INTEGRATED CONTROL OF NEMATODE PESTS OF BHINDI WITH SPECIAL REFERENCE TO ROOT-KNOT NEMATODE

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THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
MASTER OF SCIENCE IN AGRICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE, VELLAYANI
TRIVANDRUM

1981

DECLARATION

I hereby declare that this thesis entitled "Integrated control of nematode pests of bhindi with special reference to root-knot nematode" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "Integrated control of nematode pests of bhindi with special reference to root-knot nematode" is a record of research work done independently by Smt. HEBSY BAI under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

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ACKNOWLEDGEMENTS

I wish to place on record my sincere gratitude and indebtedness to Dr. M.R.G.K. Nair, Emeritus Scientist, for his sincere and invaluable guidance, critical suggestions and constant encouragement throughout the course of this study and in the preparation of this thesis.

I am grateful to the Members of the Advisory Committee, Dr. N. Mohan Das, Professor of Agricultural Entomology, Dr.K.John Kurian, Associate Professor of Entomology and Dr. S. Balakrishnan, Associate Professor of Plant Pathology, for their co-operation, constructive criticisms and helpful suggestions in the preparation of this thesis.

I take this opportunity to express my gratitude to Dr. A. Vishalakshi, Associate Professor of Entomology and Shri. P.A. Rajan Asari, Assistant Professor of Entomology for the help rendered in the different stages of the investigation.

To Shri. M.P. Abdul Razak Assistant Professor in Agricultural Statistics, I express my thanks for the help rendered in the statistical analysis of the entire investigation. My thanks are also due to the late Shri. E.J. Tho Professor of Agricultural statistics for the valuable suggestions and co-operation given in the analysis of the data.

I am grateful to Dr. N. Sadanandan, Dean, Faculty of

Agriculture, College of Agriculture, Vellayani for kindly providing the facilities to carry out these studies.

I also acknowledge the help and co-operation rendered by my parents and friends in the conduct of this investigation and preparation of the thesis.

Finally I express my thanks to the Kerala Agricultural University for the award of fellowship during the tenure of the present investigation.

HEBSY BAI

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INTRODUCTION

Bhindi (Abelmoschus esculentus) occupies a pride of place among vegetables in Kerala. Cultivators raise the crop throughout the year if water is available. A major limitation to bhindi crop is constituted by pests and diseases affecting the crop. Among the pests, the root-knot nematode Meloidogyne incognita has been found to be one of the most commonly occurring and destructive pests, taking a heavy toll of the crop every season. Due to continuous cultivation of the crop and due to the polyphagous habit of the pest, the soil usually maintains a very high population of this nematode. The high yielding varieties of bhindi like 'Pusa Sawani' have been found to be highly susceptible to infestation by the nematode. The advantages of adopting better crop husbandry practices are generally offset by infestation by the root-knot nematodes. Plants infested by the nematode loose their vigour, become stunted with discoloured leaves and suppression of flowering. When such plants are uprooted severe galling on roots and suppression of root system are observed. (Plate I). Plants which are able to survive infestation yield less and die early. It has been estimated that the reduction in yield of fruits caused by M. incognita is to the extent of 40 to 50 per cent.

Studies have been made by various workers on the control of root-knot nematode infestation on bhindi. One of the approaches chosen for the control of the nematode has been the

Plate I

Fig. a. Bhindi plants in control plot.

Fig. b. Bhindi plants in control plot and in the plot receiving the treatment, aldicarb + deep ploughing.

Plate I

Fig. a

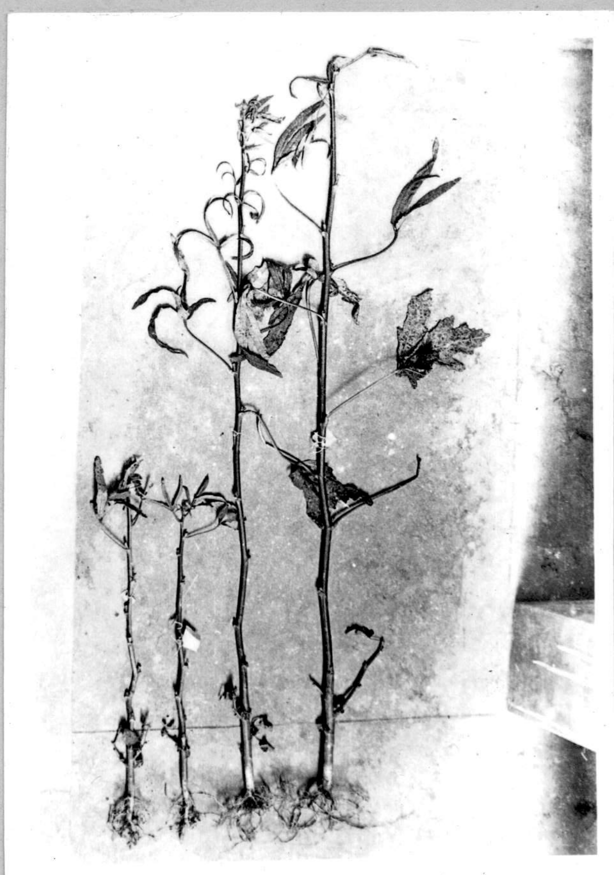

Fig. b

application of organic materials. These include application of materials like oil cakes, sawdust and green leaves (Singh and Sitaramaiah, 1969 and 1971; Sharma et al., 1971; Prem Kumar and Nair, 1976; Sitaramaiah et al., 1976 and Zaiyd, 1977). Among the cultural operations tested for the control of the nematode, crop rotation has been found to be advantageous (Sundaresh et al., 1977; Sundaresh and Shetty, 1977). Among the chemicals tried 'Vydate' oxamyl applied as foliar sprays repeatedly for five times has been found to control the nematode on bhindi (Alam et al., 1973). Non-volatile nematicides like fensulfothion, carbofuran, mocap, phorate and aldicarb have been reported to give effective control of M. incognita infesting bhindi (Sitaramaiah and Vishwakarma, 1978). Seed treatment with carbofuran has been reported to be effective in controlling the nematode on bhindi by Shivakumar et al., 1973 a, b.

From discussions undertaken at a workshop of the All India Co-ordinated Research Project on Nematode pests of crops and their control held at the Indian Agricultural Research Institute, New Delhi, it was considered worthwhile to evolve integrated approaches for the control of the various nematode pests of cultivated crops. As a part of this programme the present studies were undertaken at the College of Agriculture, Vellayani. In these studies involving field experimentation, efforts were made to ascertain the effect of combining three treatments for effective control of M. incognita infesting bhindi. The treatments included, deep ploughing as a cultural operation, seed treatment with a nematicide and soil treatment with a non-volatile nematicide as a pre-planting treatment. The effect of these treatments individually and in their various combinations was studied with reference to growth and yield of bhindi and the soil population of the nematode. A pot experiment was also done to determine the relative susceptibilit of five local varieties and an improved variety AE 112 of bhindi to infestation by M. incognita.

An exhaustive review on the control of root-knot nematode has been made and presented.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Among the different plant parasitic nematodes which damage cultivated crops the root-knot nematodes as a class rank as the most important and destructive. They damage a wide variety of crops causing economic losses. Much work has been done by workers all over the world on the control of root-knot nematodes on different crops. A review of the more important contributions made in this field is given below:-

Nattrase (1944) found that chopped napier grass applied in trenches in soil heavily infested by root-knot nematodes enabled him to grow a normal crop of potatoes.

Johnson (1963) indicated that the root-knot infested soil amended with mature dried oat straw gave good control of the nematode at 73-76°F of night temperature and 81-84°F of day temperature in the green house conditions. Less control was obtained when average daily high temperature was 85°F or higher.

Elgindi (1967) in Egypt found that sugarcane begasse and molasses when applied as organic amendments to soil, reduced the number of nematode larvae. Molasses with a two per cent sucrose concentration was the most effective giving a 50 per cent larval mortality in about nine days.

Johnson et al. (1967) found that when mature crop residues chopped to about 1/8 inch size were incorporated into soils in field plots infested with *Meloidogyne incognita*, root-knot infestation was reduced by alfalfa hay, oats straw, lespideza hay and flax hay amendments. Better reduction was obtained when amended with ten tonnes per acre than with five tonnes and when the materials were applied eight months before than shorter periods.

Singh et al. (1967) reported that gall formation on roots of tomato and okra caused by *M. javanica* was appreciably reduced if sawdust at the rate of 2,000 lb per acre was mixed with soil three weeks before planting. They found that okra yield increased by 70 per cent and tomato yield by 12 per cent over the check.

It was found that *Meloidogyne* population on tomato in India was diminished more by the pre-planting application of mustard cake to the soil than by the application of other oil cakes (Hameed 1968).

Tu and Cheng (1969) showed that fumazone, nemamort and memort G. effectively controlled *M. incognita* on tomato and increased plant growth and yields, the most profitable treatment being 28 litre per ha of fumazone. Singh and Sitarameiah (1969) found that amendment of root-knot (*M. javanica*) infested soil with oil cakes of margosa, castor peanut, mustard, mahua and linseed as wel as with sawdust at the rate of 25 quintals per ha gave effective reduction in the intensity of root galls on okra and tomato.

Studies conducted by Atwal and Mangar (1969) revealed that *Abelmoschus esculentus* when grown alone was heavily attacked by *Meloidogyne incognita* but when grown together with sesamum the infestation was almost negligible.

Nematicidal trials done by Srivastava (1969) for controlling *M. javanica* which attacked *Solanum melongena* and tomato using nemagon, hexanema, vapam and thionazin showed that nemagon at 6.67 litres per ha was significantly superior to the others, the yield obtained being nearly four times that of control.

Field trials carried out by Birat (1969) using soil fumigants for control of *M. javanica* on tomato showed that nemagon and E.D.B reduced the number of root galls and increased fruit yields. Good results were obtained with insecticides like diazinon at 2.4 kg per acre applied to soil before transplanting and chlordane and heptachlor both at 12 kg per acre.

Halteren (1969) reported that flooding or high ground water level reduced infestation of *Meloidogyne* even in highly susceptible crops.

Hameed (1970) studied the effects of incoporating organic materials with soil in a ratio of 1:3 on the incidence of *Meloidogyne* spp. in tomato. It was found that the addition of organic matter generally reduced the incidence of *Meloidogyne* spp. and that the addition of *Chrysanthemun coronarium*, *Melia azaderachta* and *Tagetes patula* had reduced nematodes substantially and increased plant growth.

Wong, Harper and Mai (1970) compared three chemicals, 1,2 dichloro propene and 1,3 dichloro propane and related chlorinated hydrocarbon compounds and D-D and methylisothiocyanate as preplanting, fall and spring soil treatments for controlling root-knot in lettuce. They found that the amount of root-knot was significantly lower in the treated plots than in the check plots, but there were no significant differences among the chemicals or between fall and spring application.

Johnson (1971) carried out pot experiments to test the influence of oat straw and mineral fertilizer soil amendments on severity of tomato root-knot nematode. A complete mineral fertilizer at 2000 to 8000 lb per acre reduced the severity of root-knot disease. Out straw induced a nutrient deficiency and reduced disease, the target dose of mineral fertilizer overcame the deficiency and increased the effectiveness of the oat straw in reducing galling.

In a study conducted by Gupta et al. (1971) for the control of root-knot nematodes in Haryana, best results were obtained with D-D at 300 litres or DBCP at 40 litres per ha.

Bindras and Kaushal (1971) showed in an experiment that chemical root dips of tomato seedlings with parathion, dimethoate and diazinon were effective, while malathion fenitrothion, formothion, disulfoton and carbofuran were ineffective.

Economic returns were obtained from bhindi and tomato grown in Meloidogyne spp. infested soil by application of mustard, mahua and margosa cakes. Root-knot incidence was much reduced by both margosa cakes and sawdust with urea (Sharma et al. 1971).

Studies on some systemic nematicides by Reddy and Seshadri (1971) revealed that thionazin and aldicarb at four to eight kg a.i. per ha in pre-inoculation treatment on tomato completely eliminated the root-knot infection while in the post-inoculation treatment it gave a high degree of control. Fensulfothion, methomyl and carbofuran gave satisfactory control at higher dosages at which however they were phytotoxic. Foliar applications of thionazin and TCPP were least effective.

Pot trials in Philippines conducted by Ducusin and Davide (1972) showed that post-plant application of nemagon gave significant increase on yield of tomato only in plants not severly infested. Field trials after addition of sawdust, chicken manure or nemagon or planting with Tagetes erecta showed reduced galling.

Johnson (1972) reported that galling of tomato roots by M. incognita was reduced by 75 to 99 per cent on plants grown in soil mulched with flax, lucerne or orchard grass residue.

Goswami and Swarup (1972) tested oil cakes of linseed, margosa, groundnut and karanj for their efficacy against M. incognita on tomato seedlings. Soil amended with Karanj and groundnut cakes showed considerable decrease in population of nematodes.

Nematicides D-D, dasanit, nemacur and tripate were found to give higher yields of tomato in an experiment of Colon Ferrer et al. (1972), dasanit giving the highest and D-D the lowest yields. McLeod (1972) studied the effectiveness of thio-bendazole, methomyl and aldicarb for control of root-knot nematode.

Nematicide trials in Kenya (1972) using D-D and E.D.B. on soil infested with root-knot nematodes indicated that root-knot infestations can be reduced and bean yields increased by 60 per cent.

Studies of Reddy and Seshadri (1972) indicated that tomato seedlings grown in thionazin and aldicarb treated sand were free of root galls even 15 days after inoculation. The two chemicals at 4 and 8 kg per ha gave complete control of the nematode upto three weeks and two weeks.

Alam et al. (1973) tested the efficacy of 'Vydate' oxamyl in controlling root-knots on egg plant and okra. Seedling dip together with foliar sprays reduced root-knot incidence in egg plant while foliar sprays alone were not effective. In okra where no seedling dip was done marked reduction of galls was seen when sprayed five times. In another experiment Alam et al. (1973) obtained a reduction in the development of root-knot on tomato and egg plant with VC - 13 and Basamid bare root dips.

Result of an evalution study of carbofuran seed treatment for the control of root-knot on okra by Sivakumar et al. (1973) showed that while seed treatment may not give absolute protection against the root-knot nematode it can effectively be employed to reduce the severity of the infestation

Homeyer (1973) achieved 90 to 99 per cent control of

M. incognita on tomato with phenamiphos at the rate of 10 to 20 kg per ha. Yield increased from 10 to over 100 per cent

Tests of three nematicides (methyl bromide, D-D sodium N - methyl dithio carbamate) against M. incognita on cucumbers growing in sandy loam soil in a green house in Greece (Kyrou 1973) showed methyl bromide at 56.7 g per sq m to be the most effective. In another experiment he found that soil treatment with D-D and D-D - MENCS controlled M. incognita.

Addition of oil cakes like groundnut, longe, neem, castor, niger and lonne and farmyard manure improved growth of tomato in terms of height, fresh weight of shoot and roots, groundnut, niger and castor being particularly good (Gowda and Setty, 1973).

Pot experiment results of Kobayashi (1973) indicated that flooding M. incognita infested soil at 30°c for 15 days killed the nematodes.

Prasad and Setty (1973) found that the plant growth regulator maleic hydrazide applied as soil drench significantly controlled the nematode population.

