.

As shown in the Table 4 and Fig. 2 b, the weight of the roots in control plants was quite high (608 g) when compared to all other treatments, but on par with the plants inoculated on 225 DAP with 10,000 nematodes (540 g) and 1,000 nematodes (525 g). There was significant difference among other treatments. There was a decline in the weight of the roots of plants inoculated earlier with different levels of inoculum and the least weight was observed in the plants treated on 45 DAP with 10,000 nematodes (240 g) with a 60.52 per cent reduction and with 1,00,000 nematodes (280 g) with 53.94 per cent reduction. As the nematodes feed on the roots they decay and death of the distal portions occur. The nematodes migrate to the healthy root, as

suggested by Loos (1959), Blake (1961 b) and Rebois et al. (1966). As the period of infection on the root system increases, decaying of root will be more as shown in the root lesion ratings (Table 6) and root length (Table 4). These roots will be very light when compared to healthy roots as shown by Sosamma et al. (1979) and Sundra Raju et al. (1979) on turmeric and ginger.

The effect of the period of inoculation on root weight was more as shown in the Table 5 f and Fig. 3 b. As the period of infection was more, more reduction was observed ie. 52.85 per cent reduction in the plants treated on 45 DAP and it decreased gradually to 16.94 per cent on 225 DAP inoculation. It shows that even at the later stages of the crop there will be considerable damage to the root weight. The effect of nematode population was proportional to the inoculum level as shown in the Table 5 f and Fig. 4 b where it was 30.26 per cent at 1,000 inoculum, it was 35.13 per cent reduction at 10,000 inoculum and 39.96 per cent at 1,00,000 population which shows a direct proportion to the inoculum level.

As shown in the Table 4 and Fig. 2 b the control plants produced longer roots of 50 cm which was on par with the plants inoculated with 1,000 nematodes on 225 DAP with 45.2 cm root length. All other treatments differ significantly from control and also among themselves. A steady

decline in the length of the roots was observed with marginal differences in the treatments treated with different levels of inoculum on various inoculation periods. It was least in the treatment given on 45 DAP with 1,00,000 nematodes which produced roots of 22 cm.

As the nematodes feed on the roots the roots decay and death of the distal portion was observed, making the roots short of length. This was observed by many other workers also. Loos and Loos (1960 b) observed shortened root length. Blake (1961 b) observed that less than 10 per cent of the roots only had a functional length of more than 60 cm. When the effect of the period of inoculation was taken into account, as seen in the Table 5 g and Fig. 3 b. The plants inoculated on 45 DAP showed 46.66 per cent reduction and it declined thereafter and it was only 22.53 per cent in the plants inoculated on 225 DAP. It indicates that more the length of the period more will be the reduction in functional length. Even the inoculation at later stages (225 DAP) could cause the reduction of roots as the nematodes enter from the root tip and arrest the growth of the root as suggested by Du Charme (1959). The reduction was more in 1,00,000 nematodes (40.72 per cent) and a little lesser in the 10,000 nematodes (35.6 per cent) and still less in 1,000 nematodes (25.56 per cent)

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shows that, higher the inoculum level more will be the reduction in the length of the root.

The total number of roots produced by the plants (Table 4 and Fig. 2 b) treated on 225 DAP with 1,000 nematodes was 242 roots which was on par with the control plants (222), and there was a gradual reduction in the number of roots produced depending upon the level of inoculum and the period of inoculation. It was very few in the plants treated on 45 DAP with 1,00,000 nematodes which provided 152 roots with a reduction of 31.53 per cent. This shows that as the nematode population and its period of infection increase the number of roots produced by the plants will also be less. The roots produced might be decayed and well rotten before the plants were harvested. This was also proved by Vander Vecht (1950) who observed a reduction of 25.30 per cent reduction in the number of roots. Blake (1961) also found reduction in the number of roots. The reduction of 28.79 per cent was seen in the plants inoculated on 45 DAP (Table 5 h and Fig. 3 b) and it reduced to 12.61 per cent in plants inoculated on 180 DAP, but in the plants treated on 225 DAP the reduction was only 1.65 per cent which shows that the nematodes at later stages could not influence the production of the roots. From Table 5 h and Fig. 4 b, it was observed that both the 10,000 and 1,00,000 nematodes could cause almost equal

reduction (20.52 per cent and 22.16 per cent respectively) but the 1,000 nematodes could cause only 10.99 per cent of reduction which shows that high population was required to cause greater reduction in number of roots.

