STUDIES ON THE CYST NEMATODE OF RICE IN KERALA

BY

USHA KUMARI R.

THESIS

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1980

DECLARATION

I hereby declare that this thesis entitled "Studies on the cyst nematode of rice in Kerala" 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, followship, or other similar title, of any other University or Society.

Usha Kumari

USHA KUMARI. R.

Vellayani,
27th October, 1990.

CERTIFICATE

Certified that this thesis, entitled "Studies on the cyst nematode of rice in Kerala" is a record of research work done independently by Smt. Usha Kumari, R. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

Dr. K. JOHN KURIYAN
Chairman,
Advisory Committee,
Associate Professor of Nematology.

Vellayani,
27th October, 1980.

Approved by:

Chairman

Dr. K. JOHN KURIYAN

Members:

1. Dr. M.R.G.K. NAIR

2. Dr. S. BALAKRISHNAN

3. Smt. K. SARADAMMA

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INTRODUCTION

INTRODUCTION

Rice is one of the most important cereals and is the staple food of millions of people. Rice is cultivated in most of the States in India and it covers an area of 40,007,400 hectares. In Kerala, rice is cultivated in an area of 840,374 hectares producing 1,294,635 tonnes of rice (Farm Guide, 1980).

It is recognised that pests and diseases are a limiting factor in the production of rice. Among these nematodes have recently been reported to constitute a major threat to the rice production. Several soil inhabiting nematodes depend on plants to derive nutrition and also interrupt the uptake of nutrients and enhance the physiological and pathogenic disorders in plants (Rao, 1978).

The important parasitic nematodes associated with rice includes Heterodera spp., Meloidogyne spp., Aphelenchoides spp., Hirschmanniella spp., Ditylenchus spp., Hoplolaimus spp., and Pratylenchus spp. Among Heterodera, the important species are Heterodera oryzae, Heterodera elachista, Heterodera graminophila, Heterodera oryzicola and Heterodera saccheri.

An obscure leaf drying disease of paddy was reported from Bihar in 1962-'63 (Birat, 1965). Failure of rice crops in two successive years in the State Agricultural Farm in Berhampur, West Bengal due to lance nematodes (Banerji and Banerji, 1966) and depletion of vigour and chlorosis followed by reduction in tiller number due to the root lesion nematode were also observed in rice (Rao and Prasad, 1977). Leaf chlorosis similar to iron deficiency in modan lands of Kerala State due to cyst nematodes has been identified only recently (Rao and Jayaprakash, 1977).

Loss due to the rice root-knot nematode, Meloidogyne spp was estimated as 15 per cent in grain yield (Biswas and Rao, 1970) and that of Pratylenchus indicus as 48.5 per cent (Rao and Prasad, 1977). Yield loss due to Aphelenchoides besseyi was 41-71 per cent in U.S.S.R. (Tikhonova, 1966), 20-55 per cent in Taiwan (Hung, 1962) and 40 per cent in India (Muniappan and Seshadri, 1964).

The cyst forming nematodes of the genus Heterodera, are one of the most economically important groups of plant parasitic nematodes. Heterodera oryzicola was

first reported from Northern areas of Kerala in 1978 and later in 1979 in the southern parts indicating that this nematode had a wider distribution.

The extent of occurrence and damage by these nematodes on rice in Kerala has not been studied and hence the present work was undertaken.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Thirty two species of nematodes are known to be associated with rice plant. Hirschmanniella, Meloidogyne, Ditylenchus, Tylenchorhynchus, Heterodera and Aphelenchoides are the predominent genera among them (Ichinohe, 1972). Early work on nematodes of rice in India relates mainly to Soilar nematodes. Soil forms and root endoparasitic forms were reported from 1955 onwards. More nematodes were brought to light during 1960's (Rao, 1970).

Among the nematodes attacking rice plant in Kerala, Heterodera oryzicola was reported in 1978 (Rao and Jayaprakash, 1978) from Palghat district and later in 1979 from Trivandrum district (Anon, 1979).

Crop loss

It was found that grain weight of upland rice in Japan was decreasing from 1951 to 1954 by infestation with Heterodera oryzae, the yield being 2870, 3050, 1030 and 950 kg per hectare respectively (Watanabe et al., 1963).

Elkhonova and Smirnov (1969) reported that the losses caused by Heterodera avenae to spring wheat grown for successive years in an experiment plot were 18 to 20

per cent in the first year, 28 to 30 per cent in the second year and 66 per cent in the third year. Brown (1969) reported that the average losses in yield of potatoes due to Heterodera rostochiensis were 1.2 tons per acre at a concentration of 10 full cysts per 100g soil and 0.85 tons per acre to a concentration of 20 eggs per gram of soil.

Losses due to Heterodera glycines were 8 million dollars from 2 million acres in 9 States in U.S.A. in 1966. In Missouri alone 1.2 million bushels were lost in that year. This loss was associated with successive planting of soybeans and limited crop rotation(Hagge, 1969). Pawelska-Kosinska and Szota (1970) tested 23 varieties and strains of sugarbeet for their tolerance to Heterodera schachtii. Root yields in infested soil were reduced from 25 to 50 per cent of those in uninfested soil. Reduction in sugar content averaged 2 per cent. No differences in the degree of tolerance were found.

Vinduska (1971) investigated the relation between the number of Heterodera schachtii cysts in soil and the sugarbeet yield and reported that 40 per cent

decrease in yield was observed with 102 living cysts per 100g soil and 20 per cent by 353 cysts per 100g soil.

Nesterov and Bukhar (1971) reported that Heterodera schachtii was an important parasite of Brassica oleracea causing 50 per cent loss. Yield losses of about 30 per cent were caused by infestation of Heterodera rostochiensis at the rate of 30 eggs per g in sandy loam (Kyrou, 1971a).

Rhoades (1972) reported that in a glass house trial, population levels of 100 and 1000 cysts of Heterodera schachtii in 3 gal. crocks of steamed sandy soil failed to significantly reduce the growth of cabbage. A 2nd and 3rd planting in the same crocks reduced the growth by 32 and 72 per cent respectively. In pot experiments, 10 cysts per kg soil of Heterodera avenae on wheat and barley caused 10 per cent loss in yield. The loss increased gradually with increase in inoculum level reaching 64 per cent with 1250 cysts per kg of soil (Mukhopadhyaya et al., 1972).

Ishmaev (1974) reported that the oat cyst nematode was wide spread on wheat, oats and barley and caused

yield losses upto 60 per cent. Olthof et al. (1974) studied the relationship between population densities of Heterodera schachtii and losses in vegetable crops. Yield losses at the highest larval density of 18,000 larvae per kg of soil were 24 per cent for cabbage, 35 per cent for rutabagas, 30 per cent for table beet and 40 per cent for spinach.

Loss due to Heterodera elachista on rice was reported as 44-49 per cent in Japan (Ohshima, 1974). When paddy was grown in pots of soil inoculated with 0, 400 or 4000 larvae of Heterodera elachista, grain weights were 71.2, 67.2 and 59.5g per pot respectively (Shimizu, 1976).

Heterodera rostochiensis caused a total annual yield loss of 1.6 to 2.4 per cent (2 to 3 million dollars) in Greece (Koliopanos, 1976). Behringer (1976) reported that an initial density of 10 cysts per pot of Heterodera schachtii decreased the yield of sugarbeet by 15 per cent. Beet eel worms, (Heterodera schachtii) could reduce sugar yield and quality. Slight infestation caused a reduction of 5 to 15 per cent and a severe infestation, 40 per cent or even more (Behringer, 1977).

Mai (1977) reported that fields heavily infested with Heterodera rostochiensis and Heterodera pallida, produced yields less than the tubers planted and caused economic losses indirectly by interaction with other microorganisms resulting in even higher yield losses than those caused by the nematode alone.

Loss due to Heterodera oryzicola was estimated as 20 per cent on rice (Rao, 1978). Jakobsen (1978) reported that barley infested with 2 pathotypes of Heterodera avenae resulted in 5 to 10 per cent yield losses. An economic loss of 50 per cent due to Heterodera schachtii over the expected yield of sugarbeet was reported by Kondic et al.(1978).

Host range

Gill and Swarup (1971) reported 21 good hosts and 12 poor hosts from among 71 plant varieties tested for Heterodera avenae, Echinochloa frumentacea, Phalaris canariensis, Phalaris paradoxa, Polypogen monospeliensis and Senebeira pinnatifida were recorded as new hosts. The nematode larvae penetrated sorghum roots but no cysts were formed. Maize was confined as a host for the nematode.

Golden Birchfield (1972) described Heterodera graminophila from roots of barnyard grass and Echinochloa colonum (L.) Link. Morgan Golden and Dickerson (1973) described Heterodera longicolla from roots of buffalo grass, Buchloe dactyloides (Nutt.) Engelm. Odihirin (1975) found Heterodera saccheri on wild grasses viz., Paspalum conjugatum, Axonopus compressus, Mariscus umbellatus and Cynodon dactylon and Elusine indica. Starhan (1976) recorded Ammophila arenaria, Elymus arenarius and Puccinellia maritinia as new hosts of the cereal and grass cyst nematode, Heterodera hordecalis.

Nematode cysts containing viable eggs were recovered from bamboo grass (Paspalum fasciculatum). The cyst and 2nd stage juveniles resembled those of Heterodera graminis except the juveniles were larger. The nematodes failed to multiply on Cynodon dactylon. Cysts and 2nd stage juveniles resembling Heterodera graminis were also found in soil around Glycine max, Vigna unguiculata and Ipomoea batatas (Pannell, 1977).

Merney and Cadet (1978) studied the penetration of juveniles and development of adults of Heterodera oryzae, on 14 plant species and two rice cultivars and found that the

rate of penetration was high in soybean (Glycine max) and nil in Pennisetum typhoides, Panicum maximum, Solanum melongena and Capsicum frutescens. In the rice cultivars the proportion of juveniles developing into males was about 50 per cent. Development of females was observed in 7 species, but only in rice cultivar Moroberekan it was equal to half number of the larvae penetrating. In Zea mays and Mariscus umbellatus the proportion of female was quite high. In Glycine max, tomato, Pueraria phaseoloides and rice cultivar Guissy the proportion of females were very low.

A population of Heterodera isolated from bananas in Senegal was conspecific with Heterodera oryzae (Taylor, 1978). Jairajpuri et al.(1979) described Heterodera delvi from the roots of Eleusine coracana.

Control

In a 4 year field trial of soil treatment with D-D and DBCP, an increase of 20-70 per cent yield was obtained in Japan by controlling Heterodera elachista on rice (Yamada et al., 1962). Saly et al.(1964) recorded highest

yields of sugarbeet roots and tops after soil treatment with nemagon emulsion at 7.5 ml per sq.m. increased sugar content by 58.50 per cent and of tops by 28.60 per cent.

Gushova (1969) studied the combined effect of control of Heterodera rostochiensis using resistant potato varieties and tiazon (dazomet). The variety Segitta alon decreased population by 20 per cent, but the variety Antinoma decreased population by 77 to 88 per cent. The use of both dazomet and resistant potatoes decreased Heterodera rostochiensis numbers by 85 to 84 per cent in one year with a high yield of tubers.

Williams and Salt (1970) applied methyl bromide, chloropicrin, D-D, dazomet, formalin and mercury salts in the first year or in the first and second years, before drilling spring wheat and found that all sterilants except mercury decreased numbers of Heterodera avenae. Dazomet gave the best control of Heterodera avenae in the first year. Two successive application of chloropicrin gave the best nematode control.

In pot experiments, methyl bromide at 114 g per sq.m. reduced the number of Heterodera avenae on wheat

and improved plant growth and yield. D-D at 40 kg per 1000 sq.m. was less effective (Kyrou, 1971b).

Mukhopadhyaye et al.(1971) reported that D-D at 200 litres per acre proved effective both as a nematicide and for increasing grain yield on wheat infested with Heterodera avenae giving 2268 kg per acre compared with 642 kg per acre in the control.

Preplant fumigation against Heterodera schachtii in in cabbage with 1-3-dichloropropene and related hydrocarbons (D-D, Telone and Vidden D) at 20 or 30 U.S. gal. per acre and Agel TG-67 (67 per cent methyl bromide, 31.75 per cent chloropicrin and 1.25 per cent gel) at 240 lb per acre increased cabbage yields by as much as elevenfold (Rudewald et al., 1971). Best results were obtained with 1,3-D at 30 U.S. gal. per acre. Agel TG-67 although least effective increased yield compared to the control. Tacconi and Ugolini (1971) reported that D-D plus methyl isothiocyanate at 457.90 kg per hectare, dichloropropene at 323.50 kg per hectare and aldicarb at 4 and 6 kg per hectare gave significantly higher yields.

The nematicides D-D, EDB and nemagon were applied at 30, 6 or 4.5 kg per 1000 sq.m. respectively to plots of sandy loam soil infested with Heterodera rostochiensis. Potatoes grown subsequently after application of D-D gave better yields (Kyrou, 1971c). Deshmukh and Veischer (1971) concluded that the highest dose of temik at 3 ppm coupled with the use of resistant varieties was necessary to reduce the nematode population of Heterodera rostochiensis to an economic level.

Preplant treatment with D-D at 30 litres per 10 ares was most effective and increased the yield of paddy by about 30 per cent (Nishizawa et al., 1972). Similar treatment with EDB (30 per cent) was not effective as D-D and a higher cyst population was recovered. Another experiment indicated that cropping of soybeans or sweet potatoes decreased the cyst population remarkably at the end of the first season. Rice yields of plots, where there had been 3 successive crops of soybeans or sweet potatoes were as much as 3.7 or 2.8 times that of the plots where rice had been successively cultivated for 4 or more years.

Telone at 250 litres per hectare by injection, nemagon 60 per cent EC at 30 litres per hectare in furrows or D-D at 350 litres per hectare by injection was tried and the yield was increased by 128.50, 102.10, 78.90 and 38.30 per cent respectively. Nemagon gave the best cost benefit ratio followed by Telone (Bhatti and Dalal, 1972).

Shiabova and Sveshnikova (1972) reported that cultivation of resistant barley decreased Heterodera avenae population by 54 to 67 per cent in the first year and by 87 to 90 per cent in the 2nd year. The corresponding figures for the resistant oat were 74 and 88 per cent. The application of D-D at 500 kg per hectare decreased the nematode population by 99.7 per cent in the first year. Yield increase was observed in the first and third years following treatment with D-D.

Vinduska (1972) tested D-D and Nematin (metam-sodium) at 100, 150 and 200 cm^3 per sq.m. on Heterodera schachtii. The average yield increased with all treatments, with a maximum of 80 per cent over the control at a dose of 200 cm^3 per sq.m. D-D. A maximum reduction in infestation of about 75 per cent was obtained with 200 cm^3 per sq.m.

of nematin. Sugar yield also increased by the application of nematicides.