Sivakumar et al. (1973) conducted one pot and two field experiments to evaluate the efficacy of soil application of fensulfothian, carbofuran and Sandoz 139 granules and of seed treatment with carbofuran against M. incognita on okra. Carbofuran seed treatment at 3 or 6 per cent a.i. gave the most economic control.

Mammen (1973) found that bhindi plants grown in pots together with Tagetes erecta were less infested with M. incognita.

Experiments of Inderjit Singh and Prasad (1974) revealed that in general thionazin, phorate and dazomet were effective as granular and dip + granular application and carbofuran and thionazin + phorate as granular application. While phorate formulations were more effective in the case of brinjal, it was thionazin applications in respect of tomato.

Sukun et al. (1974) reported that aqueous extract of leaves of Tragia involucrata and Polygonum hydropiper reduced both galling and the population of M. incognita on ladies finger without phytotoxicity.

According to Chabra and Mahajan (1974) aldicarb, fensulfothion and phorate broadcasted at 10 kg a.i. per ha before transplanting of tomato to a field infested with M. incognita, each effectively reduced the nematode populations, aldicarb giving significantly increased yields.

In pot experiments, Bindra and Soodan (1974) found brinjal plants when treated with D-D as a pre-plant soil injection with DBCP as a post plant soil drench or with a broadcast application of phorate at planting time resulted in significantly lower nematode populations. In field trials the best control of M. incognita on brinjal and tomato was obtained with D-D at 280.82 litre a.i. per ha and with DBCP at 26.92 litre a.i. per ha followed by phorate at 4.94 a.i. per ha then D-D at 224.06 litre a.i. per ha and DBCP at 20.19 litre a.i. per ha.

Sivakumar et al. (1974) found that spot application of aldicarb 10 g at 1.4 kg a.i. per ha, fenosulfothion 5g at 1 kg a.i. per ha and carbofuran at 0.6 kg a.i. per ha gave economic control of root-knot nematodes.

While evaluating the efficacy of 'Vydate' oxamyl for the control of root-knot nematodes attacking tomato Alam et al. (1975) observed that there is complete control following root dip of 5 weeks old tomato seedling at 1,200 ppm a.i. for 30 minutes and 5 sprays, less control with fewer sprays and poor control with foliar sprays alone.

Reddy et al. (1975) reported from Hebbal, Banglore when soybean was planted immediately after treatment of the plots heavily infested with root-knot with fensulfothion (10 kg a.i. per ha) aldicarb (2 kg a.i. per ha) oxamyl (8 kg a.i. per ha) methomyl (8 kg a.i. per ha) carbofuran (2 kg a.i. per ha) and benomyl (2 kg a.i. per ha) significantly controlled Meloidogyne, benomyl being the least effective.

Habicht (1975) found that raw sewage sludge (at 2.4 and 8 per cent dry weight and composit sewage sludge at 4,8 and 16 per cent dry weight incorporated into soil infested with *M. incognita acrita* (1,400 larvae per 100 g soil) and planted with tomato both significantly reduced galling. Raw sludge and higher levels of the amendments were the more effective. The main effect of the treatment appeared to be that of increased fertilization.

In their studies on the action of DL - methionine, Reddy et al. (1975) noted that the development of *M. incognita* in tomato roots was reduced when larvae were inoculated one week after application of DL - methionine but not when inoculated 14 or more days after.

Singh (1975) found in green house experiments, single foliar application of oxamyl 600 ppm significantly reduced attack of root-knot nematode on tomato and lettuce. In a field trial three foliar applications of oxamyl at 1250 ppm significantly reduced the nematode population.

Hackney and Dickerson (1975) observed that root population of *Meloidogyne* in tomato simultaneously cultivated with marigold, castor bean and chrysanthemum were significantly lower than from tomato cultivated alone.

Reddy (1975) noted that in plots infested with _Meloidogyne_ spp. D-D, DBCP, fensulfothion, aldicarb and methomyl at respectively 75 litre, 15 litre, 10 kg, 4 kg and 8 kg ai. per ha gave good control and increased yields by 15 to 37 per cent.

Villeroy and Fourcheresse (1975) in France reported that carbofuran gave effective control of _M. nassi_ on sugarbeet and _M. incognita_ on tomato.

From their experiments Castillo et al. (1975) noted that three successive crops of maize, _Tagetes erecta_, tomato with _T. erecta_ or _Crotalaria juncea_ intercrop, tomato with pre-plant soil applications of chicken dung or rice straw compost and fallow for 3 growing seasons suppressed field populations of _Meloidogyne incognita_ to varying degrees but failed to eliminate the nematode.

Reddy and Seshadri (1975) from their studies found that no galling was seen when the bare roots of tomato seedlings were dipped in aqueous solutions of thionazin at concentrations of 500, 1000, 2000 or 5000 ppm for periods from 15 minutes to 8 hours. Mixing of granular formations of thionazin and aldicarb at rates of 4 and 8 kg ai. per ha and applying in the soil also gave good control.

Johnson et al. (1975) in U.S.A. used an organic phosphate or carbamate nematicide, a herbicide and a fungicide for controlling M. incognita and weeds and increasing the growth of tomato plants. Bay 68138 + diphenamid, ethoprop + diphenamid, Bay 6318 + peblate + Dexon, fensulfothion + isopropalin + Dexon, Bay 68138 + isopropalin + Dexon and ethoprop + isopropalin + Dexon reduced population densities of M. incognita below detectable levels.

Khan et al. (1975) published the effects of monocultures and rotations with a number of vegetable crops in field populations of plant parasitic nematodes. M. incognita multiplied many times under monocultures of tomato, okra, chilli and sponge gourd on rotations of these crops in all combinations. Root-knot population decreased under marigold spinach, bottle gourd or fallow.

A report of Sitaramaiah et al. (1976) indicated that carbofuran, fensulfothion and sawdust + NPK all significantly reduced Meloidogyne javanica parasitism on Pusa Sawani and that the sawdust treatments gave the greatest yield. Mocap and sawdust + urea were less effective.

Desai et al. (1976) observed that tomato plots which were left unirrigated during summer had higher plant stand, fruit yield and shoot weight, with lower root-knot incidence than irrigated plots. Deep ploughing during summer and spot application of farmyard manure also resulted in high plant stand, fruit yield and shoot weight while spot application of manure showed the lowest disease index and gave reasonable root-knot control and better yield than with D-D soil fumigation.

Pot experiments conducted by Reddy et al. (1976) revealed that the amino acids DL - methionine and DL - valine gave greatest reduction in root galling of tomato.

Khair and Ralph (1976) carried out tests to compare the efficiency of methyl bromide and ethylene oxide fumigation for elimination of root-knot nematodes from bare roots of tomato plants. Methyl bromide reduced but did not eliminate infection, whereas ethylene oxide at relatively low concentration was lethal.

Studies of Vovlas and Lamberti (1976) on the systemic action of some chemicals in the control of root-knot nematodes of tomato revealed that oxamyl prevented larval invasion of the roots for about 25 days, aldicarb and thionazin for 18 to 20 days and carbofuran for about 12 days.

Pillai (1976) achieved 4 per cent reduction of damage to tubers of Coleus paviflorus by M. incognita with nemagon at 0.5 ml per 30 sq cm, 5.7 per cent fensulfothion at 2 g per 30 sq cm, 11 per cent with D-D at 0.5 ml per 30 sq cm and to a lesser extent with parathion and phosphamidon. Yields were increased by 53 per cent with nemagon and 47 per cent with fensulfothion.

Investigation of Rodriguez - Kabana and King (1976) on the activity of the insecticide phorate against root-knot nematodes gave results which suggested that phorate is a good nematicidal deterrent for M. incognita on cotton and tomato but is only moderately effective against M. arenaria.

Sivakumar et al. (1976) reported that application of carbofuran 0.18 and 0.36 kg ai. per ha 10 day after transplanting gave significantly higher yields of tomato in M. incognita infested fields.

Prasad et al. (1976) observed in pot experiments, soil drenches of DL - alanine, DL - Serine and DL - threonine applied at concentrations equal to their mg molecular weight to tomato plants one week after inoculation with M. incognita resulted in significantly lower reproductions of nematodes.

Studies conducted on the use of green leaves and organic wastes like Calotropis sp., Eupatorium sp., mango and cashew, farmyard manure and coconut oil cakes etc. by Kumar and Nair (1976) for the control of root-knot nematodes on okra cv. Pusa Sawani, showed that infestations were reduced and the growth of the plants were increased. Plant height and average root weight per plant were increased by most treatments.

Yein et al. (1977) found that soil application of aldicarb (1.5 kg a.i. per ha) alone or in combination with nitrogeous (12.5 kg N per ha) and phosphatic (40 kg P per ha) fertilizers significantly reduced the nematode population and their galls on root on Mung. The highest reduction of 84 to 85 per cent in the population of nematodes over the control recorded in treatment with aldicarb + nitrogen + half phosphorus was significantly higher as compared with 66 per cent reduction in treatment where aldicarb was applied alone.

Nematicide trials on tomato plants grown in a glass house in Malta carried out by Dandria et al. (1977) showed D-D at 300 litre per ha to be the most effective.

Johnson and Campbell (1977) reported that clean fallow was initially more effective in suppressing root-knot nematodes on tomato than cropping with Pennisetum americanum, Sorghum vulgare etc. or treatment with fensulfothion. After two years nematode levels increased until fallow, even in conjuction with fensulfothion was no longer effective. After four years cropping, alone or with fensulfothion failed to reduce nematode population.

Sundaresh and Shetty (1977) showed crop rotation as an effective and practical measure of controlling root-knot nematodes. Tomatoes grown in soil infested with M. incognita were much more heavily infested following crop of the susceptible plant Abelmoschus esculentus than after resistant maize.

Meloidogyne javanica gall number was reduced and plant top weight increased by addition of mustard cake, groundnut cake, linseed cake and castor cake to okra plants in pot trials conducted by Zaiyd (1977).

Minton et al. (1977) noted that application of DBCP after sub soiling and the use of cultivars of soybean with different levels of resistance to M. incognita increased plant yield but did not provide adequate residual control of the nematode for economical soybean production.

Mazumdar et al.(1977) recorded M. incognita for the first time on Solanum Khasianum in Kalyani, and found that it could be controlled by application of carbofuran at 25 kg per ha every three weeks.

Overman (1977) reported significant reduction in the incidence of Meloidogyne on tomato and increased yield by 20 per cent by application of methyl bromide at 488 kg per ha introduced into irrigation water applied through a bi-wall tube buried 10 cm deep in a plastic mulched bed.

Mahajan and Mayee (1977) tried six compounds with insecticidal and nematicidal properties for nematode control in tomato. Significant fruit yield increases were only associated with phorate, fensulfothion and aldicarb application.

In Cyprus, Panayis (1977) obtained very good control of Meloidogyne on tomato as judged by fruit yield with DBCP, D-D, Telone, Di-Trapex and methyl bromide despite some degree of galling.

Sundaresh et al. (1977) carried out an intergrated control experiment of root-knot nematode. Zea maya var. Seneca resistant to M. incognita when rotated with tomato and chilli caused a significant reduction in nematode population. Carbofuran and oil cake together caused the greatest reduction.

Of several granular nematicides compared against Meloidogyne on tomatoes, by McLeod (1977) the best results were obtained with aldicarb.

Belcher and Hussey (1977) studied the influence of *Tagetes patula* and *Arachis hypogaea* on *M. incognita*. *Tagetes patula* was 27 per cent more effective in reducing *Meloidogyne* population than peanut.

Different cropping sequences carried out by Alam et al. (1977) showed that all the cropping sequences tested brought about reductions in the populations.

D'Errico and Di Maio (1977) suggested that prophos when given both before planting and also applied to the soil surface after planting at 10 kg per ha will significantly increase yield of tomato.

Hemeng (1977) in his studies on infectivity of *M. incognita* and its control reported that in experiments, D-D, nemagon and vapam gave better control.

Prasad et al. (1977) compared the efficacy of three systemic nematicides on the control of root-knot nematode on tomato. Results showed that soil drenches of oxamyl, fensulfothion or carbofuran at 4 or 8 kg per ha can effectively control *M. incognita* on tomato.

Rao and Singh (1977) evaluated seeds of 34 varieties and selections of okra for their reaction to *M. incognita*. The results revealed that all the 34 varieties and selections of okra tested were susceptible to *M. incognita* to varying degrees. Highest root-knot developement was observed on Crimson Spineless, I.C. 10252 and Pusa Sawani.

Brown and Turner (1978) observed that plots infested with _M. javanica_ when treated with liquid phenamiphos at 8 kg a.i. per ha gave the highest yield followed by aldicarb and oxamyl. E.D.B. and Telone II did not reduce the level of root galling.

Bhatnagar et al. (1978) explored the possibility of control of root-knot nematode on okra by the application of water soluble fraction of oil cakes to soil. Of the four extracts tested (groundnut, til, mustard and taramira) groundnut gave the best control at the higher dosage. The root-knot index was 1 and the number of galls per g root was 0.52 compared with 5 and 54.63 respectively in control.

Johnson (1978) achieved an increase of 50 per cent and 33 per cent respectively in the yields of tomato compared with yields from non-treated plots, when phenamiphos and carbofuran were applied at 11 and 3 kg a.i. per ha through water in a sprinkler irrigation system.

Sitaramaiah and Vishwakarma (1978) evaluated the relative efficacy of non-volatile nematicides on field for control of root-knot nematode on okra and tomato. Mocap at higher dosages (6 and 8 kg a.i. per ha in okra and 10 kg a.i. per ha in tomato) were phytotoxic and reduced yield. Other nematicides like fensulfothion, carbofuran, phorate and aldicarb increased yield though it was not proportional to root-knot control obtained. Spot application was superior than row application or broadcasting.

D'Errico et al. (1978) reported that prophos applied at 12 kg per ha four days before transplanting tomato in April and again at 8 kg per ha at the beginning of June in Italy increased the yield by 60 per cent.

McKenry and Naylor (1978) showed that concentrations of DBCP between 40 - 200 ug per ml gave good control of root-knot nematodes on tomato. Application of DBCP did not significantly improve the growth of infested plant but gall size decreased with increasing DBCP concentrations.

Ahuja (1978) studied the effect of root dip treatment on infestation of brinjal by M. incognita. Oxamyl at 5000 ppm for 60 minutes and dimethoate at 7,500 ppm reduced galling.

Experiments of Sivakumar et al. (1978) on persistence of nematicidal activity in seed treatment of okra with carbofuran and aldicarb sulfone showed that carbofuran 12 per cent a.i. and aldicarb sulfone 3, 6 and 12 per cent a.i. gave full protection against the root-knot nematode upto 15 DAG. The number of root-knot nematode eggs present at 55 DAG was less at higher doses of both the nematicides.

The influence of different cropping sequences on the population of root-knot nematode, M. incognita and the performance of the subsequent mung bean crop was studied by Sharma et al. (1980). They found that there was high galling index and low yield of mung bean in monoculture plots of tomato or when tomato was grown in rotation with soybean, gram and groundnut. Groundnut-wheat rotation resulted in maximum yield of mung bean.

