HOST-RANGE AND SURVIVAL OF THE LESION NEMATODE, *PRATYLENCHUS GOODEYI* SHER AND ALLEN, AND ITS CONTROL IN BANANAS.

BY

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DECLARATION BY THE CANDIDATE

I HEREBY DECLARE THAT THE MATERIAL CONTAINED IN THIS THESIS IS MY OWN ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR A DEGREE IN ANY OTHER UNIVERSITY.

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QUOTATION

Man has lost his power to foresee
and forestall, he will end up
destroying the world.

Albert Schweitzer.
(Medical Missionary, Philosopher,
Theologian and Organist 1875 - 1965).

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ABSTRACT

Tests were established at the Agricultural Research Institute, Maruku, Tanzania to investigate the host range of *Pratylenchus goodeyi* Sher and Allen, effects of fallowing and soil solarisation, soil amendment and mulching, and planting clean planting materials on populations and pathogenicity of the lesion nematode, *P. goodeyi* in bananas.

Seventy six locally available plant species were used in the host-range test. Polythene films of gauges 250, 500 and 1000 mounted on wooden frames were used in the soil solarisation test. Fallowing included clean fallow, weed fallow and grass mulch fallow. The clean planting material test involved subjecting planting materials (suckers and corms) to heat from hot water or sun irradiation, paring or nematicide treatments. Sun irradiation was trapped in a solarisation box developed in this study. Locally available organic matters such as cattle manure, chicken manure, sawdust, coffee husks etc. were used as amendments in the soil amendment test. Either a completely randomised design or randomised complete-block design was used in the tests. Replicates varied from three to six.

Nematodes were extracted from soil and banana roots using the centrifugal-floatation and marceration-sieving techniques, respectively. Root necrosis was assessed using 0-5 visual scale (in which 0 = clean root and 5 = 75-100% of root cortex is lesioned).

Pratylenchus goodeyi was extracted from only 5 plant species, *Commelina benghalensis, Hyperrhenia rufa, Musa* cv Nyoya, *Plectranthus barbatus and Tripsacum laxam.* This indicates that the nematode has a narrow host-range. Populations of the nematode declined consistently in the clean fallow plots during the 500 day-time-period of the experiment. This implies a relatively poor survival of the nematode in the absence of the host plants. Soil solarisation reduced nematode populations during the initial phase (the first 200 days) of the experiment. Paring and carbofuran treatments significantly ($r = 0.89$, $P < 0.01$) increased banana yield up to 97.22%. Low *P. goodeyi* populations were associated with plants whose planting materials were subjected to a combination of treatments such as paring and solarisation, hot water and carbofuran or hot water and solarisation. Banana yield increases of up to 64.38%, 54.79 and 49.32% were associated with plants grown in soils treated with chicken manure plus mulch, compost plus mulch and coffee husks plus mulch, respectively.

The above findings do indicate that an IPM package with clean fallow, soil solarisation, soil amendments, such as chicken manure, compost and coffee husks, and rotation of bananas with non-host plants components can be a viable, inexpensive and safe management strategy against *P. goodeyi*.

CHAPTER 1

1 INTRODUCTION

Banana yields have been declining in most of the major growing areas in Tanzania from the early 1970's. Some Districts such as Bukoba and Muleba (Appendix 1) experience losses of up to 50% (RADO KAGERA, 1978;). Pests, diseases and poor agronomic practices have been identified as major causes of the decline (Bujulu *et al*, 1981; Walker *et al*, 1984; Sikora *et al*, 1990). The lesion nematode, *Pratylenchus goodeyi* Sher & Allen, is one of the most important pests in the East African banana growing areas (Gichure and Ondieki *et al*, 1977; Walker *et al*, 1984; Sikora *et al*, 1990; Waudo *et al*, 1991; Appendices 2; 3).

Nematicides can minimise banana losses due to nematodes (TARO, 1981-84; Appedices 4 and 5). But because pesticides are expensive and don't always guarantee environmental safety, there is need to seek alternative control measures that are sustainable, inexpensive and safe to the environment.