Whitehead et al. (1972a) reported that aldicarb at 5.2 or 10.3 g per hectare incorporated in the top soil before potatoes were planted controlled Heterodera rostochiensis better than D-D at 384, 769 or 1153 kg per hectare injected 15 cm deep into the top soil in the preceding autumn. The potato cyst nematode was controlled and yields of Majestic potatoes greatly increased when 1.2g aldicarb, 4.0g fensulphothion or 10.3g diazinon, disulphoton, 'Isolan' or thionazin per sq.m. were incorporated in the top soil before potatoes were planted. Diethyl phosphorothioates controlled Heterodera rostochiensis better than dimethyl phosphates (Whitehead et al., 1972 b).

Cooke et al.(1973) found an increase of 1 ton per hectare of sugarbeet by row-fumigation with 3.3 ml D-D or telone per m of row either 2 weeks or immediately before sowing or by aldicarb at 1.12 kg per hectare during sowing. Jones (1973) showed that dazomet at 200 and 350 lb per acre and dichloropropene at 24 gal. per acre, both applied in autumn, gave good increases in yields of potatoes on mineral soils but not on peat.

Dazomet at both rates substantially reduced the rate of multiplication of Heterodera rostochiensis and Heterodera pallida. Fenamiphos at 5 lb a.i. per acre applied both overall in autumn and in furrow in spring was less effective.

Whitehead et al.(1973a) found that aldicarb at 10.3 kg per hectare controlled Heterodera rostochiensis better than large amounts of dazomet at 110 to 466 kg per hectare or D-D at 102 to 439 kg per hectare. Dazomet at 329 or 439 kg per hectare applied to potato ridge, before potatoes were planted, controlled Heterodera rostochiensis in sandy loam and silt loam more effectively than D-D at 359 or 448 kg per hectare (Whitehead et al., 1973b).

Whitehead et al.(1973c)reported that application of three carbamoyl oximes, aldicarb, tripate and du Pont 1410 and one organophosphate, nemacur, all at 11.2 kg a.i. per hectare before susceptible potatoes were planted, greatly increased the yield of tubers and effectively controlled Heterodera rostochiensis. At the same dosage thionazin was as effective in peat loam.

Grujicic (1974) reported that temik 10G (aldicarb) granules applied at 5 to 10g per sq.m. during sowing of sugarbeet protected the plants against infection with Heterodera schachtii for 3 months. Harrison (1974) reported 99 per cent control of Heterodera rostochiensis on a susceptible variety of potato in infested soil, by foliar spraying with carbofuran at 2.24 or 8.96 kg per hectare and oxamyl at 1.12, 3.36 or 6.72 kg per hectare.

D-D at 600 litres per hectare, di-trapex at 600 litres per hectare, dazomet at 600 and 900 kg per hectare, nocap at 12 kg per hectare, nemacur at 20 and 30 kg per hectare, oxamyl G at 5 and 8 kg per hectare, oxamyl L at 5 and 3, and 7.5 and 4.5 kg per hectare were effective against Heterodera rostochiensis on potato (Mancini et al., 1974).

Treatments against Heterodera avenae of plots with temik or methyl bromide increased the yield of oats by 700 per cent and of barley by 270 per cent. The treatments by steam or with methyl bromide in containers completely destroyed Heterodera avenae, whereas temik merely prevented cyst formation on roots (Grosse, 1975).

Griffin (1975) could control Heterodera schachtii with foliar application of phenamiphos or oxamyl on sugarbeets under green house conditions. A treatment with either phenamiphos or oxamyl at 2,000 µg per ml resulted in the greatest increase in plant growth, and 4000 µg per ml gave the best nematode control.

Whitehead et al.(1975) reported that incorporation of nemacur at 11.2 kg a.i. per hectare to a depth of 20 cm in peaty loam in spring, controlled Heterodera rostochiensis and 5.6 kg incorporated in winter before ploughing followed by another dose of 5.6 kg incorporated in the seed bed in spring was found very effective.

Tanaka (1976) found that the damage caused by Heterodera oryzae was prevented by soil fumigation with chloropicrin or D-D and suggested that flooding during the rice growing period controlled the nematodes. Swarup et al. (1976) found that D-D at 300 litres per hectare and DBCP at 45 litres per hectare to be the optimum dose for effective reduction in nematode population as well as yield increase in barley.

Potter and Marks (1976) tried various combinations of oxamyl as soil drenches at 6.7 kg a.i. per hectare and foliar sprays at 0.04 kg a.i. per 100 litres of water to cabbage seedlings and found that pretransplant drenches provided some control of Heterodera schachtii over a 13-week period. A pretransplant or transplant drench combined with a foliar application 2 weeks after transplanting provided the most effective control.

Moss et al.(1976) concluded that aldicarb or oxamyl at 5.6 kg per hectare incorporated in the soil 15 cm deep before susceptible potatoes were planted, controlled potato cyst nematodes, Globodera rostochiensis and Globodera pallida. Nemacap 10 per cent and fostil 7.5 per cent were tested against Heterodera rostochiensis on a susceptible potato variety at 120, 200 or 280 kg per hectare and on a resistant variety at 80 or 100 kg per hectare. Treatment was effective only on the resistant variety (Gladkaya, 1976). Application of 5 ml of a 38 per cent aqueous solution of formaldehyde to 1500 ml of sandy loam prevented multiplication of Heterodera rostochiensis on susceptible potato variety and resulted in increased yields (Whitehead, 1976).

According to Griffin (1977), the sugarbeet yields using aldicarb 15G at 30 kg per hectare compared favourably with yields using D-D or 1,3-D.

D-D, furadan, temik 15G and telone II applied alone or in combination to sugarbeet grown in soil infested with Heterodera schachtii gave consistently higher yields. Furadan and temik 15G alone were less effective (Hontzas et al., 1977). Ouden and Van De Veer (1977) found aldicarb broadcast before planting reduced multiplication of Heterodera rostochiensis by 40, 55 and 21 per cent in different years. Methomyl and oxamyl were not effective as aldicarb. Phenamiphos and fensulphothion gave no significant difference although phenamiphos had a greater effect than fensulphothion.

Mackintosh et al.(1977) reported that aldicarb at 3.4 kg a.i. per hectare, oxamyl at 56 kg a.i. per hectare, carbofuran at 5.6 kg a.i. per hectare and dazomet at 224 or 336 kg per hectare increased the yields of potato in soil heavily infected with Globodera rostochiensis. Meagher et al. (1978) found that aldicarb at 9 kg per hectare increased yield of wheat by 33 per cent, MB/CP

(methyl bromide and chloropicrin) at 4 kg per hectare by 24 per cent and MB/CP at 450 kg per hectare by 56 per cent. Combination of nematicide treatment with nitrogen fertilization further increased the yields.

Steudel et al.(1978) got increased yields of 7 per cent, tops by 5 per cent (9 year means), and sugar content by 0.11%S by temik 106 at 50 kg per hectare applied in a 5 to 10 cm wide band along rows of sugarbeet immediately after sowing. The rate of nematode build up was also diminished. Stanz et al.(1978) got 94 per cent less number of eggs and larvae per cyst by application of oxamyl at the time of inoculationof Heterodera schachtii on table beet roots. Plants treated with oxamyl one week after inoculation had as many white females per gram of roots, but the resulting cysts contained 78 per cent fewer eggs and larvae.

Kotlinski (1978) concluded that optimal dose of D-D was 250 to 280 litres per hectare and the average yield increase in all experiments for all crops was 36 per cent. Griffin (1978) found preplant application of aldicarb at 30 kg per hectare, against Heterodera schachtii resulted in higher yield increase in sugarbeet than after

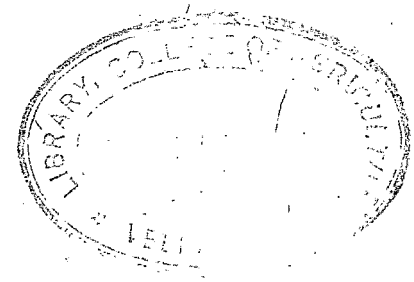
planting. Aldicarb was more effective when the soil moisture content was at 80 per cent field capacity.

Mugniery (1978) reported that the application of D-D to soil infested with Globodera rostochiensis and Globodera pallida resulted in a reduction in the number of viable larvae by 81 per cent and 98 per cent respectively. Prophos and carbofuran also reduced infestation of potatoes by 80 per cent.

O' Brien (1978) tested carbofuran, aldicarb and resistant host on development of Globodera rostochiensis on potato and found that aldicarb at 5.5 kg a.i. per hectare reduced the nematode population by 50 per cent.

In tests combining the use of a (Globodera) - resistant potato variety and a nematicide (curaterr or nemacur), applied 2 week before planting, the nematode population was reduced by 68 per cent with the resistant potato alone, 82 per cent with the potato preceded by curaterr at 5 kg per hectare and 87 per cent with the potato preceded by nemacur at 5 kg per hectare. The relative yields obtained from the above tests were 100,167 and 148 respectively (Nemagen, 1980).

MATERIALS AND METHODS



MATERIALS AND METHODS

In the present investigation, the paddy variety, Triveni, obtained from the Instructional Farm, Vellayani was used for maintenance of culture as well as for the different experiments.

Maintenance of culture of Heterodera oryzicola

The infested plots of paddy in Vellayani served as the source of inoculum of Heterodera oryzicola. Soil from the infested plot was collected at a depth of seven to fifteen cm, along with roots and mixed with farm yard manure. This was then filled in thirty cm earthen pots and the paddy variety Triveni was grown for the build up of the culture. After three months all the pots were emptied and roots were cut into small pieces and again mixed with the same soil. This was again filled in fresh pots and 3 to 5 seedlings were grown in each pot. In this way the culture was maintained and on the roots bigger cysts with more eggs were obtained.

Collection of cysts

In the present investigation the following method for collection of cysts was followed. One hundred gram of the

infested soil was placed in a polythene basin and covered with water. The soil particles were broken with hand to get a good suspension. This suspension was passed through 20 and 60 mesh sieves. The residue on 60 mesh sieve was collected. The old and empty cysts which floated on the surface of water was decanted off. The newly formed yellow and brown cysts settled down were hand picked. Cysts thus picked or one day old larvae obtained from these were used for various experiments.

E. Crop loss studies by cyst nematode Heterodera oryzicola on rice

The extent of damage done by the cyst nematode Heterodera oryzicola on rice was studied by a microplot field experiment and pot culture experiment.

A. Microplot field experiment

This experiment was conducted in the paddy fields of the Instructional Farm of the College of Agriculture, Vellayani, during November 1979, which was free of any cyst nematode.

Design

A field microplot trial was laid out in Randomised Block Design with 5 treatments including control and 6

replications. Each microplot was 1m x 1m size and had 40 plants at a spacing of 15 cm x 10 cm. The treatments were:

1. T_1 (check) - no larvae
2. T_2 - 6,000 larvae per sq.m.
3. T_3 - 9,000 larvae per sq.m.
4. T_4 - 12,000 larvae per sq.m.
5. T_5 - 18,000 larvae per sq.m.

Paddy nursery was raised in a nematode free area and 30 days old seedlings were transplanted to the experimental plots and the field around. After the establishment of the plants, i.e., after 7 days of transplanting, the cyst nematode culture was inoculated at the above rate in each microplot, uniformly around each plant.

The crop was given all recommended cultural operations and plant protection measures as and when necessary (Package of Practices, KAU 1978).

At harvest, 85 days after transplanting, five plants were selected at random from each microplot and the following observations were taken.

1. Height of plants
2. Number of tillers
3. Length of earhead
4. Number of leaves
5. Total yield per plant
6. Grain weight per plant
7. Chaff weight per plant
8. Weight of shoot
9. Weight of root
10. Total yield per plot
11. Grain weight per plot
12. Chaff weight per plot
13. Nematode population per 100 ml soil
14. Total number of cysts per plant
15. Cyst count per 100 ml soil

Estimation of nematode population from soil

A composite sample of 100ml soil was collected from each microplot and processed for extracting nematodes by the modified method of Cobb's decanting and sieving technique (Christie and Perry, 1951). The nematode suspension was drawn out at every 24 hours and counted until the suspension was nematode free.

Estimation of cyst population in roots

Roots from plants selected at random from each plot were cut into small pieces and were examined directly under stereoscopic microscope for attached cysts and the cysts were counted.

Estimation of cysts in soil

A composite sample of 100 ml soil from each plot was collected as described and the cysts were counted.

The above methods were used in all the experiments.

D. Pot culture experiment

A pot culture experiment was conducted with the following treatments.

T_1 (check) - no cysts
T_2 - 5 cysts per pot
T_3 - 10 cysts per pot
T_4 - 20 cysts per pot
T_5 - 30 cysts per pot

Earthen pots of size 20 cm were filled with sterilised wet land soil and paddy seeds were dibbled in each. The

plants were thinned to 4 plants when they have established and were inoculated with cysts at the above rates. The plants were maintained by giving recommended cultural operations (Package of Practices, KAU 1978). At harvest 105 days after planting the following observations were taken:

1. Height of plants.
2. Number of leaves.
3. Number of tillers.
4. Length of earhead.
5. Total yield per plant.
6. Weight of grainsper plant.
7. Weight of chaff per plant.
8. Weight of shoot.
9. Weight of root.
10. Nematode population per 100 ml soil.
11. Total number of cysts per plant.
12. Cyst count per 100 ml soil.

II. Host range studies

Wet land weeds found in paddy fields in Vellayani were examined for infection by this cyst nematode. These weeds were planted in earthen pots of size 20 cm, containing

sterilised wet land soil and inoculated with one day old larvae of the nematode and observed for any infection and development of the nematode. The following 14 different plants thus collected from paddy fields were screened for this purpose.

1. Paspalum commersonii Lamk.
2. Digitaria biformis Willd.
3. Fimbristylis miliacea Vahl.
4. Eragrostis tenella (Linn.) P. Beauv.
5. Kyllinga monocephala Rottb.
6. Cyperus diffusus Vahl.
7. Cyperus iria Linn.
8. Cyperus eleusinoides Kunth
9. Axonopus compressus (Swartz) P. Beauv.
10. Echinochloa colonum (Linn.) Link
11. Alternanthera sessilis Br.
12. Scirpus articulatus Linn.
13. Monochoria vaginalis Presl.
14. Vallisneria spiralis Linn.

III. Control of Heterodera oryzicola

Pot culture experiments were conducted for controlling

the cyst nematode, Heterodera oryzicola, with two sets of main treatments viz.(1) dibbling the paddy seed directly after seed treatment(2) transplanting paddy seedlings after seedling dip the following were the sub treatments.