Kaliram and Gupta (1980) conducted an experiment to test the efficacy of neem leaf extract. It was seen that best plant growth was obtained at the highest level (leaf extract prepared from 40 g neem leaves per kg of soil) which was also comparable with the next lower level (30 g neem leaves per kg of soil). There existed a positive correlation between the treatments and reduction in the number of galls.

Work done by Nandal and Bhatti (1980) showed that fensulfothion at the rate of 30 and 60 kg per ha applied as pre- and post-inoculation granular soil treatments and ethoprop at the rate of 30 and 60 kg per ha only in pre-inoculation treatment reduced root-knot galls significantly. Foliar application of methyl-O-demeton, monocrotophos and phosphamidon was not effective.

MATERIALS AND METHODS

MATERIALS AND METHODS

Experimental site.

The experiment was conducted in an area infested with root-knot nematodes at the College of Agriculture, Vellayani. The soil was of the red loam type.

Nematicides.

Temik 10 G. (Aldicarb) granules supplied by M/s. Union Carbide was used for soil application in the experiment. Furadan Flowable containing 40 per cent carbofuran supplied by M/s. Rallis India was used for treating the bhindi seeds in the field experiment.

Seeds.

The variety 'Pusa Sawani' supplied by the National Seeds Corporation was used in the field experiment. For comparing the relative susceptibility of different varieties of bhindi to infestation by the root-knot nematode, six varieties as shown below were used:

1. AE 112
2. Anakomban
3. Kizhakkan vehda
4. Kuttichini
5. Vellachini
6. Vattayila

Of these, the variety AE 112 was obtained from the Tamil Nadu Agricultural University. The others were all local varieties.

Fertilizers and Manure.

The manure used was cowdung. The chemical fertilizers used to give the required dose of N.P.K. namely Ammonium Sulphate (20.5% N), Super Phosphate (18.0% P_2O_5) and Muriate of Potash (50.0% K_2O) were obtained from FACT.

Other Materials.

The other materials used in the experiment included nematode sieves, plastic troughs, Baermann funnel, tissue papers, wire gauze, polythene bags, formalin, pots etc.

Preparation of experimental field.

Before the actual lay out of the experiment a crop of bhindi was raised in the experimental area for building up the nematode population. The crop was allowed to be in the field for sixty days. When the crop was fifteen days old, roots of bhindi plants heavily infested with galls were collected from the bulk cultivation in the Agricultural College farm, chopped and mixed with the soil after uniformly distributing them in the various plots. Forty-five days after inoculation, the aerial parts of the plants were cut at their base and the roots ploughed into the plots.

Layout of field experiment.

The field experiment was laid out in randomized block design with four replications. The details were as follows:

Gross plot size	-	3 M x 2.7 M
Net plot size	-	2.4 M x 2.25 M
Spacing	-	60 cm x 45 cm
Total number of plants in each gross plot	-	20
Number of plants in each net plot	-	6

There were seven treatments and one control as detailed below:

T_1	=	A	+	C	+	E	(Control)
T_2	=	B	+	C	+	E	
T_3	=	A	+	C	+	F	
T_4	=	B	+	C	+	F	
T_5	=	A	+	D	+	E	
T_6	=	B	+	D	+	E	
T_7	=	A	+	D	+	F	
T_8	=	B	+	D	+	F	Where :

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Treated seeds (seeds treated with 3 per cent carbofuran)

E = No nematicide treatment

F = Soil treated with Aldicarb at 3 kg a. i. per ha.

<u>Seed treatment.</u>

For treating the bhindi seeds with carbofuran, the seeds were mixed with the nematicide, water and talc in the following proportion:

Seed - 5 g
Carbofuran as Furadan Flowable - 445 mg.
Water - 75 mg
Talc powder - 400 mg

The required quantity of the nematicide concentrate was taken in a container. To this water was added and made into a slurry. The quantity of talc powder needed was weighed out separately. Furadan Flowable and the talc powder were then divided into four equal lots and one lot each of the two added to the seeds and mixed thoroughly. All the four lots were then mixed. They were kept on plastic sheets for drying for about one hour in open air in shade.

Application of nematicide in plots.

The amount of femik 10 G (16.2 g per plot) was weighed out and mixed with 125 ml of sand for application in each plot. The sand - nematicide mixture was then broadcasted uniformly in the plots. The soil was then raked to a depth of about 15 cm to mix the nematicide with the soil. The soil surface was then levelled and water sprinkled on the surface to serve as a seal for the nematicide in the soil. The plots were kept as such for two days before planting was done.

Sowing.

Shallow pits of 30 cm diameter were taken at a spacing of 60 cm x 45 cm in each plot. Four seeds were dibbled in each pit. Twenty days after germination all plants excepting two were removed from each pit.

Application of manure and fertilizers.

The plots were uniformly manured with cowdung at 12 tonnes per ha. N, P and K were used at the rate of 250 : 50 : 50 kg per ha. The entire quantities of P and K and half of N were given as basal dressing before dibbling the seeds and the balance quantity of N as top dressing one month after the first application.

Irrigation.

Watering was done twice daily.

Collection of soil samples for nematode counts.

For the assessment of pre-treatment nematode population soil samples from all the plots were collected before starting the experiment. For the assessment of nematode population in the different plots on the forty-fifth day of sowing, samples of soil were taken from five places in each plot from the root zone of the plant upto a depth of 30 cm. For making the count of nematode at harvest, soil samples were collected from five places in each plot from the root zone of the uprooted plants to a depth of 30 cm. Samples thus collected from each plot were mixed thoroughly and 500 g taken in polythene bags.

Extraction of nematodes from soil samples.

Nematodes were extracted from soil samples following the modified method of Cobb's decanting and sieving technique (Christie and Perry 1951).

The soil weighing about 100 g was transferred to a plastic basin and mixed thoroughly with three times water. Coarse particles and foreign materials were allowed to settle. The supernatent liquid was then passed through sixty-mesh sieve and the materials collected in the sieve. The sediments in the basin were discarded. The filtrate was allowed to stand for a few minutes and then decanted and passed through two-hundred-mesh sieve and then through three-hundred-and-twenty-five-mesh sieve. The fine silt and nematodes collected in these sieves were washed down into a beaker, with minimum quantity of water.

Isolation of nematodes by Baermann funnel.

Nematode suspension obtained from the soil samples processed was poured gently into a tissue paper kept in position in the Baermann funnel with help of a wire gauze. The funnel was filled with water upto a level just touching the tissue paper. The funnel was kept undisturbed and at the end of twenty-four hours about 10 cc of water was drawn out into a specimen tube by loosening the pinch cock.

Fixing and preservation of nematodes.

The nematode suspension obtained from the drawings from the Baermann funnel was allowed to settle and the volume was reduced to 5 cc by pipetting out water from the top. To this an equal quantity of boiling 10 per cent formalin was added to kill the nematodes. To ascertain whether the nematodes were properly killed a drop was examined under a stereo microscope.

Counting the nematodes.

The preserved suspension of nematodes was shaken well. The total population of nematodes and that of *M. incognita* were counted separately and recorded.

Assessment of results.

The effect of the different nematicidal treatments was assessed in terms of the yield, formation of galls on roots, plant height, number of leaves, number of branches, shoot weight, leaf area, root length and root weight of the plants under the different treatments. The details of the assessment are given below:-

Yield.

Bhindi fruits were harvested on alternate days and number of fruits and weight of fruits in each plot ascertained and recorded.

Gall formation on roots.

This was assessed in terms of the number and weight of galls found on the roots. These estimations were made on the forty-fifth day of sowing and at the final harvest of the crop. For the assessment on the forty-fifth day, one of the two plants in each pit of the net plot was uprooted with the roots intact while for the final assessment, the remaining grown-up plant in each pit was uprooted. To make the counts of galls all the roots of a plant were carefully cut out and the number of galls on each rootlet counted and recorded. The gall population was expressed as numbers of galls per 10 cm of root. For estimating the weight of galls, all the galls from the root system of a plant were cut out and weighed. The total weight of the root system was found out before cutting out the galls. Percentage weight of galls termed as root-knot index was calculated from these values.

Height of plants.

The height assessment of all the plants in the observational plot was done at the final harvest. The plant height was measured from the first node to the base of the terminal bud. Average height was calculated.

Number of leaves.

Total number of leaves on every plant in a net plot was recorded at the end of the experiment and number of leaves per plant calculated.

Number of branches.

Total number of branches produced on each plant was counted at the time of final harvest and number of branches per plant calculated.

Top weight.

Top weight of the plants at the time of harvest was assessed by cutting off the root system and weighing the shoots separately for each plant and mean per plant found out.

Leaf area.

To assess the leaf area, the fifth leaf from the terminal bud of each plant was plucked and the area of each determined by tracing the outline of the leaf on a graph paper and computing the area. The mean leaf area was then calculated.

Root length.

To assess the root length of the plant, the roots of each plant were cut out and length of each rootlet measured and total length calculated. Mean root length per plant was then determined.

Weight of root systems.

To find out weight of root system the below ground part of each plant after proper washing and drying was weighed and mean per plant ascertained.

Calender of operations.

17-12-79	-	Ploughing of the field
18-12-79	-	Weeding and breaking of clods
19-12-79	-	Laying out experimental plots Collection of pre-treatment soil sample for nematode counts
21-12-79	-	Application of aldicarb in the plots
22-12-79	-	Seed treatment
23-12-79	-	Taking pits in the plots Application of first dose of fertilizer Dibbling the seeds
12- 1-80	-	Thinning of plants
22-1-80	-	Application of second dose of fertilizer
6-2-80	-	Taking of first gall count, root length and root weight Harvest of fruits begin
14-3-80	-	Uprooting of plants followed by assessment of the various factors

Yield of fruits was recorded on alternate days from 6-2-1980.

Preparation and sterilization of pot mixture.

Pot mixture was prepared by mixing sieved field soil (red loam) sieved sand and well decomposed farmyard manure in the ratio 2:1:1. The mixture was then denematized by applying DBCP (Nemagon) at the rate of 3 ml per square metre of pot mixture laid out in beds of 15 cm thickness. The fumigant was poured in holes made in the bed and closed and the whole bed then sprayed with water to prevent the escape of the fumigant by evaporation and kept as such for 30 days. The denematized pot mixture was stored in pots and kept free from nematode contamination, for use in the experiment. Prior to the using of the soil mixture it was examined for the presence of nematodes if any.

Raising of root-knot nematode culture.

Culture of *Meloidogyne incognita* were raised in sterile soil for studies on the relative susceptibility of different varieties of bhindi to the nematode infestation. For this nucleus nematode populations were collected from four localities namely Vellayani, Adoor, Kayamkulam and Calicut. Nematode infested bhindi plants collected from these localities were brought to the laboratory and their root system washed carefully under the tap. Galled roots from these plants were cut out and placed in distilled water in petri dishes. They were examined daily under stereo microscope and the egg masses removed and kept in clean distilled water in petri dishes. The larvae obtained from these were inoculated on bhindi and coleus raised in sterilized soil in pots.

Determination of relative susceptibility of different varieties of bhindi to infestation by *M. incognita*.

The different varieties of bhindi seeds were sown in sterilized soil in pots of six inches diameter. Four seeds were sown in each pot and there were four replications for each variety under each strain of nematode population. The plants under each treatment were inoculated fifteen days after raising them. The inoculum of each strain of nematode was prepared in distilled water. Each pot was inoculated with hundred larvae. Four holes were made around the plants and 5 ml of the suspension distributed into these four holes and closed with soil. The plants were uprooted on the fortieth day after inoculation and the counts and weight of galls taken. The roots were also macerated and the total number of eggs present in the roots estimated.

RESULTS

RESULTS

EFFECT OF CULTURAL AND NEMATICIDAL TREATMENTS ON THE CONTROL OF *M. incognita* ON BHINDI

A field experiment was undertaken as detailed in 'Materials and Methods' to study the effect of normal and deep ploughing, seed treatment with carbofuran and soil application of aldicarb granules in their various combinations on the control of *M. incognita* on bhindi crop. Results of the different treatments were assessed on two occasions namely forty-fifth day of sowing and at final harvest. The observations made during these two occasions are presented below. The data were statistically analysed and the Analysis of Variance tables are given in Appendices I to III.

OBSERVATIONS ON THE FORTY-FIFTH DAY OF SOWING

Effect on root length.

Table 1 and Fig. 1 give the mean root length of bhindi plants under the different treatments. It was observed that the root length was significantly higher in plants under the treatments, seed treatment + aldicarb + deep ploughing and seed treatment + deep ploughing than in plants under control. Thus when the mean root length was 70.62 cm in control plants, it was 126.83 cm and 110.79 cm under the above said two

Table 1

Root length of bhindi plants receiving different treatments for control of *M. incognita* on the forty-fifth day of sowing

Treatments		Mean root length per plant (cm)
T_1	(A+C+E)	70.62
T_2	(B+C+E)	65.50
T_3	(A+C+F)	94.42
T_4	(B+C+F)	79.79
T_5	(A+D+E)	90.38
T_6	(B+D+E)	110.79
T_7	(A+D+F)	103.63
T_8	(B+D+F)	126.83
	CD =	37.2969

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 Kg a.i. per ha

treatments. The plants of plots receiving seed treatment + aldicarb + normal ploughing with a mean root length of 103.63 cm also showed considerable increase in root length though not statistically significant. All the other treatments did not show any significant effect on the root length, the length varying from 65.50 cm to 94.42 cm under the different treatments as against 70.62 cm in control.

Effect on root weight.

Results presented in Table 2 show that on the forty-fifth day the various treatments did not show any significant effect on the root weight of plants. As against a root weight of 5.96 g per plant in the control plots, the root weight varied from 6.20 g to 9.65 g under the different combinations of the treatments.

Effect on gall formation.

Table 3 and Fig. 1 show that gall formation on the roots by *M. incognita* was reduced significantly under all the treatments. Thus as against a number of 6.58 galls per 10 cm of the root on the plants under the control, the gall number ranged between 0.27 to 2.33 under the various combinations of the treatments. Among the different treatments, the one consisting of seed treatment + aldicarb + deep ploughing appeared to be the most effective in reducing the gall population, it being 0.27 per 10 cm root. This was followed in descending effectiveness by seed treatment + aldicarb +

Table 2

Root weight of bhindi plants receiving different treatments for control of *M. incognita* on the forty-fifth day of sowing

Treatments	Mean root weight per plant (g)
T_1 (A+C+E)	5.96
T_2 (B+C+E)	6.20
T_3 (A+C+F)	8.25
T_4 (B+C+F)	7.54
T_5 (A+D+E)	7.50
T_6 (B+D+E)	9.36
T_7 (A+D+F)	8.95
T_8 (B+D+F)	9.65

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Table 3

Gall formation on roots of bhindi plants receiving different treatments for control of *M. incognita*, on the forty-fifth day of sowing

Treatments		Mean number of galls per 10 cm of roots per plant
T_1	(A+C+E)	6.58 (2.67)
T_2	(B+C+E)	2.33 (1.79)
T_3	(A+C+F)	1.15 (1.43)
T_4	(B+C+F)	0.81 (1.32)
T_5	(A+D+E)	0.93 (1.38)
T_6	(B+D+E)	0.74 (1.29)
T_7	(A+D+F)	0.57 (1.24)
T_8	(B+D+F)	0.27 (1.13)
CD	=	(0.3891)

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Figures in parenthesis are values after $\sqrt{x+1}$ transformation

normal ploughing (0.57 per 10 cm root), seed treatment + deep ploughing (0.74 per 10 cm root), aldicarb + deep ploughing (0.81 per 10 cm root), seed treatment + normal ploughing (0.93 per 10 cm root) and aldicarb + normal ploughing (1.15 per 10 cm root). However, these treatments among themselves were on par statistically. Plants receiving deep ploughing alone as a treatment showed significantly more root-knot infestation (2.33 per 10 cm root) than the plants receiving all other treatment combinations.