Table 6 and Plates 3 a and b, shows that the plants treated on 45 DAP were severely affected with increasing inoculum level as the percentage under the rating 5 (very severe infection) was very high 52.35 to 60.39. But there were no roots left without being attacked by nematodes in the inoculum levels of 10,000 and 1,00,000 nematodes. As the period of nematode infection was more, most of the roots were attacked by the nematodes and decayed which came under rating 5 amd very few roots were left with slight and moderate infection.

The plants treated on 90 DAP also expressed the same trend i.e. most of the roots were under rating 5 and increased with the inoculum levels, it was 40.37 per cent at 1,000 population, 47.72 per cent at 10,000 population and 60.38 per cent at 1,00,000 population. The number of roots at lower ratings were very few but more than the plants inoculated on 45 DAP. In 1,00,000 nematode treatment there were no roots under rating 1.

In the plants treated on 135 DAP, though the number of roots under rating 5 were more, there were

Plate 3. Effect of Radopholus similis on roots and corm of banana

a. Roots under different root lesion ratings ranging from 1-5

b. Longitudinal section of the roots showing lesions and unaffected steel

c. Nematode affected corm

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considerably more number of roots under lower root lesion ratings (18.18 to 18.66 per cent) at all levels of inoculum, under moderate infection i.e. rating 3, when compared to the previous inoculations and unaffected roots (rating 1) were also found to some extent. This shows that though there was severe damage to the root system, enough roots were left under lower root lesion ratings which could do their function and so there was only a moderate reduction in the plant growth.

In the plants treated on 180 DAP, 33.3 to 39.27 per cent of roots were under the rating 5, but comparatively the number of roots in slight infection (rating 2) and moderate infection (rating 3) were more than in the previous inoculations, which was directly exhibited by the plants in other growth characters with a slight damage to the plants except in the inoculum level of 1,00,000 population.

The plants in the treatment on 225 DAP showed almost a reverse trend except in 1,00,000 population i.e. plants under 1,00,000 population treatment produced 30.15 per cent of roots under rating 5, around 25 per cent of roots under rating 4 and 3 and 15 per cent under rating 2. This shows that there was considerable damage to the root system but, as the plant had already attained a

mature stage it could withstand the damage and exhibited growth characters equal to the other plants inoculated on the same day. But in the plants treated with 1,000 and 10,000 more number of roots were found under the rating 2 and 3 respectively. The number of roots were less at higher ratings and there were maximum number of unaffected roots (rating 1) in the plants treated with 1,000 nematodes. So these plants grew almost equally to the control plants in some growth characters and even more in some of the characters. Thus it can be concluded that as the period of infection and level of inoculum is more, more will be the roots under higher root lesions ratings and more will be the damage to the crop, as the number of functional roots are less in those plants when compared to healthy plants.

The growth of the nematode was also studied and compared by population counts in soil and roots of the experimental plants. Table 7 and 8 shows that the nematode population increased as the period of infection was increased. But the rate of increase in every successive month was not proportionate to the previous month. Population reached its maximum during flowering period of the plants under different treatments. The plants treated on 45 DAP and 90 DAP with all initial inoculum levels

along with the plants treated with 1,00,000 nematodes on 135 DAP (T_{14}), were found to be having maximum nematode population during October, when they flowered. The flowering commenced in the month of November in the plants treated with 1,000and 10,000 nematodes on 135 DAP and 180 DAP. Flowering was observed in the plants treated on 180 DAP with 1,00,000 nematodes in the month of November, where peak population was observed. In the plants treated on 225 DAP the maximum peak reached during December when they flowered along with control plants. In all the treatments nematode population declined after flowering. The nematode population fluctuation was in accordance with the results of Jaramillo and Figuroa (1974); Koshy et al. (1975) and Vilardebo (1976).