T_1 = Carbofuran (Furadan) - 0.02% solution.
T_2 = Aldicarb sulfone (Aldoxycarb) - 0.02% solution.
T_3 = Phenamiphos (Nemacur) - 0.02% solution.
T_4 = Dibutylaminosulfanylcarbofuran (MIC) - 0.02% solution.
T_5 = Phorate (Thimet) - 0.02% solution.
T_6 = Control.

The treatments were replicated 6 times.

Dibbling the paddy seeds

In this experiment the seeds were treated with the above chemicals (0.02% solution) by soaking the seeds in each for 12 hours, and sown directly in infested soil in pots.

Transplanting paddy seedlings

In this experiment the seedlings raised in sterilized wet land soil were given root dips, for 12 hours in 0.02

per cent solutions of the above chemicals and transplanted in infested soil in pots. The paddy plants were maintained giving all recommended practices (Package of Practices, KAU 1978). At harvest i.e. after 105 days of sowing or 85 days of transplanting, the following observations were taken.

1. Height of plants.
2. Number of leaves.
3. Number of tillers.
4. Length of earhead.
5. Total yield per plant.
6. Weight of grains per plant.
7. Weight of chaff per plant.
8. Weight of shoot.
9. Weight of root.
10. Nematode population per 100 ml soil.
11. Total number of cysts per plant.
12. Cyst count per 100 ml soil.

RESULTS

RESULTS

I. Crop loss studies by cyst nematode Heterodera oryzicola on rice

A. Microplot field experiment

A microplot field experiment on rice was conducted to the study the extent of loss caused by Heterodera oryzicola at the inoculum levels of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. Their effect on 12 different characters of paddy plant and 3 characters on the cyst nematode themselves were estimated and the results are presented.

1. Height of the plant

The height of the plants at the different inoculum levels are presented in Table 1 and Appendix I. The average heights were 75.37, 74.67, 73.03 and 72.80 cm at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. respectively. There was a reduction of 4.39, 5.28, 7.36 and 7.65 per cent (Fig.1) in height of the plant over control, under field conditions.

2. Number of tillers

The average number of tillers produced under the different treatments are presented in Table 1 and

Appendix I. There were 8.77 tillers in control bgt the numbers were reduced to 7.07, 6.57, 6.33 and 6.27 at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. by the effect of nematodes. The reduction was to the extent of 19.38, 25.09, 27.82 and 28.51 per cent under the different treatments (Fig.1).

3. Number of leaves

The average number of leaves at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. were 25.90, 23.57, 22.93 and 20.70 and are presented in Table 1 and Appendix I. In control the number of leaves observed were 28.80. There was a reduction of 10.07, 18.16, 20.38 and 28.13 per cent in the number of leaves.

4. Length of earhead

The earhead length at harvest are presented in Table 1 and Appendix I. The length was 19.02, 17.52, 17.24 and 17.02 cm at 6,000, 9,000, 12,000 and 18,000 sq.m. and in control it was 20.53 cm. The reduction under the various inoculum levels were 7.36, 14.66, 16.03 and 17.10 per cent (Fig.1).

5. Weight of shoot

The mean weight of the shoot was 40.09, 35.91, 32.17 and 29.32 g per plant (Table 1 and Appendix I) at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. while in control the weight observed was 45.36g. The percentage reduction in shoot weight was 11.62, 20.83, 29.08 and 35.36 respectively in the different treatments(Fig.1).

6. Weight of root

The average weight of root under the different treatments are presented in Table 1 and Appendix I. The weight of the root was 13.72, 10.50, 10.21 and 8.95 g at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. and in control the weight was 15.91g. There was a reduction of 13.76, 34.00, 35.83 and 43.37 per cent in root weight (Fig.1) due to the cyst nematode over control.

7. Total yield per plot

Yield per plot are presented in Table 1 and Appendix I. The total yield under the different treatments were 265.00, 261.00, 256.17 and 219.50 g at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. respectively. In control the

yield was 307.50g. The percentage reduction in yield was 7.32, 15.12, 16.69 and 28.62 at the different inoculum levels (Fig.1) of the cyst nematodes.

8. Grain weight per plot

The average grain weight observed in the different treatments are presented in Table 1 and Appendix I. The grain weights were 283.33, 261.38, 237.58, 231.87 and 180.55g at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. There was a reduction of 7.75, 16.15, 18.16 and 36.28 per cent in the grain weight due to the cyst nematodes respectively (Fig.1).

9. Chaff weight per plot

The chaff weight observed by the inoculation of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. was 23.62, 24.17, 24.30 and 38.95g (Table 1 and Appendix I). The chaff weight in control was 23.42g. The percentage increase in chaff weight over control was 0.85, 3.20, 3.76 and 66.30 at the different inoculum levels of cyst nematode.

10. Total yield per plant

The average yield per plant are presented in Table 1 and Appendix I. The yield per plant was 7.86, 7.26, 6.68

and 6.07g at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m while in control it was 9.45. There was a reduction of 16.83, 23.17, 29.31 and 35.76 per cent in the yield per plant (Fig.1) by the cyst nematodes respectively.

11. Grain weight per plant

At the different inoculum levels of 0, 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. the grain weights observed were 8.28, 6.57, 5.70, 5.01 and 4.81g respectively and are presented in Table 1 and Appendix I. The percentage reduction in the grain weight was 20.65, 36.16, 39.49 and 41.91 respectively in the various inoculation levels (Fig.1).

12. Chaff weight per plant

The average chaff weight per plant are presented in Table 1 and Appendix I. The chaff weight observed was 1.33, 1.39, 1.55 and 1.67g and the chaff weight increased by 13.67, 18.80, 32.48 and 42.74 per cent at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m.

13. Nematode population in 100 ml soil

The average nematode population was 25.83, 55.50, 77.50 and 104.50 in 100 ml soil by the inoculation of

Table 1

Damage caused by Heterodera oryzicola on rice at different levels of inoculum in microplots

Characters	T_1 Mean of 6 replications	T_2(6,000) Mean of 6 replications	T_2(6,000) % increase or decrease	T_3(9,000) Mean of 6 replications	T_3(9,000) % increase or decrease	T_4(12,000) Mean of 6 replications	T_4(12,000) % increase or decrease	T_5(18,000) Mean of 6 replications	T_5(18,000) % increase or decrease	C.D.	Overall % increase or decrease
Height of plant(cm)	78.83	75.37	-4.39	74.67	-5.28	73.03	-7.36	72.80	-7.65	3.35	-6.17
Number of tillers	8.77	7.07	-19.38	6.57	-25.09	6.33	-27.82	6.27	-28.51	0.81	-25.20
Number of leaves	28.80	25.90	-10.07	23.57	-18.16	22.93	-20.38	20.70	-28.13	2.23	-19.19
Earhead length(cm)	20.53	19.02	-7.36	17.52	-14.66	17.24	-16.03	17.02	-17.10	2.95	-13.79
Shoot weight(g)	45.36	40.09	-11.62	35.91	-20.83	32.17	-29.08	29.32	-35.36	6.07	-24.22
Root weight(g)	15.91	13.72	-13.76	10.50	-34.00	10.21	-35.83	8.95	-43.37	2.27	-32.24
Yield per plot(g)	307.50	285.00	-7.32	261.00	-15.12	256.17	-16.69	219.50	-28.62	29.46	-16.94
Grain weight per plot(g)	285.33	261.38	-7.75	237.58	-16.15	231.87	-18.16	180.55	-36.28	33.61	-19.59
Chaff weight per plot(g)	23.42	23.62	+0.85	24.17	+3.20	24.30	+3.76	38.95	+66.30	..	+18.53
Yield per plant(g)	9.45	7.86	-16.83	7.26	-23.17	6.68	-29.31	6.07	-35.76	1.10	-26.27
Grain weight per plant(g)	8.28	6.57	-20.65	5.70	-36.16	5.01	-39.49	4.81	-41.91	1.18	-33.30
Chaff weight per plant(g)	1.17	1.33	+13.67	1.39	+18.80	1.55	+32.48	1.67	+42.74	..	+26.92

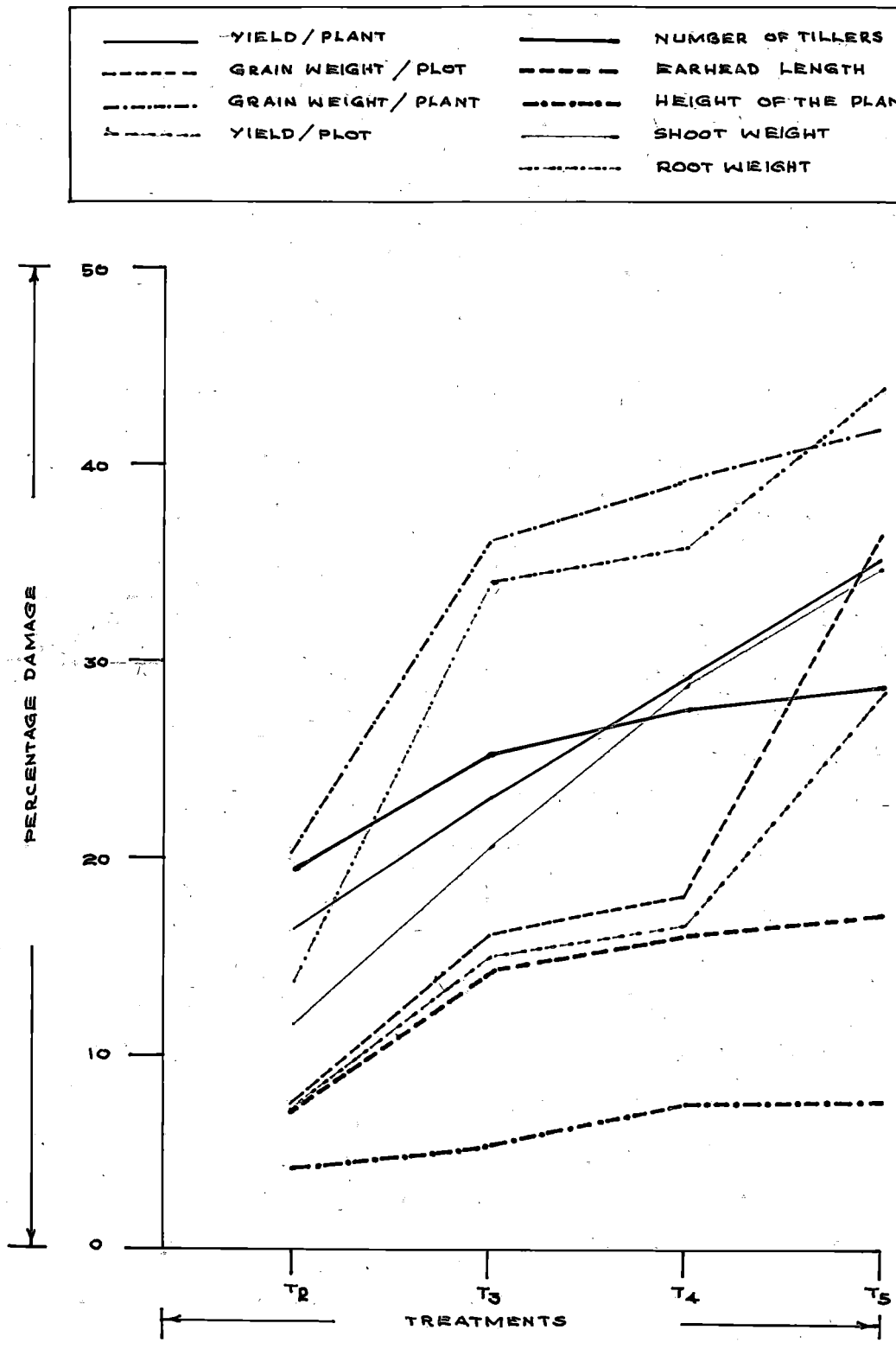


FIG: 1. DAMAGE CAUSED BY *Heterodera oryzicola* ON RICE AT DIFFERENT LEVELS OF INOCULUM IN MICROPLOTS

6,000, 9,000, 12,000 and 18,000 larvae per sq.m. (Table 3 and Appendix I).

14. Number of cysts per plant

The number of cysts per plant under the different inoculum levels of cyst nematodes were counted and are presented in Table 3 and Appendix I. The average number of cysts were 29.83, 39.00, 50.00 and 64.17 by the inoculation of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m.

15. Number of cysts in 100 ml soil

The number of cysts in 100 ml soil from the various treated plots were estimated and are presented in Table 3 and Appendix I. The cyst numbers were 16.33, 18.50, 21.67 and 23.67 at 6,000, 9,000, 12,000 and 18,000 larvae per sq.m.

B. Pot culture experiment

A pot culture experiment was conducted to study the effect of cyst nematode Heterodera oryzicola on paddy under controlled condition, with the different inoculum levels of 5, 10, 20 and 30 cysts per pot. The effect of

different inoculum levels of cyst nematode on 9 different plant characters and 3 characters on cyst nematode themselves were observed and are presented.

1. Height of the plant

The average height of the plants are presented in Table 2 and Appendix II. The heights were 67.42, 64.83, 61.00 and 60.42 cm at 5, 10, 20 and 30 cysts per pot respectively. There was a reduction of 11.09, 14.51, 19.57 and 20.32 per cent in height of the plant over control (Fig.2) by the effect of cyst nematode.

2. Number of tillers

The number of tillers produced by the plant under the various inoculum levels are presented in Table 2 and Appendix II. The number of tillers produced per plant were 2.17, 2.00, 1.83 and 1.79 at 5, 10, 20 and 30 cysts per pot. The percentage reduction in number of tillers were 31.55, 36.91, 42.27 and 43.53 respectively in the different treatments (Fig.2).

3. Number of leaves

The total number of leaves produced by the plants under the different treatments are given in Table 2 and

Appendix II. The number of leaves produced per plant were 10.33, 8.33, 7.92, 7.50 and 7.40 respectively at the inoculum levels of 0, 5, 10, 20 and 30 cysts per pot. The number of leaves were reduced by 19.36, 23.43, 27.40 and 28.27 per cent in the different treatments respectively.

4. Length of earhead

The earhead length observed in the different treatments are given in Table 2 and Appendix II. The length of earheads were 15.40, 13.28, 12.93, 12.13, and 10.58 cm at the inoculum levels of 0, 5, 10, 20 and 30 cysts per pot. There was a reduction of 13.77, 16.04, 21.23 and 31.30 per cent in the length of earhead over control by the cyst nematode (Fig.2).

5. Weight of shoot

The average shoot weight under each treatments are given in Table 2 and Appendix II. The shoot weights were 10.63, 7.01, 6.06, 5.28 and 5.04g at 5, 10, 20 and 30 cysts per pot respectively with a reduction of 34.05, 42.99, 50.33 and 52.59 per cent in shoot weight (Fig.2).