Effect on soil population of root-knot nematode.

Data on the soil population of root-knot nematodes under the different treatments (Table 4 and Fig. 1) showed that when the population was as high as 116 per 100 g of soil in control plots, it was very low under the different treatments, the population varying from 2 to 41. The maximum reductions in population were observed under treatments receiving aldicarb + seed treatment, the population being 2 and 5.5 per 100 g soil. The next in effectiveness were the treatments aldicarb + normal ploughing (6.5 per 100 g) and seed treatment + deep ploughing (8.5 per 100 g). The treatment consisting of seed treatment + normal ploughing with a population of 12.75 per 100 g ranked next. The populations under treatments aldicarb + deep ploughing and deep ploughing alone were relatively higher being, 34.75 and 41 respectively. Thus in general it could be observed that

Fig. 1. Effect of different treatments on root length, number of galls per 10 cm root, root-knot nematode and total nematode population in the soil on the forty-fifth day of sowing.

T_1 - A+C+E
T_2 - B+C+E
T_3 - A+C+F
T_4 - B+C+F
T_5 - A+D+E
T_6 - B+D+E
T_7 - A+D+F
T_8 - B+D+F

A = Normal ploughing (10 cm)
B = Deep ploughing (20 cm)
C = Untreated seeds
D = Seeds treated with 3 per cnet carbofuran
E = No nematicide treatment
F = Soil treated with aldicarb at 3 kg a.i. per ha

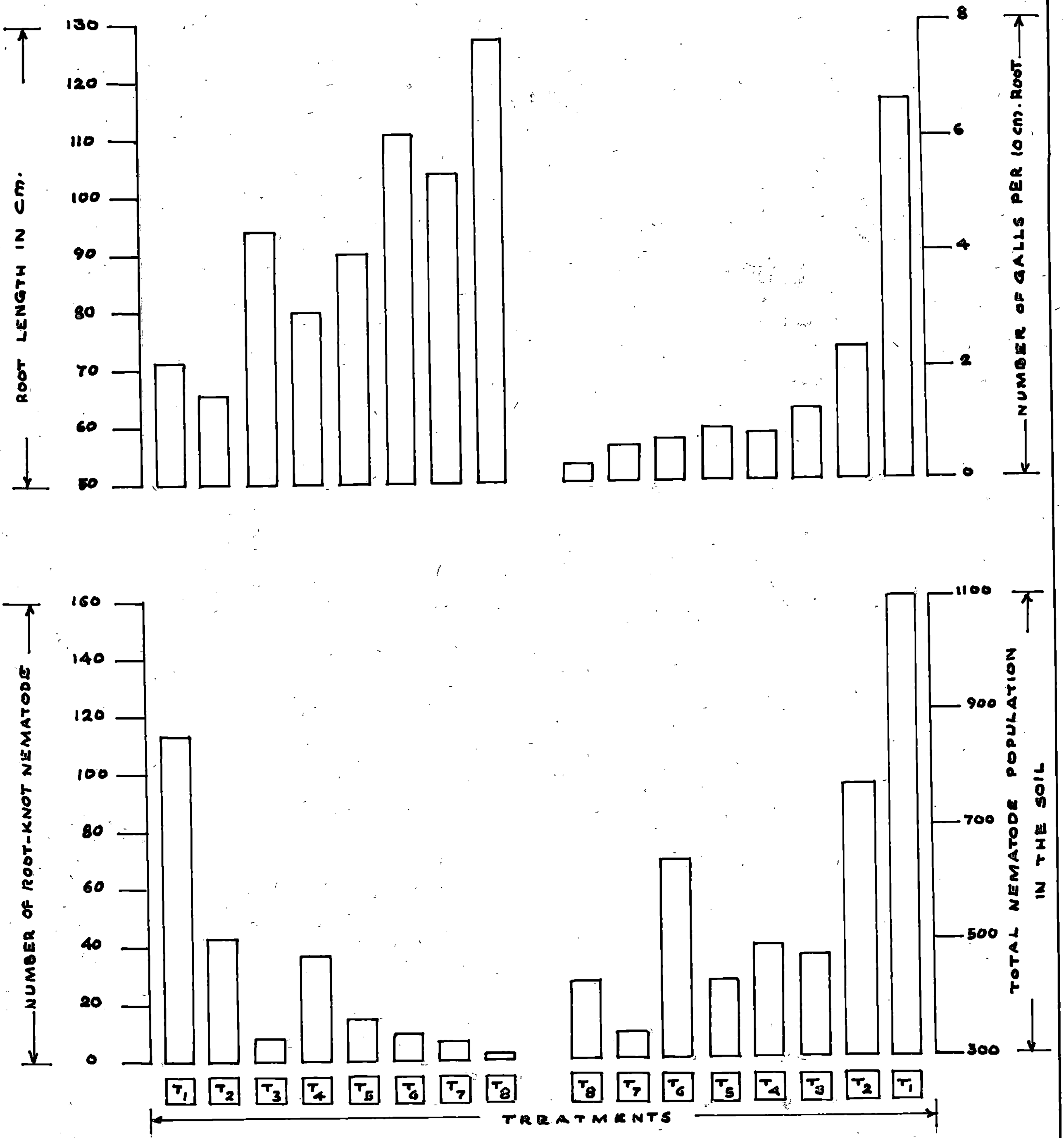

FIG: 1. EFFECT OF DIFFERENT TREATMENTS ON ROOT LENGTH, NUMBER OF GALLS PER 10 Cm ROOT, ROOT-KNOT NEMATODE, AND TOTAL NEMATODE POPULATION IN THE SOIL ON THE FORTY-FIFTH DAY OF SOWING

Table 4

Soil population of root-knot nematode in the plots receiving different treatments for control of *M. incognita* on the forty-fifth day of sowing

Treatments		Mean soil population of root-knot nematode
T_1	(A+C+E)	116 (10.97)
T_2	(B+C+E)	41 (6.02)
T_3	(A+C+F)	6.5 (2.31)
T_4	(B+C+F)	34.75 (4.06)
T_5	(A+D+E)	12.75 (3.67)
T_6	(B+D+E)	8.5 (2.86)
T_7	(A+D+F)	5.5 (2.23)
T_8	(B+D+F)	2 (1.61)

CD = (3.6545)

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nemticide treatment

F = Soil treated with aldicarb at 3 Kg a.i. per ha

Figures in parenthesis are values after $\sqrt{x+1}$ transformation

the treatments receiving aldicarb in soil or seed treatment with carbofuran gave significant reduction of soil population of 116 and 41 per 100 g soil respectively. Seed treatment with carbofuran by itself appeared to be highly effective in reducing root-knot nematode population in the soil. Thus when the population under normal ploughing was 116, it was 12.75 when seeds were treated and when the population was 41 under deep ploughing, it was 8.5 when seeds were treated. All the plots receiving aldicarb soil treatment showed the lowest population which was only expected, excepting however, in the case of aldicarb + deep ploughing with a population of 34.75, which was an anomaly.

Effect on root-knot index.

Data on root-knot index (Table 5 and Fig. 2) showed that the index, which gave an overall picture of the root infestation by the nematode, was significantly low under all combination of treatments except deep ploughing as compared to control. Thus as against a mean root-knot index of 4.88 under normal ploughing the index varied from zero to 0.31 under the different combinations of treatments and 2.87 under deep ploughing. The root-knot index was on par under the different treatments showing that all these were equally effective in controlling the nematode infestation. The treatment consisting of seed treatment + aldicarb + deep ploughing appeared to be the most effective with a root-knot

Table 5

Root-knot index of bhindi plants receiving different treatments for control of _M. incognita_, on the forty-fifth day of sowing

Treatments		Mean root-knot index per plant
T_1	(A+C+E)	4.88
T_2	(B+C+E)	2.87
T_3	(A+C+F)	0.07
T_4	(B+C+F)	0.29
T_5	(A+D+E)	0.31
T_6	(B+D+E)	0.01
T_7	(A+D+F)	0.12
T_8	(B+D+F)	0.00
	CD =	2.6359

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

index of zero. Deep ploughing by itself did not appear to be effective in reducing the root-knot index significantly; the index was 4.88 under normal ploughing and 2.87 under deep ploughing. The addition of seed treatment alone, aldicarb alone or aldicarb + seed treatment together were all highly effective in suppressing the gall formation.

Effect on total nematode population in soil.

Table 6 and Fig. 1 show that excepting deep ploughing treatment alone, all other treatments were significantly effective in reducing the total nematode population in the soil. When the population was 1102.5 per 100 g soil in the normally ploughed field, it was 772.75 under deep ploughing and 346 to 647.75 under the other combinations of treatments. Among the different treatments the most effective in reducing nematode populations were seed treatment + aldicarb combinations with population of 346 and 433.25 and seed treatment + normal ploughing with a population of 432.25. These three treatments were on par while the other treatments were significantly less effective in reducing the nematode population in the soil. But addition of aldicarb or seed treatment and their combinations were significantly effective in suppressing the nematode population in the soil.

Fig. 2. Effect of different treatments on root-knot index on the forty-fifth day after sowing and at final harvest of the plants

T_1 - A+C+E

T_2 - B+C+E

T_3 - A+C+F

T_4 - B+C+F

T_5 - A+D+E

T_6 - B+D+E

T_7 - A+D+F

T_8 - B+D+F

A =	Normal ploughing	(10 cm)
B =	Deep ploughing	(20 cm)
C =	Untreated seeds	
D =	Seeds treated with 3 per cent carbofuran	
E =	No nematicide treatment	
F =	Soil treated with aldicarb at 3 kg a.i. per ha	

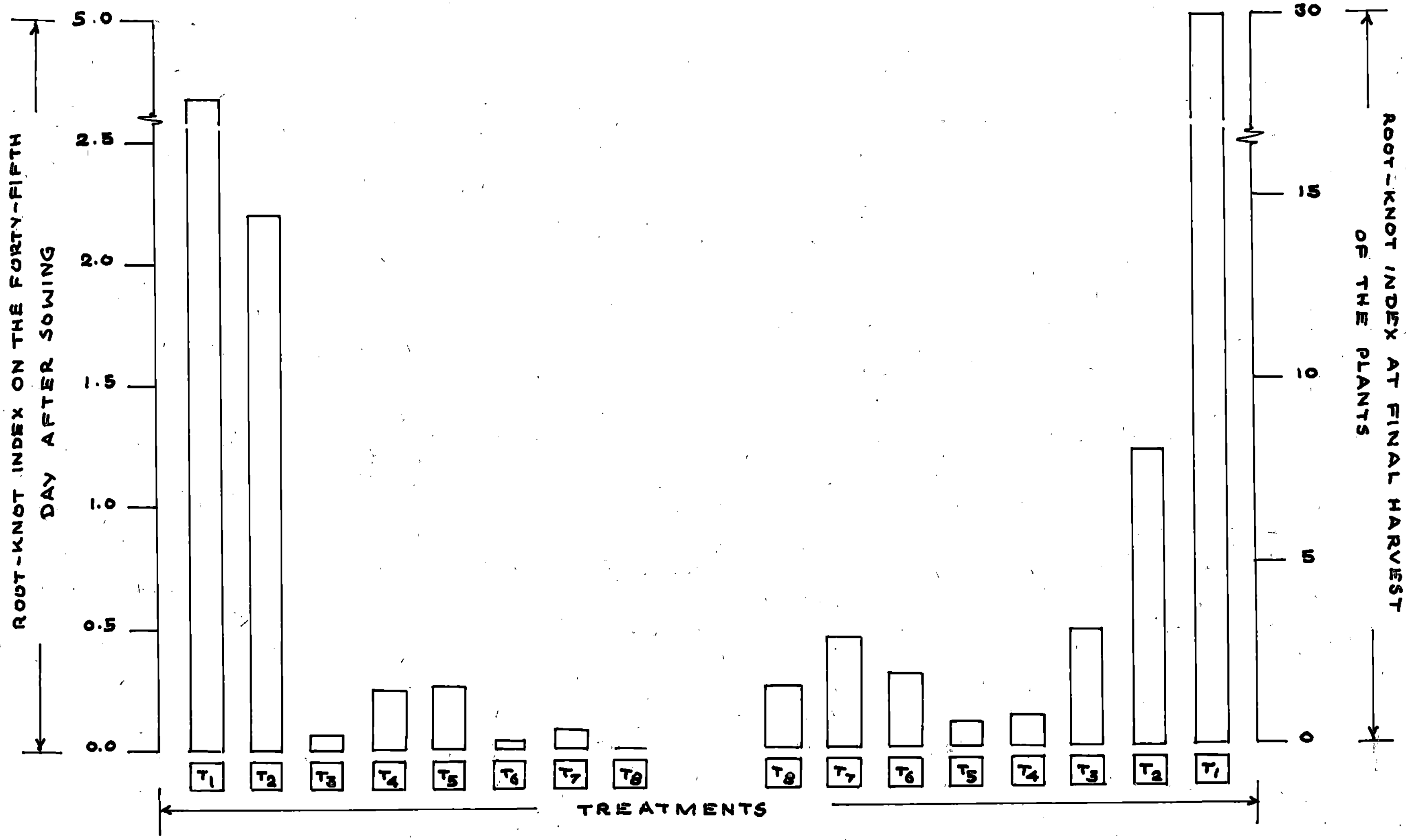

FIG. 2. EFFECT OF DIFFERENT TREATMENTS ON ROOT-KNOT INDEX ON THE FORTY-FIFTH DAY AFTER SOWING AND AT FINAL HARVEST OF THE PLANTS

Table 6

Total nematode population in the soil in the plots receiving different treatments for the control of *M. incognita*, on the forty-fifth day of sowing

Treatments		Mean total nematode population in the soil	
T_1	(A+C+E)	1102.5	(32.72)
T_2	(B+C+E)	772.75	(27.64)
T_3	(A+C+F)	472.	(21.64)
T_4	(B+C+F)	496.75	(22.30)
T_5	(A+D+E)	432.25	(20.56)
T_6	(B+D+E)	647.75	(25.04)
T_7	(A+D+F)	346.	(18.49)
T_8	(B+D+F)	433.25	(20.28)
	CD = (5.7646)		

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Figures in parenthesis are values after $\sqrt{x+1}$ transformation

OBSERVATIONS MADE AT THE FINAL HARVEST OF THE PLANTS

Effect on plant height.