The nematode counts were high in the plants treated with 1,00,000 nematodes followed by 10,000 and 1,000 nematodes at all stages of the crop growth, but the difference in the nematode population at different initial inoculum levels narrowed as the age advanced, which may be due to population density as suggested by Du Charme (1968) in citrus.

The final population counts showed that the population was more in the plants treated on 45 DAP and gradually reduced in the other inoculation periods. But in the case of the inoculum level of 1,00,000 nematodes the root

population was increasing as the inoculation period advanced from 45 DAP to 225 DAP, which may also be attributed to the population density factor. However, the total population at the time of harvest was more in the plants treated on 45 DAP with 1,00,000 nematodes (1,50,432). There was a gradual reduction in the total number of nematodes with increasing inoculation periods. This reduction was more in the case of 1,000 nematodes, followed by 10,000 and 1,00,000 nematodes, which shows that the growth of the nematode population follows the increasing trend at lower levels of initial population than at the higher levels of initial population. This can be explained by the multiplication factor given in the Table 8. The multiplication factor was inversely proportional to the initial inoculum used and directly proportional to the period of nematode infestation. It was established by Du Charme and Price (1966); Sosamma et al. (1979) and Sundara Raju et al. (1979).

A highly significant negative correlation was obtained (-0.8865) between the nematode population and the yield as shown in the Fig. 5 and Appendix V. The data fits the equation $Y = C_1 Z^p$ (Seinhorst, 1965), which shows that, the yield was maximum at no nematode level, and declined sharply with the increase in the nematode population. The yield reached its minimum at a population of 1,40,000 nematodes and established thereafter.