6. Weight of root

The weight of root per plant in the different treatments are given in Table 2 and Appendix II. The root weights were 4.65, 3.58, 3.00, 2.70 and 2.42g at 0, 5, 10, 20 and 30 cysts per pot. There was a reduction of 23.01, 35.48, 41.94 and 47.96 per cent in root weight (Fig.2) at the different inoculum levels over control.

7. Total yield per plant

The yield per plant at the inoculum levels of 0,5, 10, 20 and 30 cysts per pot was 6.51, 5.60, 5.13, 4.57 and 4.10g (Table 2 and Appendix II). The different inoculum levels reduced the yield by 13.98, 21.20, 29.80 and 37.02 per cent respectively (Fig.2).

8. Grain weight per plant

The grain weight per plant at 0, 5, 10, 20 and 30 cysts per pot was 5.97, 4.50, 4.37, 3.74 and 3.13g (Table 2 and Appendix II). The reduction in grain weight was 16.13, 26.55, 37.14 and 47.39 per cent in the different treatments respectively (Fig.2).

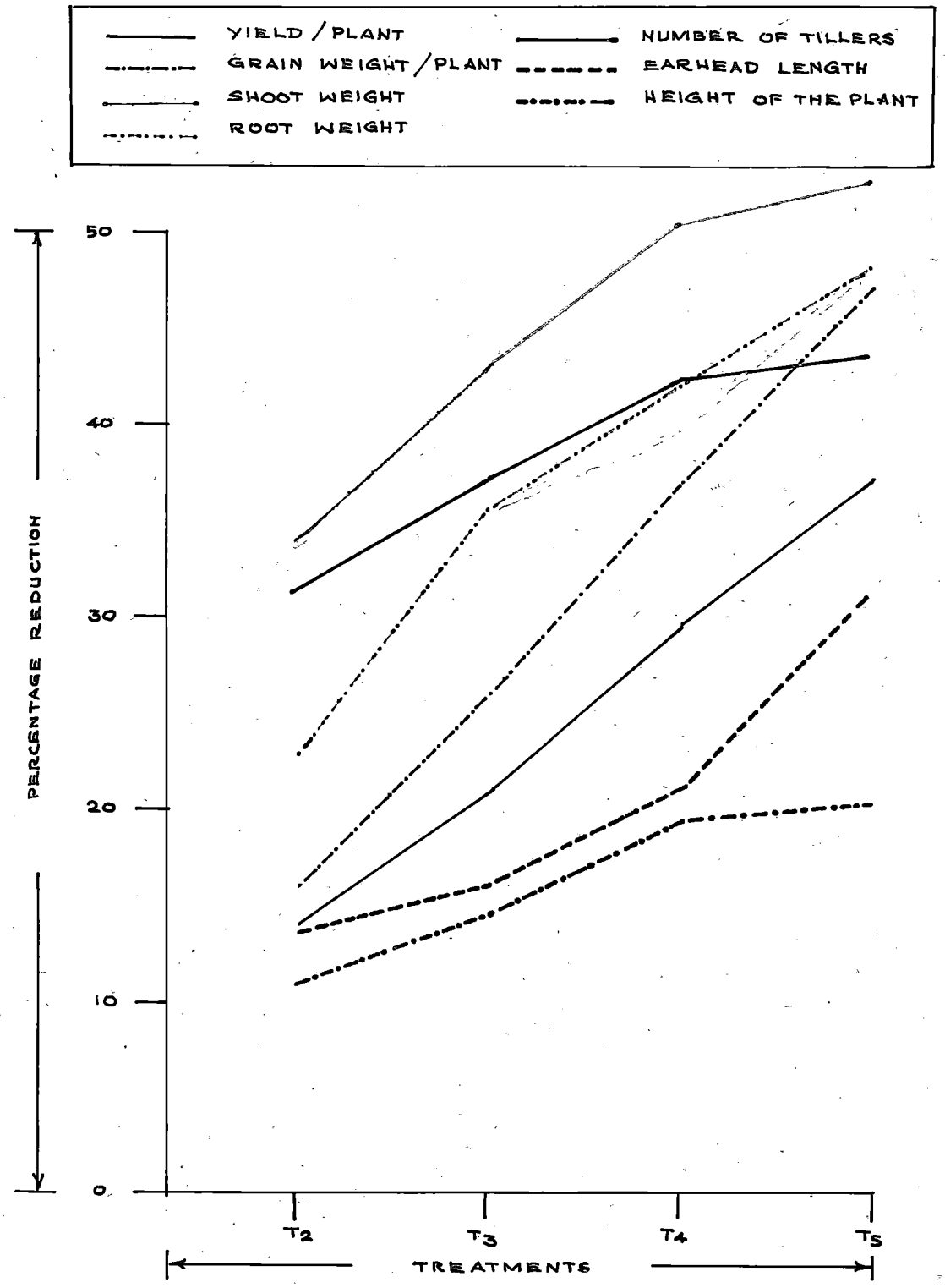


FIG: 2. DAMAGE CAUSED BY *Heterodera oryzicola* ON RICE AT DIFFERENT LEVELS OF INOCULUM IN POT-CULTURE

9. Chaff weight per plant

The average chaff weight per plant in the different treatments are presented in Table 2 and Appendix II. The chaff weights were 0.61, 0.77, 0.85 and 0.97 which showed an increase of 12.18, 41.70, 52.21 and 78.41 per cent at inoculum levels of 5, 10, 20 and 30 cysts per pot over control.

10. Nematode population in 100 ml soil

The population of cyst nematode in 100 ml soil from each treatment was estimated and are presented in Table 3 and Appendix II. The nematode population observed was 22.16, 54.33, 73.83 and 93.17 at the inoculum levels of 5, 10, 20 and 30 cysts per pot.

11. Number of cysts per plant

The number of cysts per plant are presented in Table 3 and Appendix II. The number of cysts were 17.33, 21.67, 49.33 and 60.66 at the inoculum levels of 5, 10, 20 and 30 cysts per pot.

12. Number of cysts per 100 ml soil.

The total number of cysts per 100 ml soil from each treatment was estimated and are presented in Table 3 and

Table 2

Damage caused by *Heterodera oryzicola* on rice at different levels of inoculum in pot-culture

Characters	T_1 (No cysts) Mean of 6 replications	T_2 5 cysts		T_3 10 cysts		T_4 20 cysts		T_5 30 cysts		C.D.	Overall % increase or decrease
		Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease		
Height of plant(cm)	75.83	67.42	-11.09	64.83	-14.51	61.00	-19.57	60.42	-20.32	5.72	-16.37
Number of tillers	3.17	2.17	-31.55	2.00	-36.91	1.83	-42.27	1.79	-43.53	0.76	-25.71
Number of leaves	10.33	8.33	-19.36	7.92	-23.43	7.50	-27.40	7.40	-28.27	1.45	-24.61
Earhead length(cm)	15.40	13.28	-13.77	12.95	-16.04	12.13	-21.23	10.58	-31.30	1.87	-20.59
Shoot weight(g)	10.63	7.01	-34.05	6.06	-42.99	5.28	-50.33	5.04	-52.59	2.42	-44.99
Root weight(g)	4.65	3.58	-23.01	3.00	-35.48	2.70	-41.94	2.42	-47.96	0.62	-37.10
Yield per plant(g)	6.51	5.60	-13.98	5.13	- 21.20	4.57	-29.80	4.10	-37.02	0.78	-25.50
Grain weight per plant(g)	5.97	4.50	-16.15	4.37	-26.55	3.74	-37.14	3.13	-47.39	0.80	-31.80
Chaff weight per plant(g)	0.54	0.61	+12.18	0.77	+41.70	0.83	+52.21	0.97	+78.41	..	+30.75

Table 3

Heterodera oryzicola population in soil and number of cysts in microplot and pot-culture experiments

Treatments	Field experiment			Pot culture experiment		
	Nematode population per 100 ml soil	Total number of cysts per plant	Cysts per 100 ml soil	Nematode population per 100 ml soil	Total number of cysts per plant	Cysts per 100 ml soil
T_1	0	0	0	0	0	0
T_2	23.83	29.83	16.33	22.16	17.33	10.33
T_3	55.50	39.00	18.50	54.33	21.67	13.00
T_4	77.50	50.00	21.67	73.83	49.33	18.00
T_5	104.50	64.17	23.67	93.17	60.66	21.33

Appendix II. There was 10.33, 13.00, 18.00 and 21.33 number of cysts, at inoculum levels of 5, 10, 20 and 30 cysts per pot.

II. Host range studies

Susceptibility of 14 weed plants collected from paddy fields of Vellayani were studied in pot cultures and observed for infection. The results are presented in Table 4 and the data showed that out of the 14 plants tested only one plant, Echinochloa colonum (Linn.) Link. was susceptible to the cyst nematode. The remaining 13 plants were non hosts.

III. Control of Heterodera oryzicola

The control of Heterodera oryzicola was studied and the results are presented.

A. Dibbling the nematicide treated paddy seed

1. Effect of nematicides on the height of the plant

The height of the plants under the different treatments are presented in Table 5 and Appendix III. The average

Table 4
Host range studies

Plants tested	
Paspalum commersonii Lamk.	-
Digitaria biformis Willd.	-
Panicum miliacea Vahl.	-
Eragrostis tenella (Linn.) P. Beauv	-
Kyllinga monocephala Rottb.	-
Cyperus diffusus Vahl.	-
Cyperus iria Linn.	-
Cyperus eleusinoides Kunth	-
Axonopus compressus (Swartz) P. Beauv.	-
Echinochloa colonum (Linn.) Link	+
Alternanthera sessilis Br.	-
Setaria articulatus Linn.	-
Monocheria vaginalis Presl.	-
Vallisneria spiralis Linn.	-

\+ = Host

\- = Non host.

height of the plant was 66.62 cm in T_1 (carbofuran), 64.50 cm in T_2 (aldicarb sulfone), 70.05 cm in T_3 (nemacur) 68.93 cm in T_4 (MMC), 56.59 cm in T_5 (thimet) and 52.60 cm in T_6 (check). There was an increase of 26.65, 22.62, 33.17, 31.05 and 7.58 per cent in height of the plant (Fig.3) in nematicide treated plants over check.

2. Effect of nematicides on number of tillers

The number of tillers after the nematicide treatments are presented in Table 5 and Appendix III. In check the number of tillers were 1.37. The number of tillers produced in other treatments were 2.46 in carbofuran, 2.43 in aldicarb sulfone, 2.71 in nemacur, 2.52 in MMC and 2.33 in thimet. The tiller production increased by 79.56, 77.37, 97.81, 83.94 and 70.07 per cent by the different treatments respectively (Fig.3).

3. Effect of nematicides on the number of leaves

The total number of leaves produced on the 60th day after sowing of the treated seeds, are given in Table 5 and Appendix III. The average number of leaves were 10.56 in carbofuran, 9.31 in aldicarb sulfone, 10.60 in nemacur, 10.57 in MMC, 9.62 in thimet and

7.73 in check. There was an increase of 2.83, 2.08, 2.87, 2.84 and 1.89 leaves over check.

4. Effect of nematicides on the shoot weight

The shoot weight per plant under the different treatments are given in Table 5 and Appendix III. The average weight of the shoot was 9.22, 9.06, 11.69, 10.15 and 8.34g by the application of carbofuran, aldicarb, sulfone, nemacur, FMC and thimet respectively. In check it was 7.21g. Increase in shoot weight was 2.01, 1.85, 4.48, 2.94 and 1.13g per plant by the nematicide treatment respectively. There was an increase of 27.88, 25.66, 62.14, 40.78 and 15.67 per cent (Fig.3) in the different treatments over check.

5. Effect of nematicides on the root weight

The weight of the root is presented in Table 5 and Appendix III. The maximum root weight observed was 5.40g by nemacur and it was 5.01, 5.03, 5.28 and 4.23g by carbofuran, aldicarb sulfone, FMC and thimet respectively. There was an increase of 1.56, 1.58, 1.95, 1.83 and 0.78g in root weight over check which was only 3.45g. The root weigh

increased by 45.23, 45.79, 56.52, 53.04 and 22.61 per cent by the different treatments (Fig.3).

6. Effect of nematicides on the length of earhead

Table 5 and Appendix III gives the average length of earhead at the time of harvest by the different treatments. The average length of earhead was 17.04 cm in carbofuran, 16.59 cm in aldicarb sulfone, 18.70 cm in nemacur, 17.38 cm in FMC, 15.99 cm in thimet and 15.36 cm in the check. The increase in length of earhead was 1.68, 1.23, 3.34, 2.02 and 0.63 cm in different treatments over check. The percentage increase in earhead length by the different treatments were 10.94, 8.01, 21.74, 13.15 and 4.10 per cent respectively (Fig.3).

7. Effect of nematicides on the total yield

The total yield by the plants under each treatments are presented in Table 5 and Appendix III. The maximum and minimum yield observed were 9.75 and 6.95g by nemacur and thimet and in other treatments, it was 8.33g (carbofuran), 7.03g (aldicarb sulfone) and 8.49 g (FMC). The yield increased by 2.65, 1.35, 4.07, 2.81 and 1.27g

per plant by nematicidal treatments over check which was 5.68g. There was an increase of 46.55, 23.77, 71.65, 49.47 and 22.36 per cent in yield (Fig.3) by the different treatments.

8. Effect of nematicides on the grain weight

The average grain weight per plant are presented in Table 5 and Appendix III. The average grain weight was 7.69g in carbofuran, 6.36g in aldicarb sulfone, 9.17g in nemacur, 7.90g in FMC and 6.20g in thimet. In check the grain weight was 4.78g. The nematicide treatment increased the yield by 2.90, 1.58, 4.39, 3.12 and 1.41g over check by different treatments to the extent of 60.67, 33.05, 91.84, 65.27 and 29.71 per cent (Fig.3).

9. Effect of nematicides on the weight of chaff

The average weight of chaff is given in Table 5 and Appendix III. The mean weights were 0.65, 0.66, 0.58, 0.59 and 0.74g by carbofuran, aldicarb sulfone, nemacur, FMC and thimet respectively. A reduction of 27.78, 26.67, 35.56, 34.44 and 17.77 per cent was observed by each treatment.