Data presented (Table 7 and Fig. 3) show that the mean height of the control plants was 88.79 cm while the height ranged between 85.5 cm and 122.04 cm under the different treatments. As compared to the plants receiving normal ploughing only, the plants receiving the treatments aldicarb + deep ploughing, seed treatment + deep ploughing, aldicarb + seed treatment + normal ploughing and aldicarb + seed treatment + deep ploughing were significantly effective in increasing the plant height which were 120.46 cm, 115.88 cm, 112.54 cm and 122.04 cm respectively. The treatments consisting of aldicarb + normal ploughing and seed treatment + normal ploughing though were effective in increasing the plant height considerably, the effects were not statistically significant as compared to the control plants. Deep ploughing giving a plant height of 85.5 cm was not effective in increasing the plant height. Addition of aldicarb alone was highly effective in enhancing the plant height. Thus from 88.79 cm and 85.5 cm under normal ploughing and deep ploughing respectively, addition of aldicarb raised the height to 109.58 cm and 120.46 cm respectively, both the increses being highly significant. Treatment of the seeds alone also gave similar increases in plant height, the increases being to the levels of 107.29 cm

Table 7

Height of bhindi plants receiving different treatments for control of *M. incognita*, at harvest

Treatments		Mean height per plant (cm)
T_1	(A+C+E)	88.79
T_2	(B+C+E)	85.50
T_3	(A+C+F)	109.58
T_4	(B+C+F)	120.46
T_5	(A+D+E)	107.29
T_6	(B+D+E)	115.88
T_7	(A+D+F)	112.54
T_8	(B+D+F)	122.04

CD = 22.9380

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Table 8

Fresh shoot weight of bhindi plants receiving different treatments for control of *M. incognita*, at harvest

Treatments		Mean shoot weight per plant (g)
T_1	(A+C+E)	96.88
T_2	(B+C+E)	91.58
T_3	(A+C+F)	105.92
T_4	(B+C+F)	149.50
T_5	(A+D+E)	112.83
T_6	(B+D+E)	106.00
T_7	(A+D+F)	121.54
T_8	(B+D+F)	127.04

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

and 115.88 cm respectively, both being significant. Addition of seed treatment to aldicarb treatment was also found to be advatageous as the plant heights were found to increase from 109.58 cm and 120.48 cm to 112.54 cm and 122.04 cm respectively even though these increases were not statistically significant. Similarly addition of aldicarb treatment to seed treatment proved to be advantageous, the increases being from 107.29 cm to 112.54 cm and 115.04 cm to 122.04 cm though not significant statistically.

Effect on fresh shoot weight.

The effect of the different treatments on the fresh shoot weight was not found statistically significant. (Table 8). The mean shoot weights were 96.88 g and 91.58 g per plant for the two exclusive ploughing treatments while the shoot weight under the different treatments receiving chemical applications varied from 105.92 g to 149.50 g.

Effect on root weight.

Results presented in Table 9 and Fig. 3 show that the only two treatments which gave significant increase in root weight over the control plants were aldicarb + deep ploughing and aldicarb + seed treatment + deep ploughing, with mean root weights of 34.60 g and 28.19 g per plant respectively, as against 18.87 g of control plants. The root weight under the other treatments varied from 21.27 g to 27.51 g per plant.

Table 9

Fresh root weight of bhindi plants receiving different treatments for the control of M. incognita, at harvest

Treatments		Mean root weight per plant (g)
T_1	(A+C+E)	18.87
T_2	(B+C+E)	21.27
T_3	(A+C+F)	24.58
T_4	(B+C+F)	34.60
T_5	(A+D+E)	25.73
T_6	(B+D+E)	26.41
T_7	(A+D+F)	27.51
T_8	(B+D+F)	28.19
CD = 9.2776		

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seed treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Effect on number of leaves.

It is apparent from Table 10 that the different treatments did not have any significant impact on the number of leaves produced. As against a mean number of 15.33 leaves per plant grown exclusively under normal ploughing, the plants under the other treatments showed a mean number of leaves varying from 16.58 to 19.04.

Effect on leaf-area.

The different treatments under trial were not found to have any significant effect on the mean leaf area as compared to the control plants (Table 11). The mean leaf area was 89.5 sq cm and 98.09 sq cm in plants receiving only the ploughing treatments while it ranged from 100.13 sq cm to 119.79 sq cm under the different combinations of treatments.

Effect on number of branches.

The number of branches of the plant was not found to be significantly affected by the different treatments under study (Table 12). As against a mean number of 0.59 branches per plant in control the number of branches under the different treatments varied from 0.75 to 1.13.

Effect on root length. (Plate II, III, IV, and V)

The root length of the plants also were found not affected significantly by the various treatments. When the mean root length was 169.59 cm in control plants, it varied

Plate II

Fig. a. Gall formation in control plot

Fig. b. Effect of deep ploughing on gall formation

Plate II

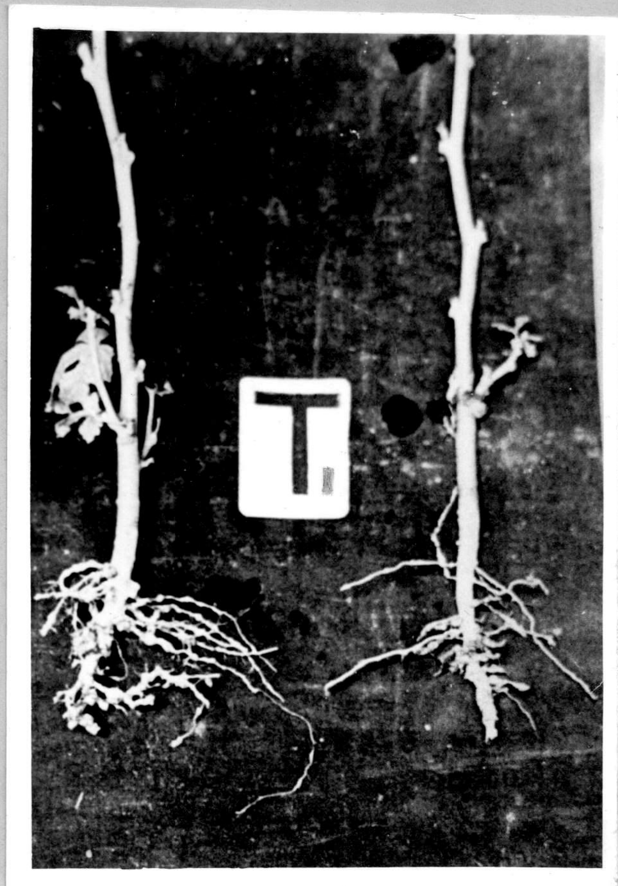

Fig. a

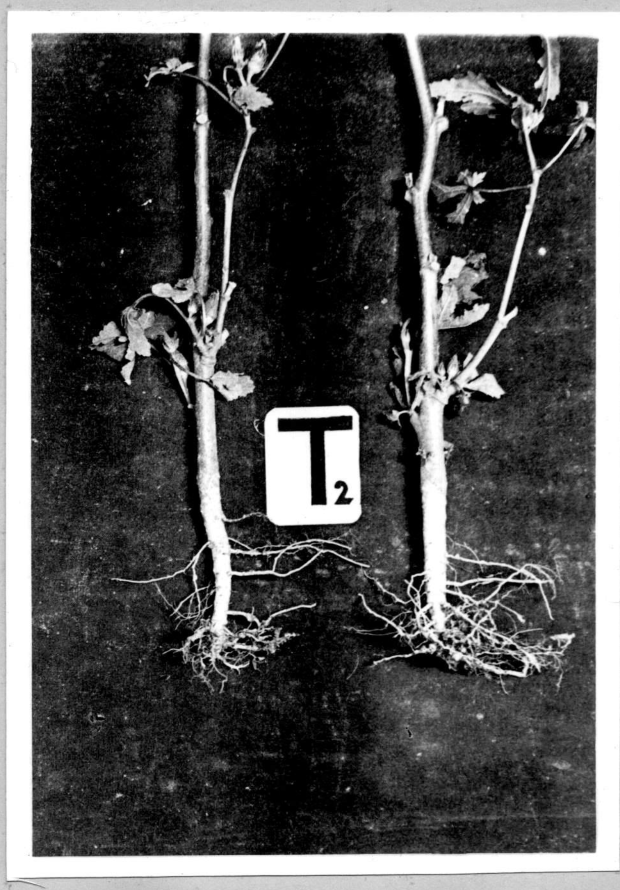

Fig. b

Table 10

Number of leaves produced on bhindi plants receiving different treatments for the control of *M. incognita* at harvest

Treatments		Mean number of leaves per plant
T_1	(A+C+E)	15.33
T_2	(B+C+E)	16.58
T_3	(A+C+F)	17.75
T_4	(B+C+F)	19.04
T_5	(A+D+E)	16.50
T_6	(B+D+E)	18.59
T_7	(A+D+F)	17.00
T_8	(B+D+F)	18.21

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seed treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Plate III

Fig. a. Effect of normal ploughing + aldicarb on gall formation

Fig. b. Effect of deep ploughing + aldicarb on gall formation

Plate III

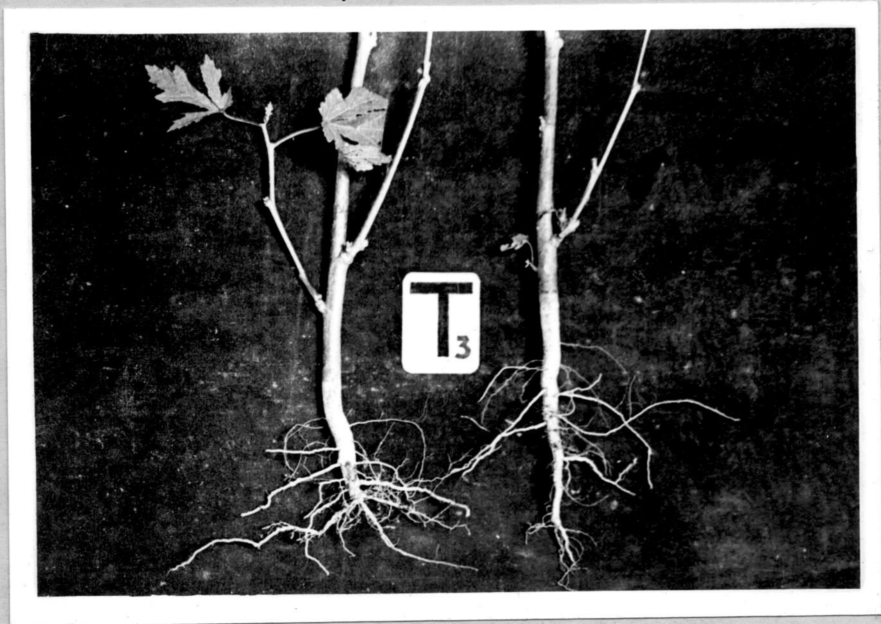

Fig. a

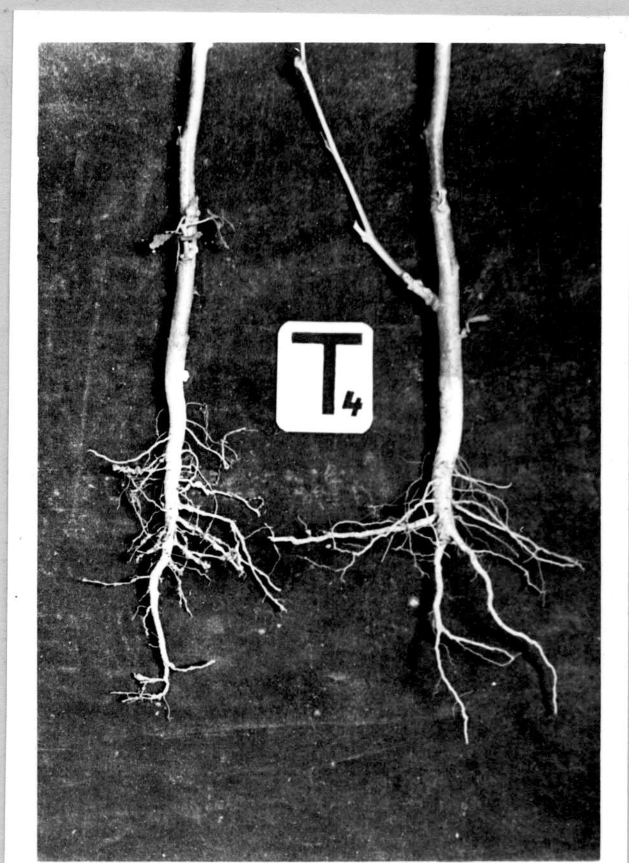

Fig. b

Table 11

Leaf area of bhindi plants receiving different treatments for the control of *M. incognita*, at harvest

Treatments		Mean leaf area per plant (sq.cm)
T_1	(A+C+E)	89.50
T_2	(B+C+E)	98.09
T_3	(A+C+F)	107.89
T_4	(B+C+F)	119.79
T_5	(A+D+E)	116.13
T_6	(B+D+E)	100.13
T_7	(A+D+F)	118.96
T_8	(B+D+F)	113.67

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Table 12

Number of branches produced on bhindi plants receiving different treatments for the control of *M. incognita* at harvest

Treatments		Mean number of branches per plant
T_1	(A+C+E)	0.59
T_2	(B+C+E)	0.96
T_3	(A+C+F)	0.83
T_4	(B+C+F)	1.04
T_5	(A+D+E)	0.88
T_6	(B+D+E)	0.96
T_7	(A+D+F)	1.13
T_8	(B+D+F)	0.75

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Table 13

Root length of bhindi plants receiving different treatments for the control of *M. incognita* at harvest

Treatments		Mean root length per plant (cm)
T_1	(A+C+E)	169.59
T_2	(B+C+E)	219.04
T_3	(A+C+F)	212.25
T_4	(B+C+F)	366.25
T_5	(A+D+E)	226.75
T_6	(B+D+E)	228.96
T_7	(A+D+F)	286.54
T_8	(B+D+F)	279.46