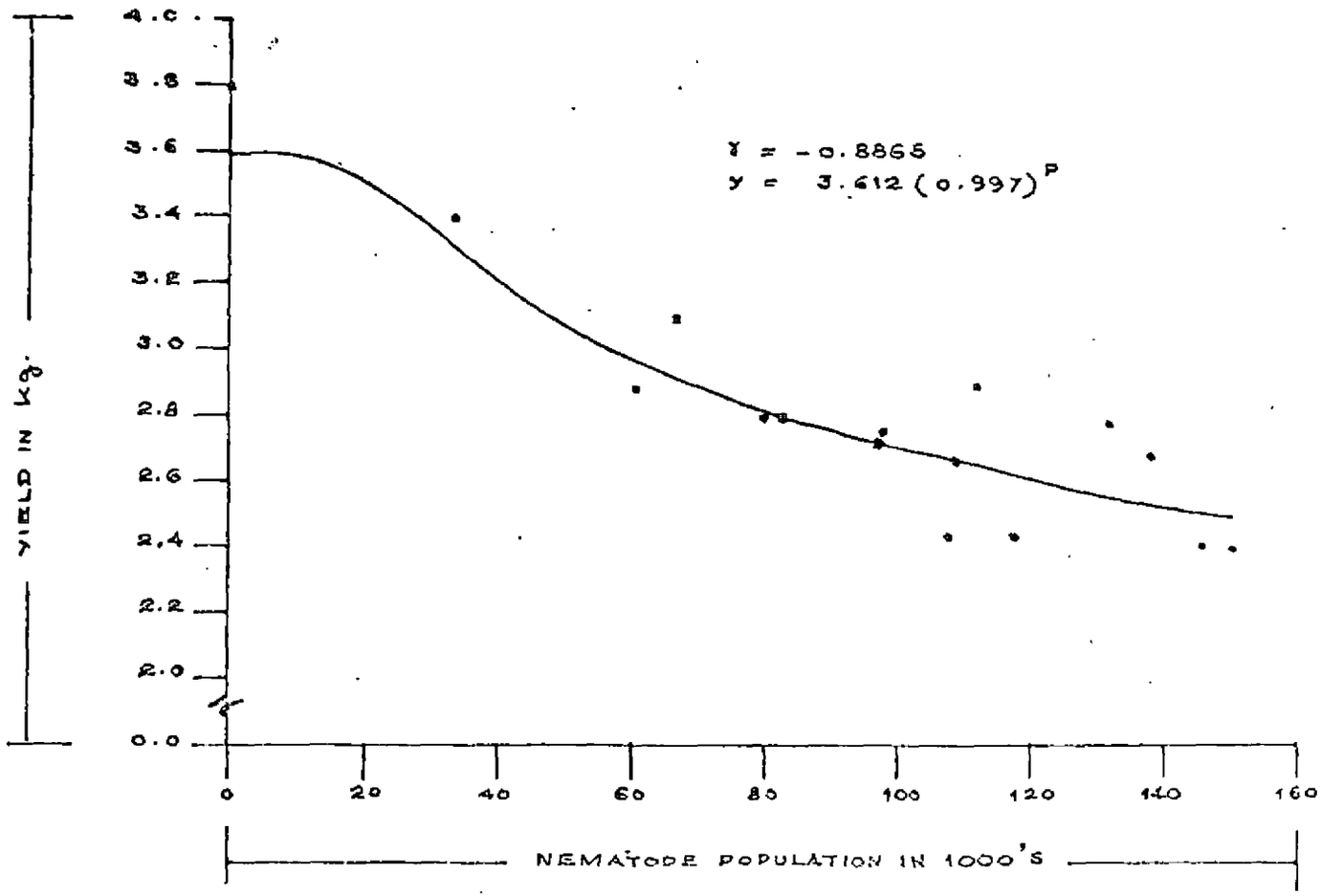

FIG: 5. REGRESSION CURVE - YIELD Vs NEMATODE POPULATION (BANANA) (*Radopholus similis*)

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Apart from the observed growth parameters, the nematode inoculated plants were found to be weak, stunted and with sickly appearance, as it was found by many workers like Suit and Du Charme (1953); Feder and Feldmesser (1956); Blake (1961 b); Decker et al. (1970) and Sundara Raju et al. (1979). As the diseased condition advanced the plants produced small and pale yellow coloured leaves, as it was observed by Fisher et al. (1971); Ichinohe (1976) and Venkatesan (1977).

The root system in the control plants was prolific, whereas, in the plants treated with nematodes it was poor, black in colour with small roots, having lesions. They also had cracks on the older roots and side roots were few. All typical symptoms of the nematode attack were also observed by Feder and Feldmesser (1956); Loos (1959); Blake (1961 a and b); Nair et al. (1966); Tomerlin and O'Bannon (1974) and Koshy et al. (1975).

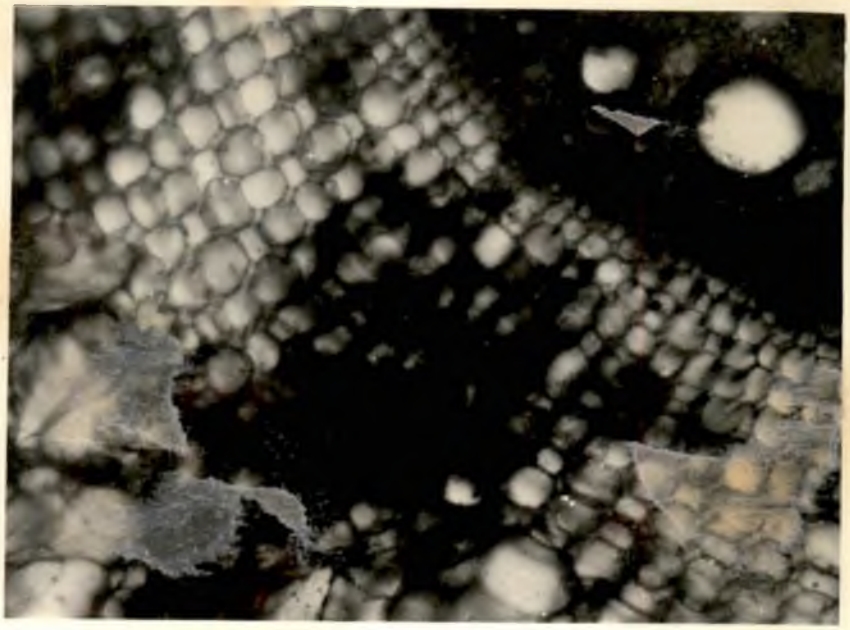
From the longitudinal and cross sections of the infested and healthy roots (Plate 4 a, b, c), it can be seen that extensive reddish brown lesions were found in the cortex, at which the cell walls found to be ruptured, forming necrotic tissue and cavities in the cortical region. Hyperplasia and hypertrophy was not observed. Even in the severely attacked root the stelar region was