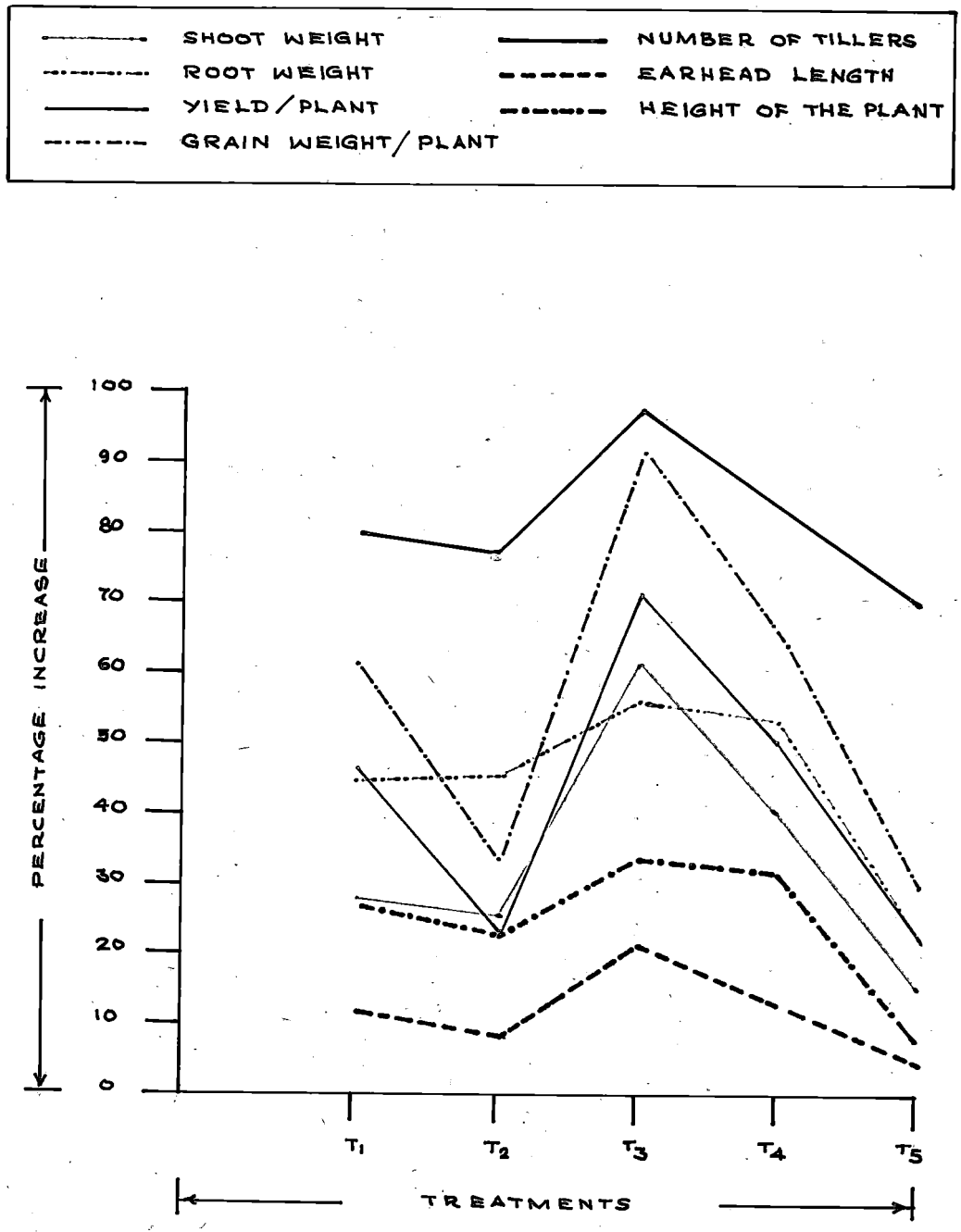


FIG: 3 EFFECT OF SEED TREATMENT BY NEMATICIDE ON RICE

10. Effect of nematicides on the nematode population in 100 ml soil

The average number of nematodes per 100 ml of soil are presented in Table 5 and Appendix III. The soil population was 29.33 in carbofuran, 34.33 in aldicarb sulfone, 21.67 in nemacur, 25.50 in FMC and 36.00 in thimet. There was a decrease of 70.57, 65.55, 78.26 74.41 and 63.88 per cent in the number of nematodes per 100 ml soil over check in the different treatments (Fig.4).

11. Effect of nematicides on total number of cysts

The number of cysts per plant under the different treatments 105 days after sowing are presented in Table 5 and Appendix III. The average number of cysts were 27.00, 32.17, 22.17, 26.33 and 43.16 by carbofuran, aldicarb sulfone, nemacur, FMC and thimet respectively. Nematicidal treatments reduced the cyst numbers by 58.14, 50.12, 65.63, 59.18 and 33.90 per cent (Fig.4).

12. Effect of nematicides on the number of cysts per 100 ml soil

The average number of cysts per 100 ml soil are presented in Table 5 and Appendix III. The numbers

Table 5

Effect of seed treatment by nematicides on rice and Heterodera oryzicola.

	T_1 Carbofuran		T_2 aldicarb sulfone		T_3 nemacur		T_4 FMC		T_5 thimet		T_6 Check	C.D.	Overall % increase or decrease
	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease			
Height of the plant(cm)	66.62	+26.65	64.50	+22.62	70.05	+33.17	68.93	+31.05	56.59	+7.58	52.60	5.88	+24.21
Number of tillers	2.46	+79.56	2.43	+77.37	2.71	+97.81	2.52	+83.94	2.33	+70.07	1.37	0.60	+81.75
Number of leaves	10.56	+36.61	9.81	+26.91	10.60	+37.13	10.57	+36.74	9.62	+24.45	7.73	1.68	+32.37
Shoot weight(g)	9.22	+27.88	9.06	+25.66	11.69	+62.11	10.15	+40.78	8.34	+15.67	7.21	1.92	+34.43
Root weight(g)	5.01	+45.23	5.03	+45.79	5.40	+56.52	5.28	+53.04	4.23	+22.61	3.45	0.84	+44.64
Earhead length(cm)	17.04	+10.94	16.59	+ 8.01	18.70	+21.74	17.38	+13.15	15.99	+ 4.10	15.36	1.18	+11.59
Yield per plant(g)	8.33	+46.65	7.03	+23.77	9.75	+71.65	8.49	+49.47	6.95	+22.36	5.68	0.66	+42.78
Grain weight per plant(g)	7.68	+60.67	6.36	+33.05	9.17	+91.84	7.90	+65.27	6.20	+29.71	4.78	0.64	+74.85
Chaff weight per plant (g)	0.65	-27.78	0.66	-26.67	0.58	-35.56	0.59	-34.44	0.74	-17.77	0.90	..	-28.44
Nematode population per 100 ml soil.	29.33	-70.57	34.33	-65.55	21.67	-78.26	25.50	-74.41	36.00	-63.88	99.66	..	-70.53
Total number of cysts per plant	27.00	-58.14	32.17	-50.12	22.17	-65.63	26.33	-59.18	43.16	-33.90	64.50	..	-53.39
Cysts per 100 ml soil	26.50	-42.59	30.83	-33.21	21.50	-53.42	25.83	-44.04	38.17	-17.31	46.16	..	-38.11

observed were 26.50, 30.83, 21.50, 25.33 and 38.17 in carbofuran, aldicarb sulfone, nemacur, FMC and thimet respectively. The reduction in number of cysts in different treatments were 19.66, 7.33, 24.66, 20.33 and 7.99 over T_6 (check). There was a reduction of 42.59, 33.21, 53.42, 44.04 and 17.31 per cent in cyst number per 100 ml soil (Fig.4).

D. Transplanting paddy seedlings after root dips in nematicide suspensions

1. Effect of nematicides on height of the plant

The average height of the plants in the different treatments are presented in Table 6 and Appendix IV. The height of the plant was 61.51 cm in carbofuran, 61.36 cm in aldicarb sulfone, 69.78 cm in nemacur, 63.08 cm in FMC and 59.42 cm in thimet and 51.18 cm in T_6 (check). The nematicidal treatments increased the height by 10.33, 10.18, 18.60, 11.90 and 8.24 cm in the different treatments over check to an extent 20.18, 19.89, 36.34, 23.25 and 16.10 per cent respectively (Fig.5).

2. Effect of nematicides on number of tillers

The mean number of tillers recorded per plant are given in Table 6 and Appendix IV. The average number of

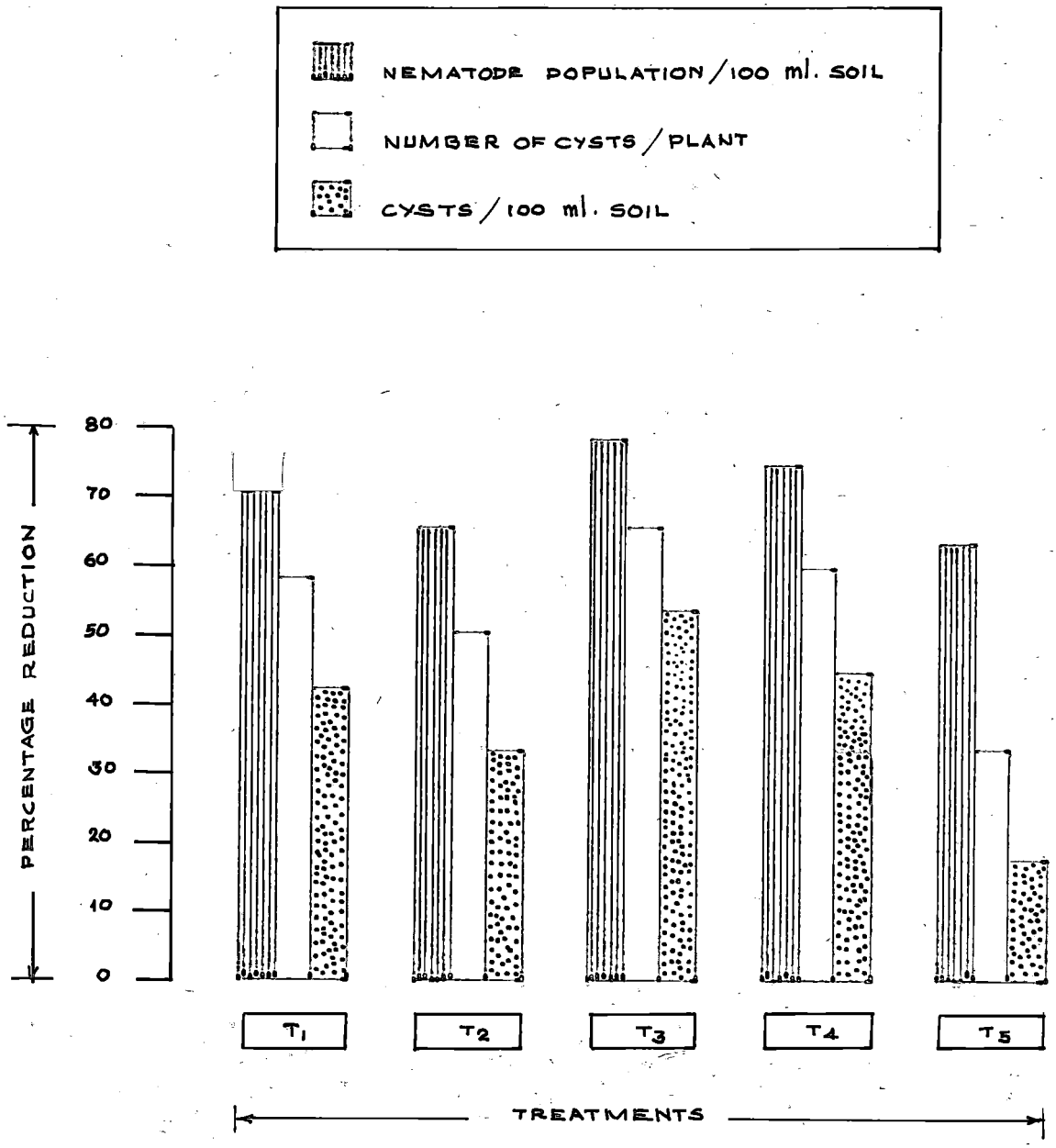


FIG: 4 EFFECT OF SEED TREATMENT BY NEMATICIDE ON *Heterodera oryzicola*

tillers were 3.24, 2.83, 3.79, 3.58 and 3.00 by carbofuran, aldicarb sulfone, nemacur, MMC and thimet respectively. There was an increase of 44.00, 25.78, 68.44, 59.11 and 33.33 per cent in tiller production (Fig.5) in different treatments over check in which the tiller number was 2.25.

3. Effect of nematicides on the number of leaves

The average number of leaves are presented in Table 6 and Appendix IV. The average number of leaves were 13.41, 13.22, 15.88, 13.50 and 12.82 in carbofuran, aldicarb sulfone, nemacur, MMC and thimet respectively while in check it was 11.03.

4. Effect of nematicides on the shoot weight

The total weight of the shoot per plant observed under different treatments are given in Table 6 and Appendix IV. The shoot weight under different treatments were 14.80g in carbofuran, 14.06g in aldicarb sulfone, 15.53g, in nemacur, 15.25g in MMC and 13.20g in thimet. There was an increase of 4.66, 3.92, 5.39, 5.11 and 3.06g in shoot weight over check, which was observed to be 10.14g.

The shoot weight increased by 45.96, 38.66, 53.16, 50.39 and 30.18 per cent by the different treatments (Fig.5) over check.

5. Effect of nematicides on the root weight

The average weight of rootsare presented in Table 6 and Appendix IV. The weight of the root was 6.51g in carbofuran, 6.25g in aldicarb sulfone, 6.76g in nemacur, 6.59g in FMC and 5.66g in thimet. The increase in root weight in different treatments were 2.02, 1.76, 2.27, 2.10 and 1.17g over check. There was an increase of 44.99,39.20, 50.56, 46.77 and 26.06 per cent (Fig.5) in the different treatments respectively.

6. Effect of nematicides on the length of earhead.

The average length of earhead at the time of harvest are presented in Table 6 and Appendix IV. The mean earhead length was 17.30, 17.09, 18.91, 17.93 and 16.30 cm by carbofuran, aldicarb sulfone, nemacur, FMC and thimet respectively. There was an increase of 1.69, 1.48, 3.30, 2.32 and 0.69 cm in length of earhead over check. The percentage increase in earhead length by the different treatments were 10.83, 9.48, 21.14, 14.86 and 4.42 respectively (Fig.5).

7. Effect of nematicides on the total yield

The average yield per plant are presented in Table 6 and Appendix IV. The yield was 8.14g in carbofuran, 7.02g in aldicarb sulfone, 9.76 g in nemacur, 8.62g in FMC and 6.92g in thimet. An increase of 2.41, 1.29, 4.03, 2.89 and 1.19g in grain weight over check was observed in the different treatments. The nematicidal treatment increased the yield respectively by 42.06, 22.51, 70.33, 50.44 and 20.77 per cent (Fig.5).