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3kg a.i. per ha

Plate IV

Fig. a. Effect of normal ploughing + seed treatment on gall formation

Fig. b. Effect of deep ploughing + seed treatment on gall formation

Plate IV

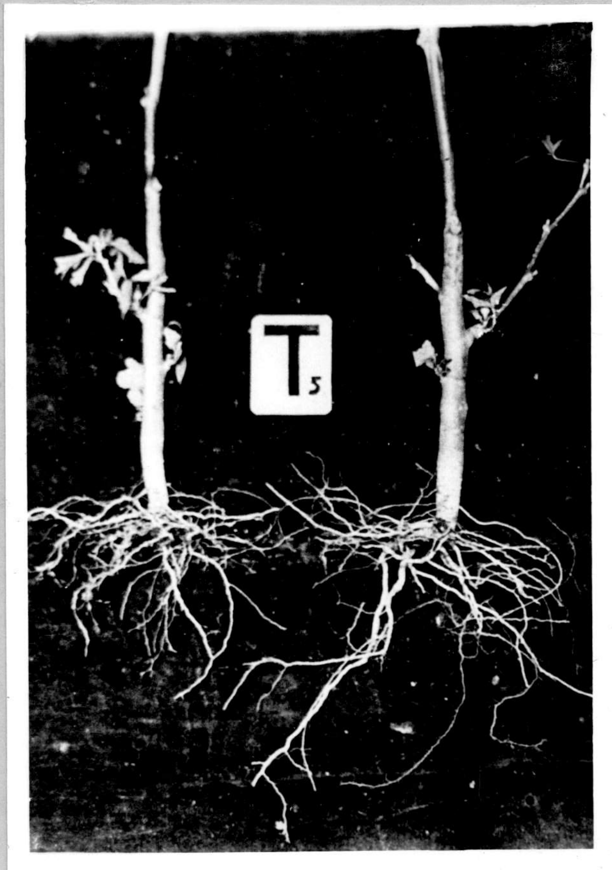

Fig. a

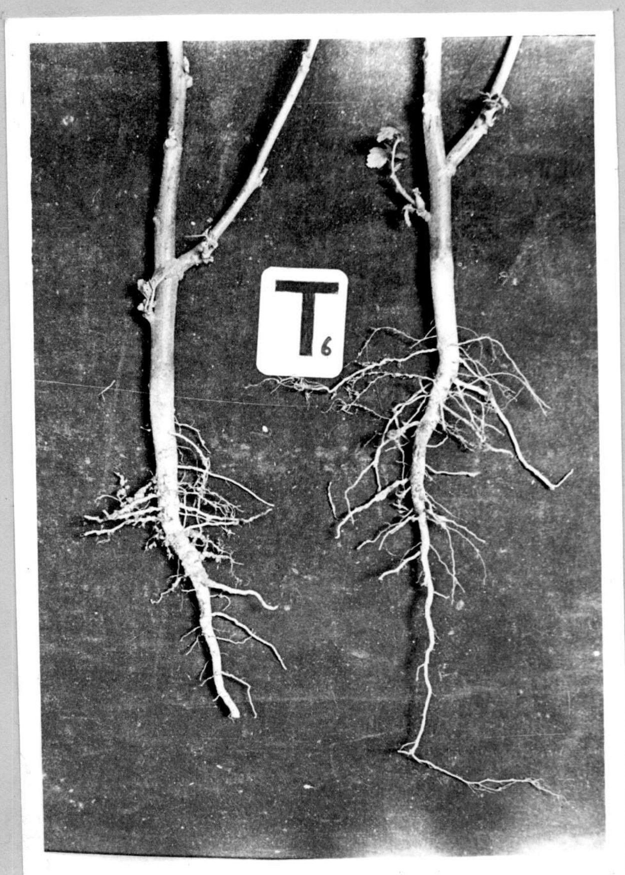

Fig. b

from 212.25 cm to 366.25 cm under the different treatments. The maximum root length of 366.25 cm was found in the plots receiving aldicarb + deep ploughing treatment followed by plots receiving aldicarb + seed treatment + normal ploughing and aldicarb + seed treatment + deep ploughing (286.54 cm and 279.46 cm)(Table 13).

Effect on gall formation. (Plate II,III,IV,V)

All the treaments under trial were found to be significantly effective in reducing gall-formation on the roots (Table 14). While the number of galls per 10 cm length of the root was 26.17 in control plants, the gall number ranged between 1.10 and 9.24 under the different combinations of treatments. All the different treatments were on par statistically in their effect in controlling gall-formation. However, the most effective treatment appeared to be the one consisting of aldicarb + deep ploughing, closely followed by seed treatment + normal ploughing, aldicarb + seed treatment + deep ploughing, aldicarb + seed treatment + normal ploughing seed treatment + deep ploughing and aldicarb + normal ploughing, the number of galls per 10 cm root in these treatments being 1.10,1.11,2.18,2.78,2.79 and 2.87 respectively. Deep ploughing by itself was highly effective in reducing gall-formation with a gall number of 9.24 per 10 cm length of root.

Effect on root-knot index.

Data on the root-knot index under the different

Plate V

Fig. a. Effect of normal ploughing + seed treatment + aldicarb on gall formation

Fig. b. Effect of deep ploughing + seed treatment + aldicarb on gall formation

Plate V

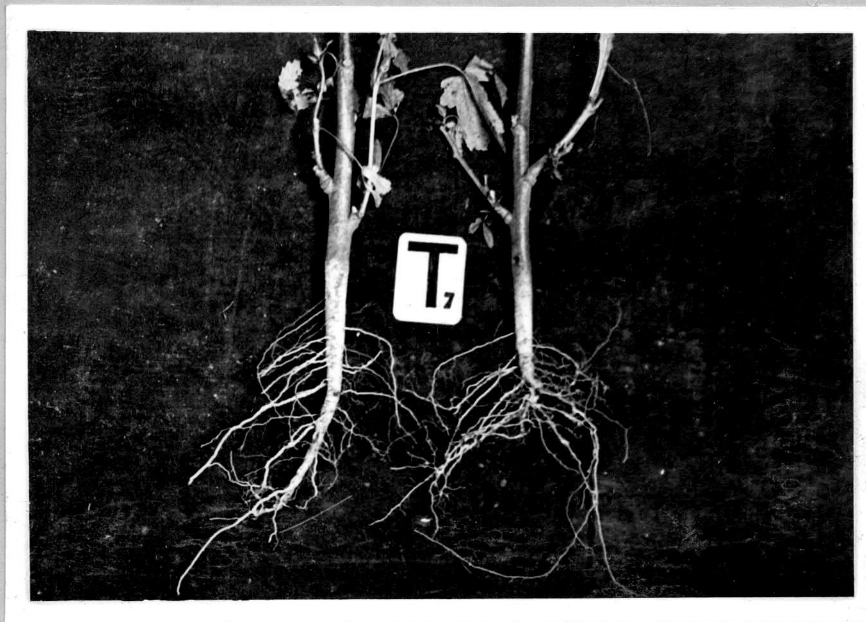

Fig. a

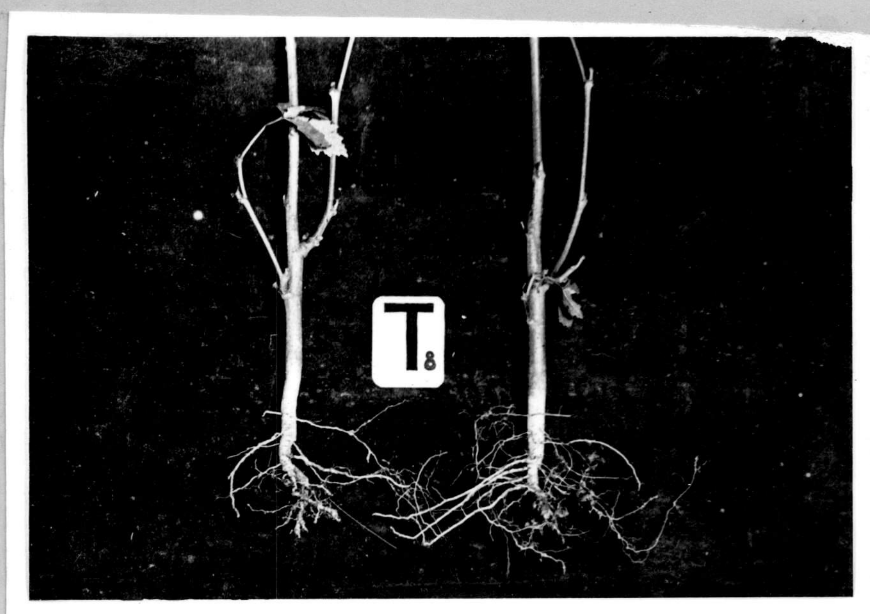

Fig. b

Table 14

Gall formation on roots of bhindi plants receiving different treatments for the control of *M. incognita* at harvest

Treatments		Mean number of galls per 10 cm of root per plant
T_1	(A+C+E)	26.17 (4.76)
T_2	(B+C+E)	9.24 (2.86)
T_3	(A+C+F)	2.87 (1.82)
T_4	(B+C+F)	1.10 (1.38)
T_5	(A+D+E)	1.11 (1.41)
T_6	(B+D+E)	2.79 (1.86)
T_7	(A+D+F)	2.78 (1.85)
T_8	(B+D+F)	2.18 (1.23)
CD =		(1.5348)

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treament

F = Soil treated with aldicarb at 3 kg a.i. per ha

Figures in parenthesis are values after $\sqrt{x+1}$ transformation

Table 15

Root-knot index of bhindi plants receiving different treatments for the control of *M. incognita* at harvest

Treatments		Mean root-knot index per plant
T_1	(A+C+E)	25.93
T_2	(B+C+E)	8.34
T_3	(A+C+F)	3.10
T_4	(B+C+F)	0.78
T_5	(A+B+E)	0.76
T_6	(B+D+E)	2.23
T_7	(A+D+F)	2.52
T_8	(B+D+F)	1.61
CD = 10.0173		

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

treatments (Table 15 and Fig. 2) showed that as against a root-knot index of 25.93 on control plants, the index under the different treatments varied from 0.76 to 8.34. Thus it is seen that all the treatments were effective in reducing the percentage of gall formation significantly. Among the various treatments the most highly effective were seed treatment + normal ploughing (0.76) and aldicarb + deep ploughing (0.78). The treatment consisting of aldicarb + seed treatment + deep ploughing with an index of 1.6 ranked next followed by seed treatment + normal ploughing (2.23), aldicarb + seed treatment (2.52), aldicarb + normal ploughing (3.1) and deep ploughing (8.34). It could thus be observed that even by deep ploughing alone, the formation of galls could be reduced significantly. Aldicarb and seed treatment were found to give effective reduction in the gall formation when applied separately or in combinations.

Effect on soil population of root-knot nematode.

Observations on the soil population of root-knot nematode under the different treatments (Table 16 and Fig. 3) showed that all the treatments were significantly effective in reducing the soil population of the nematode. As against a soil population of 133.5 per 100 g soil in the control, the population under the different treatments, varied from 2.5 to 49. Among the various treatments, the treatment including aldicarb + seed treatment + deep ploughing was the most

Fig. 3. Effect of different treatments on plant height, root weight, root-knot nematode and total population of nematodes on the soil at final harvest of plants

T_1 - A+C+E
T_2 - B+C+E
T_3 - A+C+F
T_4 - B+C+F
T_5 - A+D+E
T_6 - B+D+E
T_7 - A+D+F
T_8 - B+D+F

A = Normal ploughing (10 cm)
B = Deep ploughing (20 cm)
C = Untreated seeds
D = Seeds treated with 3 per cent carbofuran
E = No nematicide treatment
F = Soil treated with aldicarb at 3 kg a.i. per ha

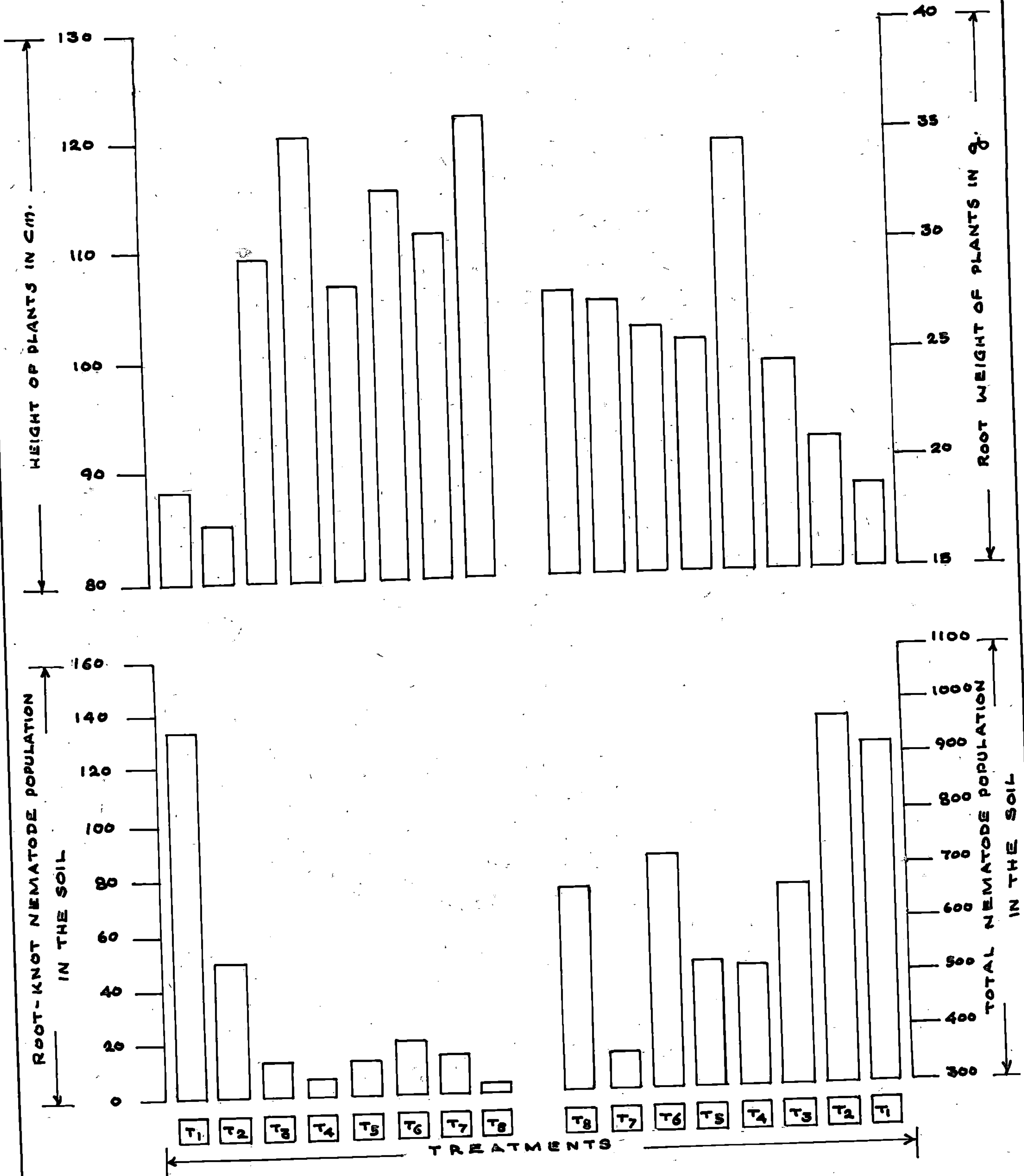

FIG: 3. EFFECT OF DIFFERENT TREATMENTS ON PLANT HEIGHT, ROOT WEIGHT, ROOT-KNOT NEMATODE AND TOTAL POPULATION OF NEMATODES ON THE SOIL AT FINAL HARVEST OF PLANTS

Table 16

Soil population of root-knot nematode in plots receiving different treatments for the control of *M. incognita* at harvest

Treatments		Mean soil population of root-knot nematode
T_1	(A+C+E)	133.5 (11.43)
T_2	(B+C+E)	49 (6.875)
T_3	(A+C+F)	13.75 (3.5125)
T_4	(B+C+F)	7. (2.7450)
T_5	(A+D+E)	11.5 (3.3825)
T_6	(B+D+E)	20 (4.2825)
T_7	(A+D+F)	15 (3.6450)
T_8	(B+D+F)	2.5 (1.7225)

CD = 2.4055

A = Nomal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Figures in parenthesis are values after $\sqrt{x+1}$ Transformation

effective in reducing the soil population which was 2.5 per 100 g soil at harvest followed by aldicarb + deep ploughing (7 per 100 g soil), seed treatment + normal ploughing (11.5 per 100 g soil), aldicarb + normal ploughing (13.75 per 100 g soil), aldicarb + seed treatment + normal ploughing (15 per 100 g soil), seed treatment + deep ploughing (20 per 100 g soil) and deep ploughing alone (49 per 100 g soil). All the treatments were on par in their effect in reducing soil population but among the various treatments deep ploughing alone was significantly less effective than the others. Here also deep ploughing by itself could give significant reduction in the nematode population in the soil. Use of aldicarb and seed treatment by themselves were highly effective in reducing the soil population while combination of these two did not appear to be advantageous to any significant levels.