Although Integrated Pest Management (IPM) packages against pests are the most promising management strategies, lack of information on viable IPM components against *P.*

goodeyi makes adoption of IPM in management of this important pest impractical. However, there are possible IPM components against *P. goodeyi* which can include cultural practices such as crop rotation, fallowing, soil amendments and solarisation, and use of nematode free planting materials. The success of crop rotation depends on factors such as host-range and longevity of the pest in the absence of the host. Information on host range and survival of *P. goodeyi* in the absence of the host is lacking. Therefore this study was undertaken to:-

i) determine the host range of *P. goodeyi*,

ii) determine effect of fallowing and soil solarisation on *P. goodeyi* populations,

iii) Investigate effects of soil amendments and mulching on populations and pathogenicity of *P. goodeyi* and

iv) compare efficacy of various planting material cleaning methods against *P. goodeyi*.

CHAPTER 2

LITERATURE REVIEW

2.1 Bananas and their Economic Importance

Bananas *(Musa spp.)* are large perennial herbaceous plants made up of a corm, bulb or rhizome, the underground stem (Simmonds, 1966). The corm has a central cylinder where shoots and roots originate and an outer cortex (Simmonds, 1966). Eyes on the upper and middle parts of the corm give rise to suckers (Turnner, 1970) which grow into shoots. A group of shoots from a single parent form a stool or mat. Stools are sympodial (Hulttum, 1955).

Bananas were derived from hybridisation of two wild species, *Musa acuminata* L. and *M. bulbisiana* L. Edible bananas have an AA, AAA, AB, AAB, ABBB or AAAA genome. The AA, AAA, AAB and ABB genomes are the most common ones (Simmonds, 1966). Most of the cooking bananas in East Africa have the AAA genome (Simmonds, 1966).

Bananas are soft and sweet when ripe and can be eaten without cooking (Simmonds, 1966). Edible bananas are parthenocarpic, although their wild parents contain seeds (Simmonds, 1966).

Plate 1: A field showing toppling of banana plants caused by *Pratylenchus goodeyi*.

Plate 2: A homestead in Bukoba District (Tanzania) whose bananas have been badly damaged by *Pratylenchus goodeyi*.

bunch size, thin pseudostems, stuntedness, yellowing of leaves, leaning and toppling or snapping at ground level (Sikora, *et al* 1990) are associated with nematode and/or weevil damage. Walker *et al* (1984) reported a 30% banana loss in Tanzania.

Table 1: Principal world producers of bananas and plantains in 1988 ('000 tonnes)

Country	Banana	Plantains	Total	% of Total
Uganda	460	6630	7090	10.8
Brazil	5139	-	5139	7.8
India	4600	-	4600	7.8
Philippines	3685	-	3685	5.6
Colombia	1300	2191	3491	5.3
Ecuador	2238	850	3088	4.7
Tanzania	1300	1300	2600	3.9
Rwanda	-	2140	2140	3.3
Zaire	345	1520	1860	2.8
Indonesia	1860	-	1860	2.8
Nigeria	-	1800	1800	1.6
Mexico	1800	-	1800	1.6
Others	19906	7540	27446	41.7

Source: INIBAP, 1989.

2.2.1 Lesion Nematodes

Members of the genus *Pratylenchus* Filipjev 1936 are called lesion nematodes because of the lesions they cause on plant roots or meadow nematodes due to their frequent occurance in meadows (Mai and Lyon, 1960) The genus has 63 species (Handoo and Golden, 1989).

Lesion nematodes are migratory endo-parasites with feeding sites 1-4 cells beneath the epidermis in the cortical parenchyma (Doncaster, 1971; Dropkin, 1980). They penetrate cell walls mechanically using their stylets and with the help of enzymatic activities (Dropkin, 1980). The nematodes lay eggs at their feeding sites. A complete life cycle from egg through 1st-4th juvenile stages to adult takes three to four weeks depending on environmental conditions. Moulting terminates each juvenile stage. The nematodes are dispersed by run-off and irrigation water, farm implements and animals, but to a large extent, by transportation of infested planting material (Loos, 1961; Jones and Kempton, 1978; Stover, 1972). Active movement can enable the nematode to move only 47-95 cm per year (Stover, 1972).

2.2.2 *Pratylenchus goodeyi* Sher and Allen

Pratylenchus goodeyi is a small sluggish lesion or meadow nematode whose females measure 0.64-0.68 mm. and males 0.55-0.57 mm long (Sher and Allen, 1953). Its body is cylindrical with a low flat head that is not distinctly off-set. Its cephalic framework is sclerotised and the lip region has four annules. The body annules are about 1 um wide and the nematode has four incisures in the lateral field extending from median bulb to the tail. It has a well developed stylet, 16-18 um long, with pronounced knobs flattened anteriorly. The vulva is posterior (V = 73-75%). Its single ovary is out-streched anteriorly with small post-vulval sac measuring one body thickness. The median oesophageal bulb is ovate, more than one half as wide as the the body and the oesophageal glands are in a lobe over-lapping the intestine ventrally. Its tail is conoid, tapering to a narrow almost pointed terminus, dorsal contour of the tail sinuates anteriorly to the terminus. The tail has 22-24 annules with a visible phasmid, 10-14 annules from tail tip (Machon and Hunt, 1985). Males are common and have a similar body form to the females. These have slender circular spicules and simple gubernacular. Their bursa envelops the tail tip (Machon and Hunt, 1985).