8. Effect of nematicides on the grain weight

The mean grain weight per plant are presented in Table 6 and Appendix IV. The grain weight was 7.51, 6.36, 9.23, 8.05 and 6.23g by carbofuran, aldicarb sulfone, nemacur, FMC and thimet respectively. There was an increase of 2.66, 1.51, 4.38, 3.20 and 1.38g in grain weight over check in the different treatments. The grain weight increased by 54.85, 31.13, 90.31, 77.73 and 28.45 per cent (Fig.5) by the different treatments respectively.

9. Effect of nematicides on the weight of chaff

The average weight of chaff per plant in different treatments are presented in Table 6 and Appendix IV.

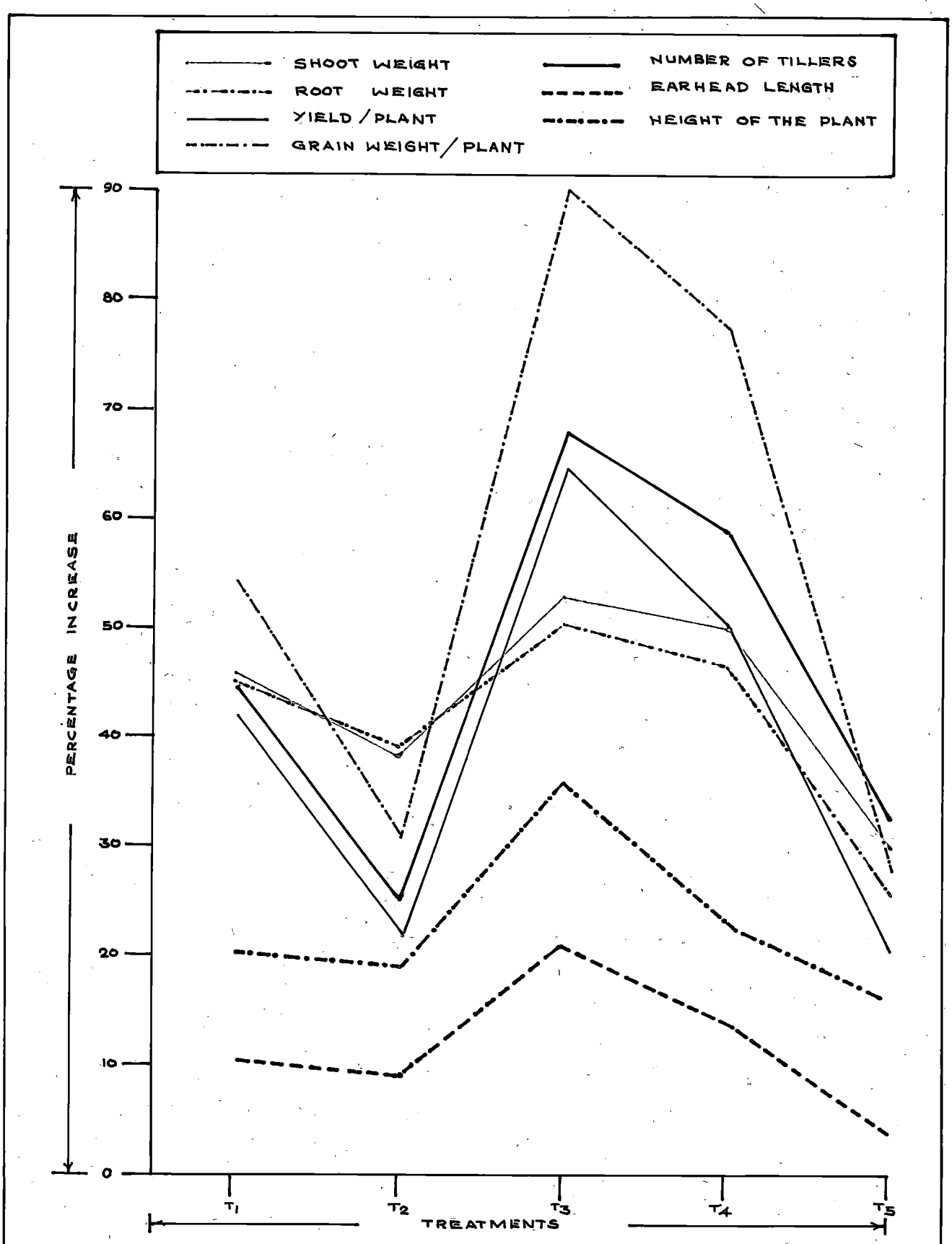


FIG: 5. EFFECT OF SEEDLING DIP IN NEMATICIDE SUSPENSION ON RICE

The mean chaff weight was 0.63, 0.66, 0.53, 0.57 and 0.69g in carbofuran, aldicarb sulfone, nemacur, FMC and thimet respectively. There was a decrease of 0.24, 0.21, 0.33, 0.30 and 0.18g in chaff weight over check. The percentage decrease in chaff weight was 27.59, 24.14, 39.08, 34.48 and 20.69 in the different treatments respectively.

10. Effect of nematicides on the nematode population in 100 ml soil

The nematode population in 100 ml of soil at the time of harvest are given in Table 6 and Appendix IV. The population in different treatments were 30.67, 31.83, 24.17, 25.66 and 33.33 respectively in carbofuran, aldicarb sulfone, nemacur, FMC and thimet. The decrease in population observed over check was 69.28, 68.12, 75.79, 74.32 and 66.66 per cent (Fig.6) in the different treatments.

11. Effect of nematicides on total number of cysts

The total number of cysts per plant are presented in Table 6 and Appendix IV. The average number of cysts produced were 28.00 in carbofuran, 31.83 in aldicarb

sulfone, 22 in nemacur, 25.50 in FMC and 44.33 in thimet. There was a decrease of 55.79, 49.74, 65.26, 59.73 and 30.00 per cent in the different treatments over check (Fig.6).

12. Effect of nematicides on the number of cysts per 100 ml soil

The average number of cyst per 100 ml soil in different treatments are presented in Table 6 and Appendix IV. The number of cysts were 22.00, 29.00, 20.33, 23.16 and 29.50 in carbofuran, aldicarb sulfone, nemacur, FMC and thimet respectively. The reduction in number of cysts over control by the nematicide treatment was 52.99, 40.20, 59.08, 54.31 and 39.18 per cent (Fig.6).

Table 6

Effect of seedling dip in nematicide suspension on rice and Heterodera oryzicola

Characters	T_1 carbofuran		T_2 aldicarb sulfone		T_3 nemacur		T_4 FMC		T_5 thimet		T_6 (check) mean of 6 replications	C.D.	Overall % increase or decrease
	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease	Mean of 6 replications	% increase or decrease			
Height of the plants (cm)	61.51	+20.18	61.36	+19.89	69.78	+36.34	63.08	+23.25	59.42	+16.10	51.18	6.93	+23.15
Number of tillers	3.24	+44.00	2.83	+25.78	3.79	+68.44	3.58	+59.11	3.00	+33.33	2.25	0.59	+46.13
Number of leaves	13.41	+21.58	13.22	+19.85	15.88	+43.97	13.50	+22.39	12.82	+16.23	11.03	2.77	+24.80
Shoot weight(g)	14.80	+45.96	14.06	+38.66	15.53	+53.16	15.25	+50.39	13.20	+30.18	10.14	1.57	+43.67
Root weight(g)	6.51	+44.99	6.25	+39.20	6.76	+50.56	6.59	+46.77	5.66	+26.06	4.49	0.66	+41.32
Earhead length(cm)	17.30	+10.83	17.09	+ 9.48	18.91	+21.14	17.93	+14.86	16.30	+ 4.42	15.61	0.98	+12.15
Yield per plant(g)	8.14	+42.06	7.02	+22.51	9.76	+70.33	8.62	+50.44	6.92	+20.77	5.73	0.74	+49.63
Grain weight per plant(g)	7.51	+54.85	6.36	+31.13	9.23	+90.31	8.05	+77.73	6.23	+28.45	4.85	0.80	+56.49
Chaff weight per plant(g)	0.63	-27.59	0.66	-24.14	0.53	-39.08	0.57	-34.48	0.69	-20.69	0.87	0.03	-24.33
Nematode population per 100 ml soil.	30.67	-69.28	31.83	-68.12	24.17	-75.79	25.66	-74.32	33.33	-66.66	99.83	..	-70.83
Total number of cysts per plant	28.00	-55.79	31.83	-49.74	22.00	-65.26	25.50	-59.73	44.33	-30.00	63.33	..	-52.10
Cysts per 100 ml soil	22.80	-52.99	29.00	-40.20	20.33	-58.08	23.16	-54.31	29.50	-39.18	48.50	..	-48.95

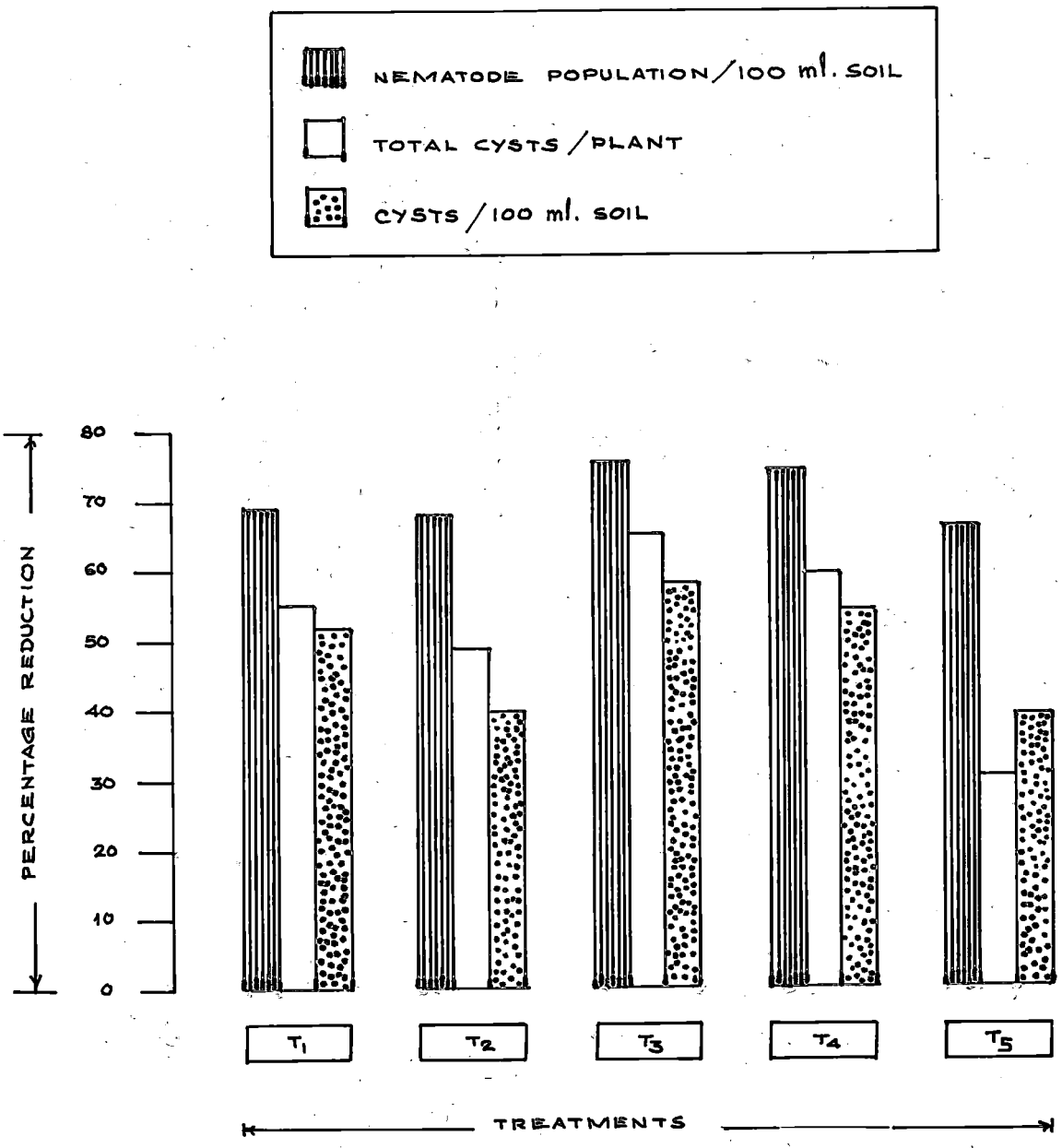


FIG: 6. EFFECT OF SEEDLING DIP IN NEMATICIDE SUSPENSION ON *Heterodera oryzicola*

DISCUSSION

DISCUSSION

The present investigation comprises of crop loss studies, host range and control of the cyst nematode Heterodera oryzicola, on rice.

Heterodera oryzicola was recently reported to attack rice plants in Kerala, especially in Palghat and Trivandrum districts. The extent of damage, host range and control of this nematode have not been studied in detail. Hence the present investigation on this cyst nematode was undertaken to throw light on the above aspects.

The extent of damage caused by Heterodera oryzicola on rice at four different inoculum levels was studied by field and pot culture experiments. There was considerable reduction in the growth of the plant and yield both in the field and controlled conditions, at all the different levels tried.

The effect of nematodes on 12 different plant characters was studied at field and pot culture conditions. From Table 1 and 2 it may be seen that the average height of the rice plant was considerably reduced due to the cyst nematode under both the above conditions. The height of

the plant reduced as the inoculum level was increased and the height was minimum in the highest inoculum level of 18,000 larvae and 30 cysts (T_5 treatments). In the micro-plot experiment, the height of the plant observed under check was 78.83 cm, but inoculation of 6,000 larvae per sq.m (T_2) reduced the height to 75.37 cm, 9,000 larvae per sq.m (T_3) to 74.67 cm, 12,000 larvae per sq.m.(T_4) to 73.03 cm and 18,000 larvae per sq.m (T_5) to 72.80 cm. Thus at each inoculum level there was a reduction of 4.39, 5.28, 7.36, and 7.65 per cent in height of the plant. Similarly in the pot culture experiment, the height of the plant in check was 75.83 cm, but was only 67.42 cm by inoculation of 5 cysts (T_2), 64.83 cm by 10 cysts (T_3), 61.00 cm by 20 cysts (T_4) and 60.42 cm by 30 cysts (T_5). Thus at each inoculum level, there was a reduction of 11.09, 14.51, 19.57 and 20.32 per cent in the height of the plant. The reduction in height caused by the inoculation of cyst nematode in the two experiments was statistically significant. The overall percentage reduction in height of the plants in microplot experiment was 6.17 whereas it was 16.37 per cent in pot culture experiment. The congenial conditions for rice plant

prevalent in the field might be the reason for this difference. However the height of the plant reduced significantly in both conditions due to the cyst nematode. Similar significant reduction in height of the plant in moong (Vigna radiata L.) Wilczek due to Heterodera cajani was also reported by Gaur and Singh (1977). Muthukrishnan et al.(1977) also found that due to Hirschmanniella oryzae the height of the plant was reduced from 51.40 cm in control to 43.00 cm at 1000 nematodes per seedling.