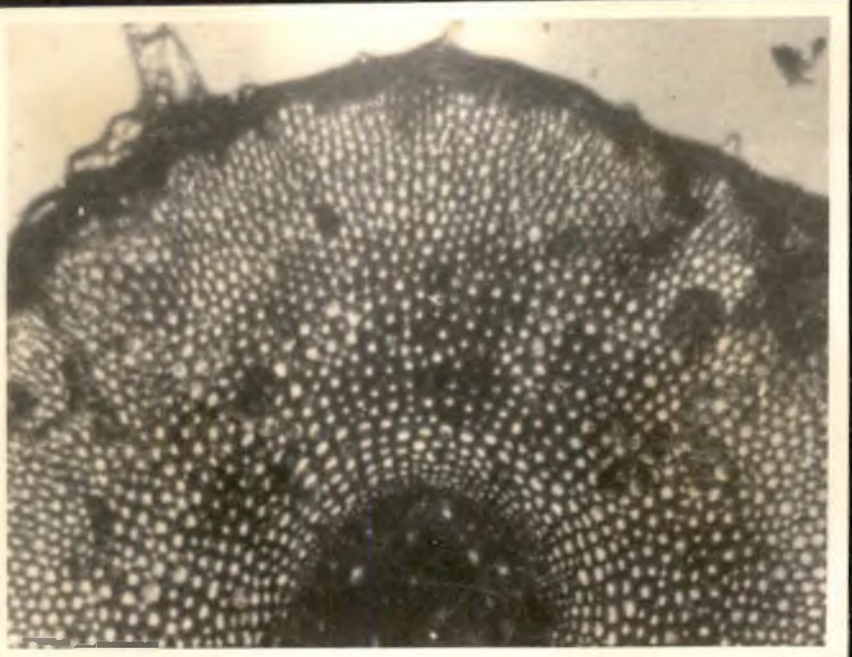
Plate 4. Histopathological changes of the nematode infested banana roots compared with healthy root.

a. Cross section of the healthy root

b. Cross section of the nematode infested root showing cavities in the cortex and unaffected pith

c. Longitudinal section showing the lesion in cortical cells





not damaged by the nematode, the reason attributed by Blake (1966) was that strongly developed endodermis in the banana roots, prevent the nematode from entering into the stelar region.

Such histopathological changes were also observed by workers like Vander Vecht (1950) on ginger, Blake (1966); Taylor (1969) on banana, Vilsoni (1976) on ginger and Venkatesan (1977) on pepper roots.

Thus it may be concluded that burrowing nematode infestation reduced the growth by 13.24 per cent in height 11.6 per cent in number of leaves and 4.95 per cent in the girth of the pseudo stem and 17.54 to 36.23 per cent in the yield of banana. An initial population of 1,000 nematodes during early growth stage is enough to cause growth reduction of 11.1 per cent in height, 7.73 per cent in number of leaves, 4.95 per cent in the girth of the pseudostem, 31.83 per cent in weight of the corm, 44.08 per cent in root weight, 38 per cent in root length, 27.03 per cent in number of roots and 35.79 per cent in yield. From the results it can be seen that the banana plant should be protected from this nematode upto a period of 180 DAP and infections after this time may not affect the plant significantly. The histological changes caused by the nematode had been brought out.

SUMMARY

SUMMARY

The pathogenicity of the burrowing nematode Radopholus similis, on banana was studied using Nenthran variety in pot cultures.