Effect on total nematode population in the soil.

Data presented in Table 17 and Fig. 3 showed that the population of the total nematode reduced to significant levels under three treatments only; the maximum reduction with a population of 372.75 per 100 g soil could be observed under the treatment aldicarb + seed treatment + normal ploughing, closely followed by the treatment consisting of seed treatment + normal ploughing with 540.75 nematodes per 100 g soil and aldicarb + deep ploughing (535.5 per 100 g soil). All the other treatments were not effective in ultimately

Table 17

Total nematode population in soil in the plots receiving different treatments for the control of *M. incognita*, at harvest

Treatments		Mean of total nematode population in the soil	
T_1	(A+C+E)	925.25	(30.08)
T_2	(B+C+E)	973	(30.79)
T_3	(A+C+F)	665.5	(25.66)
T_4	(B+C+F)	535.5	(23.04)
T_5	(A+D+E)	540.75	(22.76)
T_6	(B+D+E)	753.25	(31.31)
T_7	(A+D+F)	372.75	(19.27)
T_8	(B+D+F)	672.75	(25.09)

CD = (7.2320)

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

Figures in parenthesis are values after $\sqrt{x+1}$ transformation

reducing the overall nematode population. Deep ploughing as such appeared not to have any effect on total nematode population.

Effect on yield.

Results of these observations are given in Table 18 and Fig. 4. Data on the number of fruits per plant under the different treatments show that against a mean number of 10.63 fruits per plant in control plots, the number of fruits per plant varied from 12.75 to 15.75 under the different treatments. The highest number of 15.75 fruits per plant was produced by the plants under the treatment aldicarb + deep ploughing closely followed by the treatment consisting of seed treatment + deep ploughing with a mean number of 15.29 fruits per plant. All the other treatments including aldicarb + normal ploughing, aldicarb + seed treatment + normal ploughing and aldicarb + seed treatment + deep ploughing ranked next with mean production of 14.13 to 14.42 fruits per plant. All these treatments were on par in the production of fruits. The two treatments, deep ploughing alone and seed treatment + normal ploughing were not effective in significantly increasing the number of fruits produced.

In terms of weight of the fruits also the treatment consisting of aldicarb + deep ploughing gave the highest yield of 350.46 g per plant closely followed by aldicarb +

Fig. 4. Effect of different treatments on the number and weight of fruits produced per plant at final harvest of the plants.

T_1 - A+C+E
T_2 - B+C+E
T_3 - A+C+F
T_4 - B+C+F
T_5 - A+D+E
T_6 - B+D+E
T_7 - A+D+F
T_8 - B+D+F

A = Normal ploughing (10 cm)
B = Deep ploughing (20 cm)
C = Untreated seeds
D = Seeds treated with 3 per cent carbofuran
E = No nematicide treatment
F = Soil treated with aldicarb at 3 kg a.i. per ha

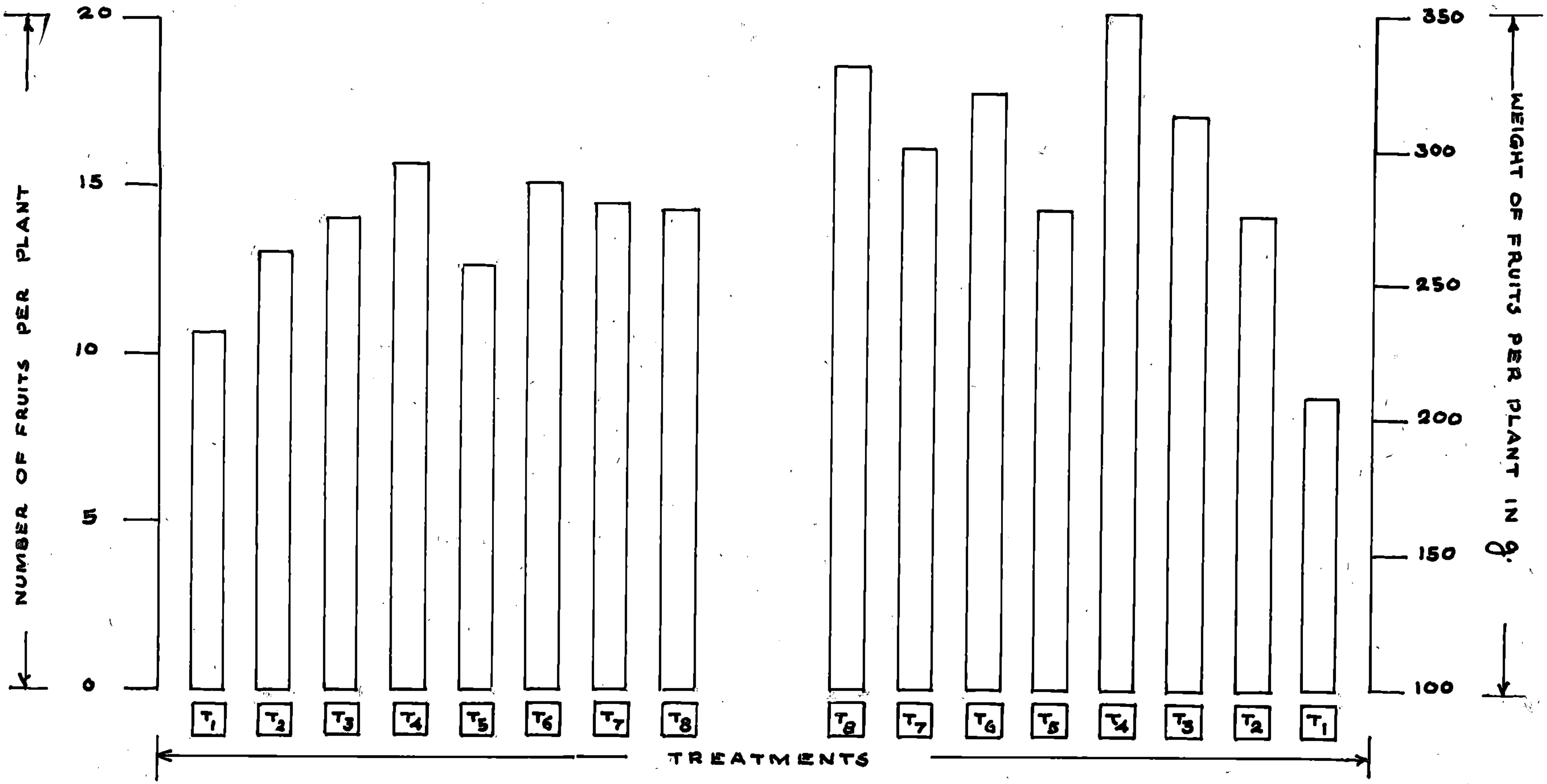

FIG: 4. EFFECT OF DIFFERENT TREATMENTS ON THE NUMBER AND WEIGHT OF FRUITS PRODUCED PER PLANT AT FINAL HARVEST OF THE PLANTS

Table 12

Yield of bhindi plants receiving different treatments for the control of M. incognita, at harvest

Treatments		Mean weight of bhindi fruits per plant (g)	Mean No. of bhindi fruits per plant
T_1	(A+C+E)	206.99	10.63
T_2	(B+C+E)	275.90	13.12
T_3	(A+C+F)	312.71	14.13
T_4	(B+C+F)	350.46	15.75
T_5	(A+D+E)	278.00	12.75
T_6	(B+D+E)	321.89	15.29
T_7	(A+D+F)	301.71	14.42
T_8	(B+D+F)	329.77	14.38
	CD	73.7923	2.6576

A = Normal ploughing (10 cm deep)

B = Deep ploughing (20 cm deep)

C = Untreated seeds

D = Seeds treated with 3 per cent carbofuran

E = No nematicide treatment

F = Soil treated with aldicarb at 3 kg a.i. per ha

seed treatment + deep ploughing with a yield of 329.77 g per plant. The treatments consisting of deep ploughing alone and seed treatment + normal ploughing gave yields (275.90 g and 278.0 g per plant) which were not significantly more than the yield in the control plot (206.99 g per plant) indicating that these two treatments were not effective in controlling the nematode infestation significantly. The other treatments nemely aldicarb + normal ploughing, seed treatment + deep ploughing and aldicarb + seed treatment + normal ploughing with yields of 312.71 g, 321.89 g and 301.71 g per plant respectively gave significant increase over control indicating that these treatments were also highly effective.

SCREENING OF BHINDI VARIETIES AGAINST DIFFERENT POPULATIONS OF *M. incognita*

Results of these studies are presented in Tables 19 and 20. With respect to the effect of infestation by *M. incognita* on different varieties of bhindi (Table 19) mean root weight was least in the local variety Kuttichini (3.61 g) which was on par with AE 112 and Vattayila with root weight of 4.56 g and 4.06 g respectively. The root weight of Khizhakkan venda, Anakomban and Vellachini was significantly higher than that of the others being 5.69 g, 7.04 g and 7.27 g respectively. As regards gall formation, maximum gall formation of 169.63 per g root was observed in the variety Vellachini. This was on par with Khizhakkan venda (154.38 per g root). Vattayila with 132.81, Kuttichini with 127.81 and Anakomban with 115.44 ranked next. The variety AE 112 was the least infested variety with a gall count of 84.13 per g root. This was significantly less than in all the other varieties. With regard to galls with egg masses also, the maximum number was in the variety Vellachini with 25.94 per g root which was on par with Vattayila, Khizhakkan venda and Anakomban with 24.25, 24.50 and 21.19 respectively. In Kuttichini, however, the egg mass bearing galls were less in number being 20.31. The lowest number of 13.44 galls with egg masses per g root which was significantly less than in all other varieties was observed in AE 112. Considering the number

Table 19

Effect of infestation by M. incognita on root growth and gall formation on different varieties of bhindi.

Bhindi Varieties	Root weight per plant(g)	No. of galls per g root	No. of galls with egg masses per g root	No. of eggs in per g root
AE 112	4.56	84.13 (9.19)	13.44 (3.65)	2321.56 (47.85)
Vellachini	7.27	169.65 (13.02)	25.94 (5.06)	5714.38 (75.18)
Vattayila	4.06	132.81 (11.50)	24.25 (4.92)	4869.50 (69.65)
Kizhakkan Venda	5.69	154.38 (12.40)	24.50 (4.95)	4921.50 (70.10)
Kuttichini	3.61	127.81 (11.29)	20.31 (4.50)	4346.63 (65.69)
Anakomban	7.04	115.44 (10.73)	21.19 (4.59)	4147.25 (64.24)
CD	1.6559	(0.93)	(0.58)	-

Figures in paranthesis are values after $\sqrt{x}$ transformation.

of eggs in a g root, it was observed that this did not vary significantly in the different varieties. However, the lowest number of 2321.56 eggs was observed in the variety AE 112 as against 4147.25 to 5714.38 per g root in the other local varieties.

As regards the response of the plants to the different populations of *M. incognita* collected from different localities it was observed that the four populations did not vary significantly in their effect on such factors as root weight, number of galls per g root, number of galls with egg masses and number of eggs per g root (Table 20).

Table 20

Effect of different populations of *M. incognita* on root growth and gall formation on bhindi.

Locality of population	Root weight per plant (g)	No. of galls per g root	No. of galls with eggs masses per g root	No. of eggs in per g root
Adoor	5.07	132.46 (11.51)	20.25 (4.50)	4122.54 (64.11)
Calicut	5.39	131.96 (11.46)	22.79 (4.77)	4711.71 (68.51)
Trivandrum	5.68	138.13 (11.74)	22.21 (4.69)	4613.54 (67.75)
Kayamkulam	5.33	120.25 (10.95)	20.83 (4.55)	4276.25 (65.21)
C D	-	-	-	-

Figures in paranthesis are values after $\sqrt{x}$ transformation

DISCUSSION

DISCUSSION

In the present studies efforts were made to ascertain the effect of three treatments, namely, deep ploughing, seed treatment with carbofuran and soil treatment with aldicarb individually and in combinations on the control of root-knot nematode, M. incognita infesting bhindi. The results were assessed in terms of the growth characters of the plants, infestaion by nematodes on roots, soil population of nematodes and yield. Observations on the effect of the treatments were made on two occasions. The first was 45 days after sowing and the second at the final harvest of the plants. Results presented show that the different treatments influence the various factors under consideration in different ways.

Considering the effect of deep ploughing as an exclusive treatment, it may be observed that as compared to the normal ploughing, this treatment did not affect significantly any of the growth characters such as plant height, top weight, leaf number, leaf area, number of branches, root length and root weight(Tables 7 to 13). But as regards the effect of the treatment on the root infestation by the nematode, some significant effects could be observed. Thus on the forty-fifth day of sowing, the number of galls on the roots was less under this treatment

(Table 3). The observations made at the time of final harvest showed that with respect to both number of galls and weight of galls (root-knot index), deep ploughing showed significant reduction of both (Tables 14 and 15). The soil population of root-knot nematodes was also significantly reduced by deep ploughing as could be observed on both the occasions (Tables 4 and 16). But as regards yield, (Table 18) though an increase in yield both in number of fruits and weight of fruits could be observed in plots receiving deep, ploughing, these were not significant. Thus as against yield values of 10.63 fruits and 206.99 g per plant under control, they were 13.12 and 275.90 g per plant under deep ploughing. The increase in yield of 32. 8 per cent seen in plants due to deep ploughing could thus be attributed to a decrease in the nematode population brought about by this treatment. This reduction of nematode population, however, did not appear to be sufficient to influence the growth characters of the plant.

Considering the effect of treatment of the soil with aldicarb granules, it was found that all the growth characters of plants showed an increase and the factors which were statistically significant were plant height, root length on the forty-fifth day and root weight at harvest, (Table 7,1 & 9).

Highly significant results were observed in the effect of aldicarb on the root infestation by the nematode and this could be observed at both the occasions (Tables 3 and 14). The root-knot indices for example under the aldicarb treatments were 0.07 and 0.29 as against 4.88 in control, while at harvest these were 3.1 and 0.78 as against 25.93 under control. So also at harvest the number of galls per 10 cm of root was 2.87 and 1.1 under the aldicarb treatments as against 26.17 in control. It could thus be observed that the aldicarb treatment, which was a pre-planting treatment kept the population of the nematode at a very low level in the soil. The data of the soil population of the nematode presented (Tables 4 and 16) also show the same effect. The nematicide appeared to keep the population of the nematode in the soil at low levels throughout the period of the crop thereby affording an effective protection to the crop throughout its life. The population of the total nematodes also showed significant reduction by aldicarb (Tables 6 and 17). But there was a build up of these towards the end of the cropping period. The effect of the aldicarb treatments on the yield of the crop also was remarkable and significant increase in the yield was obtained on plants receiving deep ploughing in addition to aldicarb. (Table 18). Thus a combination of deep ploughing + aldicarb appeared to be advantageous over normal ploughing and aldicarb as could be seen from yield of 350.46 and 312.71 g per plant in control. This high increase in the yield in plots receiving aldicarb treatments was evidently due to the control of the nematode population in the soil.