The inoculation of cyst nematode also caused reduction in number of tillers per rice plant. From Table 1 and 2 it can be seen that the average number of tillers per plant was 8.77 and 3.17 in check (T_1) in both conditions. But the number of tillers reduced to 7.07, 6.57, 6.33 and 6.27 per plant by inoculation of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. respectively in field experiment. The tiller numbers were 2.17, 2.00, 1.83 and 1.79 per plant at inoculum levels of 5, 10, 20 and 30 cysts per pot in pot experiment. Thus there was a reduction of 19.38, 25.09, 27.82 and 28.51 per cent and 31.55, 36.91, 42.27 and 43.53 per cent in tiller production at each

inoculum level under the field and pot experiments, which was statistically significant. The overall reduction in tiller production was 25.20 in field experiment and 25.71 in pot experiment. Mathur and Prasad (1972) also reported 21.78, 16.76 and 73.79 per cent reduced tiller production in rice at inoculum levels of 100, 1,000 and 10,000 nematodes per plot over control. The tiller production in rice was also reported to be reduced by infestation with Hirschmanniella oryzae, H.imamuri and H. spinicaudata (Dabotola and Bridge, 1979).

The number of leaves reduced considerably due to the infection of Heterodera oryzicola both in field and pot conditions, as evidenced by the results presented in Table 1 and 2. There were 28.80 leaves in check but was reduced to 25.90, 23.57, 22.93 and 20.70 by the inoculation of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. respectively. Similarly under pot conditions there were 10.33 leaves in check but was reduced to 8.33, 7.92, 7.50 and 7.40 by the inoculation of 5, 10, 20 and 30 cysts per pot respectively. Thus there was a reduction of 10.07, 10.16, 20.38 and 28.13 per cent in field conditions and 19.36, 23.43, 27.40 and 28.27 per cent in pot experiments. The reduction was statistically significant.

The overall reduction in the two experiments was 19.19 and 24.61 per cent.

From Table 1 and 2 it may also be seen that inoculation of cyst nematode reduced the length of earhead in both the conditions. The maximum reduction here also was in the highest inoculum level. The earhead length from plants free of nematodes was 20.55cm in field conditions and 15.40 cm in pot conditions. But the earhead length was reduced by 7.36 per cent at 6,000 larvae per sq.m, 14.66 per cent at 9,000 larvae per sq.m, 16.03 per cent at 12,000 larvae per sq.m. and 17.10 per cent at 18,000 larvae per sq.m. in field conditions and 13.77 per cent at 5 cysts per pot, 16.04 per cent at 10 cysts per pot, 21.23 per cent at 20 cysts per pot and 31.30 per cent at 30 cysts per pot in pot conditions. This reduction in length of earhead caused by cyst nematodes was not statistically significant under field conditions but was significant under pot conditions. There was an overall reduction of 13.79 and 20.59 per cent in either conditions.

The effect of nematodes on shoot weight presented in Table 1 and 2 also show a similar trend. The shoot

weight in check in field experiment was 45.36g but was reduced to 40.09, 35.91, 32.17 and 29.32g at inoculum levels of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. Likewise the shoot weight in check in pot experiment was 10.65 g but was reduced to 7.01, 6.06, 5.28 and 5.04g at inoculum levels of 5, 10, 20 and 30 cyst per pot. The reduction produced was to the extent of 11.62, 20.83, 29.08 and 35.36 per cent in field conditions and 34.05, 42.99, 50.33 and 52.59 per cent in pot experiment under T_2, T_3, T_4 and T_5 respectively, which was found to be statistically significant. The reduction in shoot weight reported was in agreement with the findings of Mathur and Prasad (1972) who got 2.8 to 54.4 per cent reduction by Hirschmanniella oryzae on rice. Similar reductions in shoot weight was reported by Gaur and Singh (1977) in moong due to Heterodera cajani and by Santo and Bolander (1979) in sugarbeet due to Heterodera schachtii.

Significant reduction in root weight was also caused by the cyst nematode in field and pot conditions as presented in Table 1 and 2. The root weight was reduced by 13.76, 34.00, 35.83 and 43.37 per cent at 6,000, 9,000

12,000 and 18,000 larvae per sq.m. in field trial and 23.01, 35.48, 41.94 and 47.96 per cent at 5, 10, 20 and 30 cysts per pot in pot trial. The overall reduction in the two trials was 32.24 and 37.10 per cent. The poor underground system resulting in poor growth of the plant may be one of the factors for the reduction in plant growth characters. Mathur and Prasad (1972) reported a reduction of 9.7 to 63.32 per cent in root weight in rice by Hirschmanniella oryzae. Babatola and Bridge (1979) got a reduction in fresh root weight of 31-37 per cent in rice by Hirschmanniella sp.

The yield of paddy was reduced at all the inoculum levels in both the experiments. Nematode free plants produced an yield of 9.45 g per plant in field conditions and 6.51 g per plant in pot conditions (Table 1 and 2). But the infestation by cyst nematode reduced the yield significantly at all inoculum levels. The percentage reduction in yield per plant was 16.83, 23.17, 29.31 and 33.76 per cent by inoculation of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. in field condition and 13.98, 21.20, 29.80 and 37.02 per cent by inoculation of 5, 10,

20 and 30 cysts per pot in pot experiment. The overall reduction in yield per plant was 26.27 and 25.50 per cent in field and pot conditions. This is in agreement with the findings of Rao (1978) who reported 20 per cent yield loss due to Heterodera oryzicola in rice. An yield loss of 44-49 per cent due to Heterodera elachista on rice was also reported by Ohshima (1974). This difference in yield loss may be attributed to the difference in species of cyst nematode as well as variety of rice used.

Total yield of uninoculated plot of size one sq.m. was 307.50g (Table 1) but the inoculation of larvae of cyst nematodes reduced the yield significantly by 7.32, 15.12, 16.69 and 28.62 per cent in T_2, T_3, T_4 and T_5 treatments. There was an overall yield loss of 16.04 per cent on plot basis. The grain weight per plot (Table 1) was also significantly reduced by the infection of cyst nematode to an extent of 7.75, 16.15, 19.16 and 36.28 per cent under different treatments, with an overall reduction of 19.59.

The grain weight per plant also reduced at the different inoculum levels both in field and pot conditions

significantly. In field conditions the grain weight per plant reduced to 20.65, 36.16, 39.49 and 41.91 per cent and in pot culture to 16.13, 26.55, 37.14 and 47.39 per cent in T_2, T_3, T_4 and T_5 treatments respectively (Table 1 and 2). The overall damage under the two conditions were 33.30 and 31.80 per cent respectively. Similar significant reduction in grain yield of 31-37 per cent due to Hirschmanniella sp. was reported by Babatola and Bridge (1979).

Though the chaff weight per plot was increased in terms of weight in the different treatments by 0.85, 5.20, 3.76 and 66.30 per cent (Table 1) with an overall increase of 18.53 per cent, the increase observed was not statistically significant. Similarly the chaff weight increase per plant in field conditions was 13.67, 18.80, 32.48 and 42.74 per cent and 12.18, 41.70, 52.21 and 78.41 per cent (Table 1 and 2) in pot cultures also was not statistically significant. However there was an overall increase of 26.92 and 50.75 per cent in chaff weight under the two conditions. Production of chaff from 4.8 to 24.2 per cent in rice due to Hirschmanniella spp. was also reported by Babatola and Bridge (1979).

The soil population of cyst nematode and number of cysts in root and soil also were estimated in the above two experiments. In the field conditions there was an average of 23.83, 55.50, 77.50 and 104.50 cyst nematodes and in pot cultures, 22.16, 54.33, 73.83 and 93.17 cyst nematodes under T_2, T_3, T_4 and T_5 treatments (Table 3). The cyst numbers per plant in field experiment was on an average of 29.83, 39.00, 50.00 and 64.17 and in pot culture experiment 17.33, 21.67, 49.33 and 60.66 for treatments T_2, T_3, T_4 and T_5 respectively. The cyst numbers per 100 ml of soil were 16.33, 18.50, 21.67 and 23.67; 10.33, 13.00, 16.00 and 21.33 in field and pot culture experiments respectively. Similar increase in cyst number was also reported by Sharma and Sethi (1975) on cowpea. The cyst population increase was 20.12 in 10, 594.5 in 100, 679.5 in 1,000 and 456.0 in 10,000 larvae per 500g soil. Thus the cyst nematode thrived and multiplied on the paddy plants in both the conditions satisfactorily. Several workers have shown that an upset in the normal balance between various plant constituents results from nematode parasitism. Reports of Van Gundy and Martin (1961), Shafiee and Jenkins (1963) and Heald

and Jenkins (1964) indicated that nematodes do have a profound influence in the uptake and accumulation of various nutrients in the host. The normal growth of the plant will be thus impossible.

The above two experiments on crop loss clearly indicate that the cyst nematode, Heterodera oryzicola damages the rice crop both quantitatively and qualitatively (Plate 1 and 2). The extent of damage is of the order of 6.17 per cent to 33.30 per cent taking into consideration all the characters studied and an yield loss of 16.94 per cent to 33.30 per cent in the field microplot experiment. The damage in the pot experiment was 16.37 per cent to 44.99 per cent and 25.50 to 31.80 per cent respectively. The differences observed in the extent of damage may be due to the differences existing in the rhizosphere in the field and pot conditions and their effect on the plant and nematode. However the reduction in growth and yield characters of the rice plant was maximum at the highest level of inoculum in both the conditions, showing that the more the nematode population, the more the damage to the plant.

Plate 1

Damage caused by *Heterodera oryzicola* on rice at different levels of inoculum in microplots.

Plate 2

Damage caused by *Heterodera oryzicola* on rice at different levels of inoculum in pot culture.

Plate 1

Plate 2

In the host range studies, the result presented in Table 4 show that out of the 14 weed plants found in paddy fields, tested against Heterodera oryzicola, only one plant Echinochloa colonum (Linn.) Link. was infested. Some of the plant species recorded as good hosts of other Heterodera species were proved to be non-hosts of Heterodera oryzicola. Mermy and Cadet (1978) reported penetration of 14 plant species and two rice cultivars by Heterodera oryzae. Taylor (1978) isolated Heterodera oryzae from Banana. Golden and Birchfield (1972) described Heterodera graminophila from roots of Echinochloa colonum. Gill and Swarup (1971) recorded Echinochloa frumentacea as a host of Heterodera avenae.

The experimental studies on the con trol of Heterodera oryzicola, indicated that nemacur at 0.02 per cent solution was superior over the other nematicides tried as evidenced by the improvement of plant growth characters and increase in yield, coupled with reduction in nematode population. The results obtained from the other nematicides under study also were significantly superior, in comparison to untreated plants. None of the nematicides

used namely, carbofuran, aldicarb sulfone, nemacur, MMC and thimet was phytotoxic at the doses tried to the rice plant.

Increase in height of the plant produced by the use of carbofuran, aldicarb sulfone, nemacur, MMC and thimet was statistically significant over the check (Table 6 and 5). There was an increase of 20.18, 19.89, 36.34, 23.25 and 16.10 per cent by seedling treatment and 26.65, 22.62, 33.17, 31.05 and 7.58 per cent by seed treatment with the above nematicides respectively. Nemacur treated plants exhibited maximum increase in height in both, with others in the following order: MMC, carbofuran, aldicarb sulfone and thimet. There was an overall improvement of 23.15 and 24.21 per cent by the two methods of treatments. Mathur and Prasad (1973) reported a similar increase in height of paddy plant by 45.40and 60.70per cent with preplanting application of D-D. Increase of plant height by treatment with phenamiphos or oxamyl (Griffin,1975) and carbofuran, aldicarb, or fensulphothion (Dorn and Stock, 1976) are reported on other crops.

Carbofuran, aldicarb sulfone, nemacur, FMC and thimet gave significant increase in number of tillers over check per plant either by seedling dip or seed treatment (Table 6 and 5). The number of tillers increased by 44.00 and 79.66 per cent with carbofuran; 25.78 and 77.37 per cent with aldicarb sulfone; 68.44 and 97.81 per cent with nemacur; 59.11 and 83.94 per cent with FMC and 33.33 and 70.07 with thimet under the two types of treatments, respectively. The overall increase in tiller was 46.13 by seedling treatment and 81.75 per cent by seed treatments. Here also plants treated with nemacur had the maximum increase in number of tillers, and the others in the same order as above.

There was also an increase in number of leaves by the plants treated with nematicides (Table 6 and 5). The number of leaves increased by seedling treatment with carbofuran by 21.58 per cent, with aldicarb sulfone 19.85 per cent, with nemacur 43.97 per cent, with FMC 22.39 per cent and with thimet 16.23 per cent with an overall improvement of 24.80 per cent. By seed treatment number of leaves increased by 36.61 per cent with carbofuran;

26.91 per cent with aldicarb sulfone; 37.13 per cent with nemacur, 36.74 per cent with FMC, and 24.45 per cent with thimet with an overall increase of 32.37 per cent. Nemacur treated plants had the maximum increase in number of leaves, and the others in the above order. Increase in number of leaves by mocap, nemagon, dasanit, temik and nemacide was also reported by Jacob and Kuriyan (1979) in pepper.

Carbofuran, aldicarb sulfone, nemacur, FMC and thimet gave significant increase in shoot weight also, both in seedling treatment and seed treatment. Nematicidal treatment increased the shoot weight by 45.96, 38.66, 53.16, 30.39 and 30.18 per cent by seedling treatment; 27.88, 25.66, 62.14, 40.78 and 15.67 per cent by seed treatment respectively (Table 6 and 5). Thus there was an overall increase in shoot weight of 43.67 and 34.43 per cent in the two experiments. Here again the effect of nematicides was in the above order. Similar increase in shoot weight of 96.00and 70.20 per cent in rice by controlling Hirschmanniella oryzae with D-D was reported by Mathur and Prasad (1973). Increase in top weight by application of

tomik in sugarbeet (Steudel et al., 1978), in sugarbeet (Kuthe and Rosener, 1976) and by nemagon in sugarbeet (Saly et al, 1964)have also been reported.

Increase in root weight observed by nematicidal treatment was also statistically significant. From Table 6 and 5 it can be seen that carbofuran increased root weight by 44.99 and 45.23 per cent; aldicarb sulfone by 39.20 and 45.79 per cent; nemacur by 50.56 and 56.52 per cent; FMC by 46.77 and 53.04 per cent and thimet by 26.06 and 22.61 per cent with an overall increase of 41.32 and 44.64 per cent in seedling treatment and seed treatment respectively. Maximum increase was with nemacur while the other nematicides showed an increase in root weight in the same order as above. Root yield increase in sugarbeet with nemagon was reported by Saly et al.(1964) and with tomik by Vinduska (1973). Similarly root weight increase of barley by controlling Heterodera avenae using aldicarb was reported by Kuthe and Rosener (1976).