The experiment was laid out in randomised block design with 5 replications and 16 treatments. Pure culture of Radopholus similis was raised and multiplied on plant cultures and tissue cultures. Three levels of inoculum viz. 1000; 10,000 and 1,00,000 nematodes were inoculated at five different periods of the crop growth at an interval of 45 days from planting, i.e. 45, 90, 135, 180 and 225 days after planting on banana plants raised in concrete pots containing sterilised pot mixture. The plants were maintained by giving all recommended agronomic practices

Growth parameters like height of the plant, number of leaves and girth of the pseudostem were observed and compared. All the characters studied were significantly reduced on nematode inoculated plants over untreated plants. A proportional reduction with increase

in the inoculum level and period of infestation, was observed. A maximum reduction of 13.24 per cent in height of the plants, 11.6 per cent in number of leaves and 5.14 per cent in the girth of the pseudostem, was recorded in the plants treated earlier with 1,00,000 nematodes. The nematode population build up was also observed by taking 100 g of soil sample and 1 g of root sample. The nematode population increased as the time advanced during active growth period of the plant, but at decreased rate afterwards. They reached its maximum at the flowering stage of each plant and reduced thereafter. The rate of multiplication of the nematode was calculated and was found to be high for 1000 nematodes, ranging from 34.11 to 107.96 as the period of infestation increased and medium for 10,000 nematodes, ranging from 6.74 to 11.86 and least for the 1,00,000 nematodes 1.12 to 1.5.

Duration of flowering was found to be earlier in the infested plants. At the time of harvest three yield components viz. yield, number of hands and number of fingers were taken. Yield was found to be significantly higher in control. Maximum reduction of 36.84 per cent in yield was observed in the plants treated on 45 DAP

with 1,00,000 population. Other two characters were not significant, but a reducing trend was observed. Five underground plant characters were also observed at the time of harvest, viz. weight of the corm, weight of the roots, length of the roots, number of roots and the root lesion ratings. All of them were found to be significantly inferior in the nematode inoculated plants than the control plants with a maximum reduction of 44.79 per cent in corm weight, 53.94 per cent in weight of the roots, 56 per cent in the length of the roots and 31.53 per cent reduction in the number of roots, in the plants treated with 1,00,000 nematodes on 45 DAP. The same treatment had the maximum of 60.39 per cent roots severely affected under root lesion rating 5. All other treatments followed it based on the inoculum level and period of infestation. Apart from these, the nematode attacked plants were weak, stunted and produced small pale yellow coloured leaves. Histopathological studies revealed that the nematodes caused lesions in the cortex where the necrosis of cells and large cavities were observed. It was also found that the stelar region was not affected.

Based on the results it can be concluded that the damage done by the nematodes to the plant will be

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proportional to the initial inoculum level and time of inoculation. Even a population of 1000 nematodes at early stages will be sufficient to cause considerable reduction in the yield and other characters. The most susceptible period of infestation will be earlier to 180 days where maximum damage was recorded and the damage was negligible thereafter.

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* Originals not seen

Appendix - I

Date of observation	Degrees of freedom	Total S.S.	Treatment		Block df = 4		Error		'F'
			S.S.	M.S.	S.S.	M.S.	S.S.	M.S.	
45 DAP	Tot. 79 Tr. 15 Er. 60	1101.55	7.1	4.766	20.675	5.168	1073.725	17.896	0.266 N.S.
90 DAP	Tot. 19 Tr. 3 Er. 12	346.95	1.75	5.8333	126.7	31.675	218.5	18.208	0.320 N.S.
135 DAP	Tot. 34 Tr. 6 Er. 24	953.543	399.943	66.657	183.543	45.886	370.057	15.419	4.323**
180 DAP	Tot. 49 Tr. 9 Er. 36	2052.42	1690.42	187.824	126.52	31.63	235.48	6.541	28.75**
225 DAP	Tot. 64 Tr. 12 Er. 48	6263.754	5845.754	487.146	127.6	31.9	290.4	6.05	80.52**
At flowering	Tot. 19 Tr. 15 Er. 60	8755.89	8333.89	555.59	44.075	11.018	377.925	6.299	88.207**

N.S. - Not significant.