Usefulness of aldicarb granules for the control of *M. incognita* on tomato had already been established by previous workers like Reddy and Seshadri (1971), McLeod (1972), Reddy and Seshadri (1972), Chabra and Mahajan (1974), McLeod (1977) and Sitaramiah and Viswakarma (1978). Sitaramiah and Viswakarma (1978) had also reported the efficacy of aldicarb for the control of *M. javanica* infesting bhindi. Averre et al. (1974) had reported that aldicarb granules incorporated in soil before transplanting gave effective control *M. incognita* infesting Sweet potato. The present investigation also established the superiority of aldicarb in controlling root-knot infestation on bhindi.

Seed treatment with carbofuran by itself was found to be effective in benefitting the growth features such as height, top weight, number of leaves, leaf area, number of branches, root length and root weight (Tables 7 to 13) though these effects were not statistically significant. with regard to gall-formation on the roots, the seed treatments gave highly significant results by showing reduction in the root infestation by the nematode. Thus on the forty-fifth day of sowing, the root-knot index was 4.88 under control as against 0.31 and zero under seed treated plots. At harvest, the index was 25.93 in control while it was 0.76 and 2.23 on plants receiving seed treatment. Similar results could be observed in the gall populations also which at harvest was 26.17 per 10 cm of root in control and 1.11 and 2.79 per 10 cm root on plants receiving seed treatment. The soil population of the nematode also showed similar patterns and severe reductions of the soil populations could be observed both on the forty-fifth day of sowing and at harvest (Tables 4 and 16). These observations showed that the seed treatment using carbofuran was an effective treatment in reducing the nematode population in the soil and thereby reducing the nematode infestation of the roots.

Carbofuran is a systemic insecticide which is known to have nematicidal properties also. The seeds were treated with the flowable concentrate formulation of carbofuran in such a way that every seed had a coating of the insecticide on it. The insecticide deposit on the seed appeared to percolate in the soil all round the seed. It has already been observed that systemic insecticides move in soil (Visalakshi et al., 1979) and this property appeared to have enabled the insecticide in spreading itself in the root zone of the plants. The suppression of the nematode by this toxicant in the root zone appeared to be sufficient for keeping the roots free from nematode infestation significantly. The systemic toxicity of the chemical also appeared to contribute in controlling the nematode infestation on the roots. The results presented show that there was a tendency for the infestation of the roots to increase as time advanced. The seed treatment was also seen to be highly effective in suppressing the total nematode population in the root zone (Tables 6 and 17). Here also there was a tendency for the population to build up as time passed. Considering the effect of seed treatment on the yield it was observed that the yield was considerably increased in plots receiving the seed treatment. The increase in yield was higher when seed treatment was combined with deep ploughing and the yield in such plots was significantly higher than the yield in control (321.89 g per plant as against 206.99 g per plant). The increase in yield in plots receiving normal ploughing and seed treatment though high, was not significantly more than that in control (278.09 g per plant as against 206.99 g per plant). The higher yield in plants receiving seed treatment could be attributed to the effect of this treatment in reducing nematode populations in the root zone and preventing root infestation. The relatively higher yield in plots receiving deep ploughing in addition to seed treatment could be due to the better control of the nematode brought about by both the treatments and also by a better movement of the toxicant in the deeply ploughed soil. The present findings about the effectiveness of seed treatment with carbofuran agreed with similar findings reported earlier by Sivakumar et al. (1973, a, b). They had reported that carbofuran seed treatment at 3 or 6 per cent concentrations gave economical control of M. incognita infesting bhindi. They found that the reniform nematode Rotylenchulus reniformis could also be controlled by the seed treatment.

By and large, the plants receiving combination of seed treatment and aldicarb treatment showed better growth and better yield than the plants receiving these two treatments individually (Table 18). These differences were however, not significant statistically. As regards the root infestation by the nematode, combinations of these treatments did not show any advantage over the individual treatments (Tables 4 and 14). The combinations of seed treatment and aldicarb were, however, found to be effective in suppressing the soil population of root-knot nematode to the minimum of 2 and 2.5 per 100 g soil at the two occasions as against116 and 133.5 respectively in control. Combinations of the treatments did not give any advantage in reducing the total population of nematodes (Table 17). In the matter of yield, aldicarb alone was giving better yield than combination of aldicarb + seed treatment. Thus as against yield of 312.71 and 350.46 g per plant under aldicarb treatments, the corresponding yields were 301.71 and 329.77 g per plant under combinations of aldicarb + seed treatment. Comparing seed treatment alone and the combinations, slight increase in the yields was observed when the treatments were combined than under seed treatment alone. Thus when the yields were 278.0 and 321.89 g per plant under the exclusive seed treated plots, the corresponding yields were 301.71 and 329.77 under the combinations. The differences were only marginal and not significant.

Cost Benefit Ratio.

The cost benefit ratios of the different treatments are given below:-

Treatment	Increase in yield per ha (kg)	Gross income Rs. per ha	Cost of treatment Rs. per ha	Additional income due to treatment Rs. per ha
Aldicarb soil treatment	5313.32	2656.66	1155	1501.66
Carbofuran seed treatment	4255.55	2127.78	250	1877.78
Carbofuran seed treatment + aldicarb soil treatment	4547.40	2273.70	1405	868.70

It is observed that by seed treatment there was a net profit of Rs. 1877.78 per ha while by aldicarb soil treatment there was a net profit of Rs. 1501.66 per ha. When the two treatments were combined there was a profit of Rs. 868.70 per ha.

From an overall appraisal of the results presented and discussed the following conclusions can be drawn.

1. Deep ploughing (20 cm) is helpful in reducing both the soil population of _M. incognita_ and infestation of the roots by it, thereby contributing to an increase in yield.

2. Use of aldicarb as a soil treatment at the rate of 3 kg a.i. per ha before sowing the seeds is significantly effective in controlling the nematode infestation and increasing the yield.

3. Treatment of the seeds with Furadan Flowable Concentrate at a dosage of 3 per cent by itself is effective in reducing nematode infestation, increasing the yield to significant levels.

4. Combining aldicarb treatment with seed treatment is not advantageous as the combinations do not give significantly better reduction in the nematode infestation and better yield than the individual treatments.

5. Among all the treatments under trial, the one which has given the highest number of 15.75 fruits per plant and the highest yield of 350.46 g fruits per plant consists of deep ploughing + soil treatment with aldicarb. All the other

treatments excepting deep ploughing are on par with this treatment.

Observations made on the relative susceptibility of five local varieties of bhindi and one improved variety namely AE 112 of Tamil Nadu Agricultural University have shown that while all the local varieties were equally susceptible to infestation by the nematode , AE 112 showed significantly low susceptibility. The relative resistance of this variety was manifested in terms of the root weight, the number of galls and the proportion of egg producing galls. This variety thus appeared to be suitable for cultivation where root-knot nematode is a problem.

Populations of *M. incognita* collected from different parts of Kerala did not vary in their capacity to infest bhindi plants. All of them caused the same type and extent of damage to the crop.

SUMMARY

SUMMARY

A field experiment was conducted to ascertain the effect of deep ploughing, seed treatment with carbofuran and soil application of aldicarb granules individually and in combination on the control of the root-knot nematode M. incognita infesting bhindi. The result were assessed in terms of growth of the plants, gall and nematode populations and yield.

Deep ploughing (20 cm) did not affect plant height, top weight, leaf number, leaf area, number of branches, root length and root weight of the plants significantly. The root-knot index, the number of galls per 10 cm root and soil population of root-knot nematode showed significant decrease due to deep ploughing as compared to normal ploughing. The number and weight of fruits per plant showed considerable increase due to deep ploughing, the increase in the weight being to the extent of 32.8 per cent; this was not statistically significant.

Treatment of soil with aldicarb granules at 3 kg a.i. per ha increased plant height, top weight, leaf number, leaf area, number of branches, root length and root weight considerably over control though not statistically significant. The root-knot index, the number of galls per 10 cm root length and soil population of root-knot nematode showed highly

significant reduction due to the aldicarb treatment. The yield-increase both in numbers and weight was highly significant over control. Aldicarb treatment in combination with deep ploughing showed higher response in growth of plants, gall formation and yield than aldicarb with normal ploughing. The increase in yield in terms of weight was 50 and 69 per cent over control in the two aldicarb treatments.

Treatment of seed with 3 per cent Carbofuran showed increase in all the growth parameters though not significantly. The reduction in root-knot index, gall population and soil population of nematodes over control were highly significant under the seed treatments. Seed treatment in combination with deep ploughing gave an added effect in all these respects over seed treatment with normal poughing. Yield of fruits both in numbers and in weight showed remarkable increase under seed treatment as compared to control plants. The yield-increase, however, was significant only when seed treatment was combined with deep ploughing. The increases in weight of yield under the two seed treatments over control were 34 and 55 per cent respectively.

Treatments comprising combinations of all the three factors, namely, ploughing, seed treatment and aldicarb treatment increased all the growth parameters but not significantly. The root-knot index and populations of galls and nematode showed significant reduction as compared to control but they were not significantly different from the treatments receiving aldicarb and seed treatment alone. The yield of bhindi, both in number and weight increased significantly under these treatments as compared to control. The yield in terms of weight was higher in the treatment which included deep ploughing also, the increase over control being 46 and 59 per cent respectively.

The maximum yield increase of 69 per cent over control was obtained in the treatment consisting of deep ploughing and soil treatment with aldicarb followed by 59 per cent in the treatment consisting of deep ploughing + aldicarb + seed treatment, 55 per cent in the treatment consisting of deep ploughing + seed treatment, 50 per cent in the treatment comprising aldicarb treatment of the soil and 46 per cent in the treatment consisting of aldicarb + seed treatment.

Cost benefit ratio calculations showed that there was a net profit of Rs. 1877.78 per ha under seed treatment, Rs. 1501.66 per ha under aldicarb treatment and Rs. 868.70 per ha under the combined treatment.

Among the six varieties of bhindi including five local and the improved AE 112 examined for susceptibility to infestation by M. incognita, the improved variety AE 112 showed significantly lower susceptibility than all the local varieties. All the local varieties showed equal susceptibility to nematode infestation. The populations of

M. *incognita* infesting bhindi collected from different parts of the State did not vary in their capacity to infest and damage bhindi.

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*Originals not seen

APPENDICES

APPENDIX I

Summary of Analysis of Variance Table relating to the data collected on the forty-fifth day after sowing (Tables 1 to 6).

Characters	Mean squares		
	Block df=3	Treatment df=7	Error df=21
Root length	1245.08	1722.14*	643.06
Root weight	1.75	11.27 N.S.	2.26
Number of galls per 10 cm root	0.67	1.00**	0.07
Soil population of root-knot nematode	5.84	37.36**	6.17
Root-knot index	8.18	13.20**	3.21
Total nematode population in the soil	38.83	87.66**	15.36

*Significant at 5 per cent level.

N.S. Not significant

**Significant at 5 and 1 per cent levels.

APPENDIX II

Summary of Analysis of Variance Table relating to the data on plant growth characters observed at final harvest of plants (Tables 7 to 13).

Characters	Mean squares		
	Block df=3	Treatment df=7	Error df=21
Height of plants	921.48	1089.14**	243.23
Fresh shoot weight	348.23	1379.27 N.S.	694.32
Fresh root weight	26.53	103.69 N.S.	39.79
Leaf area	85.60	491.32 N.S.	565.82
Number of leaves	1.93	6.28 N.S.	8.74
Number of branches	0.43	0.12 N.S.	0.11
Root length	2153.82	8280.73 N.S.	7349.45

**Significant at 5 and 1 per cent levels.

N.S. Not significant

APPENDIX III

Summary of Analysis of Variance Table relating to the data on nematode population and yield of bhindi at harvest (Tables 14 to 18)

Characters	Mean squares		
	Block df=3	Treatment df=7	Error df=21
Number of galls per 10 cm root	3.66	5.14**	22.88
Root-knot index	80.08	294.99**	46.39
Soil population of root-knot nematode	3.15	38.37**	2.68
Total nematode population in the soil	38.06	76.24**	24.18
Yield (weight of fruits)	3073.30	7872.59**	2517.24
Yield (number of fruits)	5.29	10.58**	3.27

**Significant at 5 and 1 per cent levels

APPENDIX IV

Summary of Analysis of Variance Table relating to the data on responses of different bhindi varieties to infestation by M. incognita (Table 19)

Characters	Mean squares	
	Treatments df=5	Error df=12
Root weight	9.58*	1.24
Number of galls per g root	7.19**	0.39
Number of galls with egg masses	1.07*	0.16
Number of eggs in a g root	59.37 N.S.	190.73

*Significant at 5 per cent level

**Significant at 5 and 1 per cent levels

N.S. Not Significant

APPENDIX V

Summary of Analysis of Variance Table relating to the data of performance of different populations of M. *incognita* (Table 20)

Characters	Mean square	
	Treatment df=3	Error df=12
Root weight	0.25 N.S.	0.67
Number of galls per g root	0.44 N.S.	051
Number of galls with egg masses	0.063 N.S.	0.15
Number of eggs in a g root	17.28 N.S.	26.48

N.S. Not significant

ABSTRACT

A field experiment was undertaken to ascertain the effect of the treatments, deep ploughing, seed treatment with carbofuran and aldicarb treatment of soil, when applied individually and in combinations on the control of the root-knot nematode *M. incognita* infesting bhindi. A randomized block design was adopted for the experiment with eight treatments including control and four replications each. To ensure uniform population of the nematode in the different plots a crop was raised and the root system of the plants ploughed back into the soil on the forty-fifth day of sowing. Further, galled roots of bhindi collected from different parts of the farm were chopped and added to the soil to ensure a high and uniform initial population of the nematode. Deep ploughing was done to a depth of 20 cm. Seed treatment was done using the flowable concentrate of carbofuran, to give a 3 per cent deposit. Aldicarb was applied to the soil as granules, raked into it and sealed with a layer of water, a day prior to sowing.

Results were assessed in terms of the growth parameters, gall and nematode population and yield. Results indicated that deep ploughing by itself was effective in reducing galling of the roots by the nematode and increased yield by 33 per cent. Treatment of soil with aldicarb gave significant reduction of

nematode infestation and increased yield significantly to the extent of 50 to 69 per cent. Seed treatment by itself was highly effective in reducing nematode infestation and increased yield, the yield-increase being to the extent of 34 to 55 per cent. Combination of aldicarb and seed treatment also were highly significant in their effect in suppressing nematode infestation and increasing the yield, the increase being 46 to 59 per cent. In all the treatments, those receiving deep ploughing gave added effect. Combination of aldicarb and seed treatment was not advantageous over these treatments given individually.

Five local strains and an improved strain AE 112 of bhindi were screened in pots for their susceptibility to infestation by *M. incognita*. Results assessed in terms of gall and egg formation indicated that the improved variety AE 112 was significantly less susceptible than the local varieties which among themselves were all equally susceptible. The populations of *M. incognita* infesting bhindi collected from different parts of the State did not vary in their capacity to infest and damage bhindi.