The earhead length and consequently the yield was also increased significantly both by seedling treatment and seed treatment with nematicides. The earhead length increased by 10.83, 9.48, 21.14, 14.86 and 4.42 per cent

in seedling treated plants and 10.94, 8.01, 21.74, 13.15 and 4.10 per cent by seed treatment with carbofuran, aldicarb sulfone, nemacur, FMC and thimet respectively. The yield increase due to the nematicides under the two treatments per plant were 42.06 and 46.65 per cent; 22.51 and 23.77 per cent; 70.33 and 71.65 per cent; 50.44 and 49.47 per cent; and 20.77 and 22.36 per cent respectively. A consequent increase in grain weight was also observed in all the treatments. Maximum increase of 90.31 and 91.84 per cent over control was obtained by nemacur in the two types of treatments. FMC increased the grain weight by 77.73 and 65.27 per cent; carbofuran by 54.85 and 60.67 per cent; aldicarb sulfone by 31.13 and 33.05 per cent and thimet by 28.45 and 29.71 per cent in the two types of treatments. Thus there was an overall increase of 12.15 and 11.59 per cent in earhead length, 40.63 and 42.78 per cent in the yield per plant under the two types of application of nematicides. This increase in yield was in agreement with the finding of Tanaka et al.(1962) who reported an yield increase of rice by 20-70 per cent by the application of D-D or EDB and Nishizawa et al.(1972) who reported 30 per cent increased yield by preplant treatment with D-D.

The plants raised from treated seedlings and seeds had a reduction in chaff weight than check. The chaff weight per plant decreased by 27.59 per cent with carbofuran, by 24.14 per cent with aldicarb sulfone, by 39.08 per cent with nemacur, by 34.48 per cent with FMC and by 20.69 per cent with thimet by seedling treatment. In seed treatment, the chaff weight decreased by 27.78 per cent, 26.67 per cent, 35.56 per cent, 34.44 per cent and 17.77 per cent respectively. Though the reduction was not statistically significant, there was an overall reduction of 24.33 per cent and 28.44 per cent in chaff weight by either method of treatment.

There was a definite decrease of cyst nematode population in soil and consequent reduction in cyst numbers as seen in Table 6 and 5. The cyst nematode population per 100 ml soil in check plants were 99.83 and 99.66 but they were reduced by 69.28 and 70.57 per cent by carbofuran, 68.12 and 65.55 per cent by aldicarb sulfone, 75.79 and 78.26 per cent by nemacur, 74.32 and 74.41 per cent by FMC and 66.66 and 63.80 per cent by thimet under the seedling dip and seed treatment trials. Consequent reduction in cyst numbers per plant was 55.79 and 58.14 per cent by carbofuran; 49.74 and 50.12 per cent by

aldicarb sulfone; 65.26 and 65.63 per cent by nemacur; 59.73 and 59.18 per cent by FMC and 30.00 and 33.90 per cent by thimet by the two treatments of nematicides. Likewise the number of cysts per 100 ml soil was also reduced by 52.99 and 42.59 per cent with carbofuran, 40.20 and 33.21 per cent with aldicarb sulfone, 58.08 and 55.42 per cent with nemacur, 54.31 and 44.04 per cent with FMC and 29.18 and 17.31 per cent with thimet under the seedling and seed treatments. Thus there was an overall reduction of 70.83 and 70.53 per cent in nematode population per 100 ml soil, 48.95 and 38.11 per cent in cyst numbers per 100 ml soil and 52.10 and 53.39 per cent in number of cysts per plants by the above two types of applications of nematicides. The reduction observed was statistically significant. Reduction in nematode population by application of nematicides had already been reported. Aldicarb at 5.5 kg a.i. per hectare reduced the populations of Globodera rostochiensis on potatoes by 50 per cent (O' Brien, 1978). Nemacur controlled potato cyst nematode at 2.9 to 10.3 kg a.i. per hectare (Whitehead et al. 1973d). Harrison (1974) reported 99 per cent

control of Heterodera rostochiensis on potato with carbofuran and oxamyl. Steele (1976) also found seedling dip of sugarbeet in aldicarb, aldicarb sulfoxide and aldicarb sulfone , effectively prevented nematode development in roots. Morris and Proudfoot (1974) got significant reduction in new cyst formation on potato roots by application of furadan, nemacur, temik and vydate. Vindachm (1973) got a reduction in cyst population of 36 per cent by temik. Temik at 5 kg per hectare was effective in producing potato tubers free of infection (Raj and Nimula, 1971). Thus the results obtained in the present control trials agree with the results of similar trials already reported.

Thus it had been found that nemacur, FMC, carbofuran, aldicarb sulfone an d thimet as 0.02 per cent solution gave consistent and significant control of cyst nematode, H.oryzicola, based on all the characters studied. There was considerable yield increase in the different treatments as evidenced by the results presented.

In conclusion, the investigations carried out here reveal the extent of damage to rice plant leading to

yield loss, host range and control of cyst nematode Heterodera oryzicola. It is evident that this nematode causes considerable reduction in plant growth and consequent reduction in yield both quantitatively and qualitatively. The results throw light to the fact that the cyst nematode can be a limiting factor in rice production, left uncontrolled. The extent of occurrence of this cyst nematode in the other rice growing tracts of Kerala may be estimated. The results obtained in the experiments on control will be useful in formulating suitable pest management practices against this cyst nematode problem and thereby increasing yield of rice.

SUMMARY

SUMMARY

The extent of crop loss caused by cyst nematode Heterodera oryzicola at different levels of inoculum in rice variety, Triveni was estimated in both field and pot culture experiments. It was found that the extent of damage caused to the crop, progressively increased with the increase of inoculum levels of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. in field experiment and 5, 10, 20 and 30 cysts per pot in pot culture experiment. The growth characteristics such as height of the plant, number of tillers, number of leaves, shoot weight, root weight, earhead length, total yield and grain weight showed graded reductions as the number of nematode larvae or cysts inoculated increased from 6,000 to 18,000 and 5 to 30 respectively. The extent of damage is of the order of 6.17 per cent to 32.24 per cent in the field experiment and 16.37 to 44.99 per cent in the pot culture experiment taking into consideration for all the characters studied. An yield loss of 16.94 per cent to 33.30 per cent in the field microplot experiment and 25.50 to 31.80 per cent in pot culture experiment was observed. The reduction in growth and yield characters of

the rice plant was maximum at the highest level of inoculum in both the conditions, showing that the more the nematode population, the more the damage to the plant.

In the host range studies, out of the 14 weed plants found in paddy fields and tested against Heterodera oryzicola, only one plant Echinochloa colonum (Linn.) Link, was found as host.

Five nematicides namely carbofuran, aldicarb sulfone, nemacur, FMC and thimet at 0.02 per cent solution were used for treating the seeds and seedlings of paddy. Nemacur was found superior over the other nematicides tried as evidenced by the improvement of plant growth characters and increase in yield, coupled with reduction of nematode population. Nemacur was followed by FMC, carbofuran, aldicarb sulfone and thimet, which also gave superior results in comparison to untreated plants. The overall increase in yield was between 42.78 to 74.85 per cent with seed treatment whereas with seedling treatment the yield increase was 49.63 to 56.49 per cent.

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* Originals not seen.

APPENDICES

Appendix I

ANOVA table of Table 1 and Table 3

Characters	Total S.S.	Replication df=5		Treatment df=4		Error df=20		F
		S.S.	M.S.	S.S.	M.S.	S.S.	M.S.	
Height of the plant	370.49	73.77	14.75	141.78	35.44	154.94	7.75	4.58**
Number of tillers	43.36	8.58	1.72	25.77	6.44	9.01	4.51	14.30**
Number of leaves	325.47	28.08	5.62	228.86	57.23	68.53	3.43	16.70**
Earhead length	195.86	23.09	4.62	53.16	13.29	119.62*	5.98	2.22 NS
Shoot weight	1560.87	81.21	16.24	971.93	242.98	507.73	25.39	9.57**
Root weight	371.41	102.90	20.58	197.36	49.34	71.15	3.56	13.87**
Total yield per plot	40548.17	2379.77	475.95	26202.33	6550.58	11966.07	598.30	10.95**
Grain weight per plot	56851.77	5660.94	1132.19	35614.42	8903.60	15576.42	778.82	11.43**
Chaff weight per plot	11220.91	2825.04	565.01	1094.08	273.52	7301.79	365.09	0.75 NS
Total yield per plant	69.02	12.03	2.41	40.36	10.09	16.62	8.31	12.14**
Grain weight per plant	72.26	5.18	1.04	47.90	11.98	19.18	0.96*	12.49**
Chaff weight per plant	14.35	2.75	0.55	0.91	0.23	10.69	0.53	0.42 NS
Nematode population per 100 ml soil	333.52	1.21	0.24	309.04	77.26	23.27	1.16	66.60**
Total number of cysts	205.40	3.84	0.77	169.55	42.39	32.01	1.60	26.49**
Cysts per 100 ml soil	63. 07	2.28	0.46	59.45	14.86	1.34	0.07	212.29**

** Significant at 5 and 1 per cent level

N.S. Not significant

Appendix II

ANOVA table of Table 2 and Table 3

Characters	Total S.S.	Treatment df=4		Error df=25		F
		S.S.	M.S.	S.S.	M.S	
Height of the plant	1515.20	937.12	234.28	578.08	23.12	10.13**
Number of tillers	19.47	9.13	2.28	10.35	0.41	5.52**
Number of leaves	70.74	33.37	8.34	37.38	1.50	5.58**
Earhead length	135.76	74.23	18.56	61.53	2.46	7.54**
Shoot weight	227.67	124.08	31.02	103.59	4.14	7.49**
Root weight	26.75	18.74	4.69	8.01	0.32	14.62**
Yield per plant	31.67	20.92	5.23	10.76	0.43	12.15**
Grain weight per plant	40.33	29.02*	7.26	11.31	0.45	16.04**
Chaff weight per plant	2.91	0.70	0.17	2.21	0.09	1.97 N.S
Nematode population per 100 ml soil	301.00	291.64	58.33	9.36	0.37	157.65**
Total number of cysts	181.28	172.28	43.07	9.00	0.36	119.64**
Cysts per 100 ml soil	55.64	50.81	12.70	2.83	0.11	115.45**

** Significant at 5 and 1 per cent level.

N.S. = Not significant.

Appendix III
ANOVA table of Table 5

Characters	Total S.S.	Treatment df=5 S.S.	Treatment df=5 M.S.	Error df=30 S.S.	Error df=30 M.S.	F
Height of the plant	2241.89	1495.12	299.02	746.78	24.89	12.01**
Number of tillers	14.58	6.77	1.35	7.81	0.26	5.20**
Number of leaves	98.15	36.82	7.36	61.33	2.04	3.60*
Shoot weight	149.98	70.63	14.13	79.36	2.65	5.34**
Root weight	32.58	17.18	3.44	15.41	0.51	6.69**
Earhead length	70.99	40.72	8.14	30.28	1.01	8.07**
Yield per plant	71.21	61.79	12.36	9.42	0.31	39.38**
Grain weight per plant	80.47	71.61	14.32	8.86	0.30	48.51**
Chaff weight per plant	2.12	0.41	0.08	1.71	0.05	1.46 N.S.
Nematode population per 100 ml soil	135.80	110.24	22.05	25.56	0.85	25.94**
Total number of cysts per plant	56.35	45.63	9.13	10.72	0.36	25.36**
Number of cysts per 100 ml soil	27.56	17.79	3.56	9.77	0.33	10.79**

** Significant at 5 and 1 per cent level
* Significant at 5 per cent level.

N.S. = Not significant

Appendix IV
ANOVA table of Table 6

Characters	Total S.S.	Treatment df=5		Error df=30		F
		S.S.	M.S.	S.S.	M.S.	
Height of the plant	2122.44	1083.89	216.78	1038.54	6.26	34.63**
Number of tillers	16.63	9.23	1.85	7.40	0.25	7.48**
Number of leaves	238.70	72.35	14.47	166.35	5.55	2.61*
Shoot weight	172.60	119.50	23.90	53.10	1.77	13.50**
Root weight	31.25	21.80	4.36	9.45	0.31	13.84**
Earhead length	61.70	40.95	8.19	20.75	0.69	11.84**
Yield per plant	73.51	61.54	12.31	11.97	0.40	30.86**
Grain weight per plant	85.21	71.42	14.28	13.79	0.46	31.07**
Chaff weight per plant	2.16	0.41	0.08	1.74	0.06	1.43 N.S.
Nematode population per 100 ml soil	124.74	109.75	21.95	14.99	0.50	43.90**
Total number of cysts per plant	60.03	43.63	8.73	16.40	0.55	15.87**
Number of cysts per 100 ml soil	34.41	23.78	4.76	10.63	0.35	13.60**

** Significant at 5 and 1 per cent level
* Significant at 5 per cent level.
N.S. Not significant.

ABSTRACT

The cyst nematode Heterodera oryzicola was observed to be an important pest of rice, affecting the growth and yield of paddy plant. However, detailed investigations on this nematode was not done earlier. The present study was hence undertaken to study the extent of loss, host range and control of this cyst nematode.

The extent of loss caused by Heterodera oryzicola on rice variety Triveni was studied at four inoculum levels of 6,000, 9,000, 12,000 and 18,000 larvae per sq.m. in the field experiment and 5, 10, 20 and 30 cysts per pot in pot culture study. There was considerable reduction in growth and yield of the paddy plant in both field and controlled conditions at all the different levels tried. This nematode caused considerable damage to the crop by depressing the height of the plant, number of tillers, number of leaves, earhead length, shoot weight, root weight, total yield and grain weight.

Fourteen weed plants from paddy field was tested for host range studies. Out of these only one plant Echinochloa colonum (Linn.) Link, was found to be the host.

Five nematicides namely carbofuran, aldicarb sulfone, nemacur, FMC and thimet at 0.02 per cent solution were used for treating the seeds and seedlings for controlling the cyst nematodes. It was found that these five nematicides gave good control of this cyst nematode and substantially increased the height of the plant, number of tillers, number of leaves, earhead length, shoot weight, root weight, yield and grain weight. There was also reduction in chaff weight, nematode population in soil and cyst population in soil and plant. Maximum control of the cyst nematode with increase in yield was obtained by nemacur followed by FMC, carbofuran, aldicarb sulfone and thimet, both in the seed and seedling treatments.