** - Significant at 0.05 and 0.01 levels.

Appendix - III

Date of observation	Degrees of freedom	Total S.S.	Treatment		Block d.f = 4		Error		'F'
			S.S.	M.S.	S.S.	M.S.	S.S.	M.S.	
45 DAP	Tot. 79 Tr. 15 Er. 60	138.3875	10.7875	0.719	4.2312	1.05	123.368	2.056	0.349 N.S.
90 DAP	Tot. 19 Tr. 3 Er. 12	21.75	0.55	0.1833	1.5	0.375	19.7	1.64	0.111 N.S.
135 DAP	Tot. 34 Tr. 6 Er. 24	36.243	6.543	1.09	5.457	1.364	24.248	1.01	1.079 N.S.
80 DAP	Tot. 49 Tr. 9 Er. 36	66.125	24.225	2.692	1.55	0.387	40.35	1.1	2.401*
25 DAP	Tot. 64 Tr. 12 Er. 48	77.961	33.1615	2.7634	2.038	0.509	42.7615	0.891	3.101**
At lowering	Tot. 79 Tr. 15 Er. 60	87.5469	35.3468	2.356	3.1562	0.789	49.043	0.817	2.88**

N.S. - Not significant.

* - Significant at 0.05 level.

** - Significant at 0.05 and 0.01 level.

APPENDICES

Appendix - I

Date of observation	Degrees of freedom	Total S.S.	Treatment		Block df = 4		Error		'F'
			S.S.	M.S.	S.S.	M.S.	S.S.	M.S.	
45 DAP	Tot. 79 Tr. 15 Er. 60	1101.55	7.1	4.766	20.675	5.168	1073.725	17.896	0.266 N.S.
90 DAP	Tot. 19 Tr. 3 Er. 12	346.95	1.75	5.8333	126.7	31.675	218.5	18.208	0.320 N.S.
135 DAP	Tot. 34 Tr. 6 Er. 24	953.543	399.943	66.657	183.543	45.886	370.057	15.419	4.323**
180 DAP	Tot. 49 Tr. 9 Er. 36	2052.42	1690.42	187.824	126.52	31.63	235.48	6.541	28.75**
225 DAP	Tot. 64 Tr. 12 Er. 48	6263.754	5845.754	487.146	127.6	31.9	290.4	6.05	80.52**
At flowering	Tot. 19 Tr. 15 Er. 60	8755.89	8333.89	555.59	44.075	11.018	377.925	6.299	88.207**

N.S. - Not significant.

** - Significant at 0.05 and 0.01 levels.

Appendix - II

Date of observation	Degrees of freedom	Total S.S.	Treatment		Block d.f = 4		Error		'F'
			S.S.	M.S.	S.S.	M.S.	S.S.	M.S.	
45 DAP	Tot. 79 Tr. 15 Er. 60	31.4875	1.487	0.09	2.05	0.5125	27.95	0.465	0.02 N.S.
90 DAP	Tot. 19 Tr. 3 Er. 12	8.55	0.55	0.1833	2.3	0.575	5.7	0.475	0.386 N.S.
135 DAP	Tot. 34 Tr. 6 Er. 24	17.543	3.943	0.657	0.971	0.243	12.628	5.261	1.248 N.S.
180 DAP	Tot. 49 Tr. 9 Er. 16	27.12	9.52	1.057	1.52	0.38	16.08	4.47	2.368*
225 DAP	Tot. 64 Tr. 12 Er. 48	54.861	25.2615	2.106	5.015	1.254	24.59	0.512	4.11**
At flowering	Tot. 79 Tr. 15 Er. 60	145.8	83.8	5.56	4.8	1.2	57.2	0.953	8.86**

N.S. - Not significant.

* - Significant at 0.05 level.

** - Significant at 0.05 and 0.01 level.

Appendix - III

Date of observation	Degrees of freedom	Total S.S.	Treatment		Block d.f = 4		Error		'F'
			S.S.	M.S.	S.S.	M.S.	S.S.	M.S.	
45 DAP	Tot. 79 Tr. 15 Er. 60	138.3875	10.7875	0.719	4.2312	1.05	123.368	2.056	0.349 N.S.
90 DAP	Tot. 19 Tr. 3 Er. 12	21.75	0.55	0.1833	1.5	0.375	19.7	1.64	0.111 N.S.
135 DAP	Tot. 34 Tr. 6 Er. 24	36.243	6.543	1.09	5.457	1.364	24.248	1.01	1.079 N.S.
180 DAP	Tot. 49 Tr. 9 Er. 36	66.125	24.225	2.692	1.55	0.387	40.35	1.1	2.401*
225 DAP	Tot. 64 Tr. 12 Er. 48	77.961	33.1615	2.7634	2.038	0.509	42.7615	0.891	3.101**
At flowering	Tot. 79 Tr. 15 Er. 60	87.5469	35.3468	2.356	3.1562	0.789	49.043	0.817	2.88**

N.S. - Not significant.

* - Significant at 0.05 level.

** - Significant at 0.05 and 0.01 level.

Appendix - IV

Character	Total df = 79 S.S	Treatment df=15 S.S	Treatment df=15 M.S	Block df = 4 S.S	Block df = 4 M.S	Error df = 60 S.S	Error df = 60 M.S	F
1. Yield	12.3787	10.2637	0.6842	0.0379	0.0094	2.077	0.0034	19.76**
2. Number of hands	25.8	4.6	0.306	0.925	0.23	20.275	0.3379	0.907 N.S
3. Number of fingers	1516.75	456.35	30.423	31	7.75	1029.4	17.1566	1.77 N.S
4. Duration of flowering	27,073.5	25,140	1676	103.5	25.87	1830	30.5	55.85**
5. Weight of the corm	45.3547	40.37	2.6913	0.2795	0.069	4.704	0.078	34.325**
6. Weight of the roots	10,084,80	7,154,50	47,696.66	7448.75	1862.1875	2,855,81.25	4,759.6875	10.02**
7. Length of roots	5781.55	3595.55	239.703	101.3	25.325	2084.7	34.745	6.898**
8. Number of roots	99,422.49	59,379.69	3958.66	337.425	84.36	39,705.375	661.76	5.98**

N.S - Not Significant

** - Significant at 0.05 and 0.01 levels

Appendix - V

Source	S.S.	d.f	M.S.	'F'
Regression	0.03397	1	0.03397	51.403^{**}
Error	0.00925	14	0.0006608	
Total	0.04322	15		

Correlation coefficient = r = -0.8865

$y = 3.612\ (0.997)^{p}$

PATHOGENICITY OF BURROWING NEMATODE, *RADOPHOLUS SIMILIS,* (COBB 1893) THORNE, 1949 ON BANANA

By

P. SATYANARAYANA

ABSTRACT OF A
THESIS
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VELLAYANI, TRIVANDRUM

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ABSTRACT

Pathogenicity of the burrowing nematode, Radopholus similis on banana was studied at the College of Agriculture, Vellayani, with three levels of population viz. 1000, 10,000 and 1,00,000 nematodes at five different growth stages of the crop starting from 45 days after planting and with 45 days interval. It was observed that the general growth of the plant was retarded. The reduction was directly proportional to the initial inoculum used and the period of infestation. A reduction of 36.84 per cent was seen in the yield of plants inoculated earlier with 1,00,000 nematodes and as high as 60.52 per cent reduction in weight of the roots in the plants treated with 10,000 nematodes.

Nematode population was found to reach its peak during the flowering season of the plant and decreasing thereafter. The multiplication of the nematode was observed to be inversely proportional to the initial inoculum level. Population of even 1000 nematodes at active growth stage was enough to cause severe reduction in the plant's growth. It was seen that plants could

withstand the damage caused by the nematode feeding at later stages i.e. after 180 days after planting. So the plants should be protected from the nematodes at earlier stages.

The histological changes in the roots infested by nematodes revealed that the nematodes feed on the cortical tissue causing reddish brown lesions on the roots and nematodes could not enter the stelar region of the root even under severely infested conditions.