The lesion nematode, *P. goodeyi* was first isolated from banana roots in Grenada (Cobb, 1919) and was later found in banana fields in the Canary Islands (De Guiran and Villardebo, 1962), Kenya (Gichure and Ondieki, 1977; Waudo *et al*, 1991), Tanzania (Walker *et al*, 1984) and Uganda (Karamura, 1991). Besides banana plants, the nematode has been found in association with citrus plants (Machon and Hunt, 1985) and maize (Sikora *et al*, 1990). No work, however, has been done to establish the host-range of this nematode. Knowledge of a pathogen's host-range is important in formulation of a viable and effective management strategy using crop rotation, trap crops and/or inter-cropping.

Above-ground symptoms observed on bananas infected with *P. goodeyi* include leaf chlorosis, leaning, stuntedness, reduced bunch size and toppling. Below-ground symptoms include red-brown lesions on roots and corms (Appendices 2 & 3) and pruned root systems (Blake, 1969).

2.2.3 Control of Banana Nematodes

Early attempts to control banana nematodes started with management of *Radopholus similis* using 1, 2-dibromo-3-chlro-propane or DBCP (Leach, 1958; Loos and Loos, 1960). The DBCP was applied at 6-8 points, 30-40 cm. apart around a stool twice a year with hand injectors. Because the application of this chemical was labour intensive, it was replaced by granular non-volatile nematicides such as carbofuran, fenamiphos, ethoprop, aldicarb and oxamyl

(Stover and Simmonds, 1987).

Disinfection of planting material (suckers) by paring (Loos and Loos, 1961), hot water treatment (Blake, 1961; 1969; Colbran and Sanders, 1961) and Nemagon (chemical) treatment (Guerout, 1975; Mateille *et al*, 1988) are common cultural practices against *R. similis* in Central and South America, New South Wales and Queensland, Australia. Loos and Loos (1960) reported a 99% reduction in nematode populations in pared banana suckers. Hot-water treatment involving immersion of infected suckers in hot water maintained at 55 ^{0}C for 20 minutes or at 50-53 ^{0}C for 20 minutes (Blake, 1961; Colbran and Sanders,1961) was found to be effective against *R. similis* (Mallamaire, 1939). The former hot water treatment had adverse effects on banana suckers (Blake, 1961).

Use of fallowing, flooding and/or crop rotation are feasible cultural practices against *R.similis*. This nematode can't survive for more than six months in the absence of its host plant (Tarjan, 1961; Blake, 1969). Flooding for 5-6 months has been used to free fields of *R. similis* in Panama, Honduras and Surinam (Loos,1961; Maas, 1969). Loos and Loos (1960) reported that growing sugarcane (*Saccharum officinarun* L.) for five months in *R. similis* infested fields eradicates the nematode.

Little has been done to control *P. goodeyi*. Therefore an effective, sustainable , environmentally safe, economically feasible and socially acceptable intergrated pest management (IPM) package against *P. goodeyi* needs to be developed.

2.3 Soil Amendment in Nematode management.

Decomposable organic matter such as chicken manure, farm yard manure, barks of hard-wood plant species, castor bean pomace, corn bran, mollasses, chitin, cotton and alfalfa meals, oil cakes, saw-dust, green manure, etc., have been used as soil amendments in controlling plant parasitic nematodes (Linford *et al*, 1938; Duddington *et al*, 1956; Van der Laan, 1956; Johnson, 1959; Lear, 1959; Huchinson, 1960; Hams and Wilkin, 1961; Hollis and Rodriguez-Kabana, 1966; Watson, 1969; Sayre, 1971; Mankau and Das, 1974; Malek and Gartner, 1975; Mishra and Prassad, 1978; Sitaramiah and Singh, 1978; Khan *et al*, 1979; Castillo, 1985; Spiegel *et al*, 1987).

Efficacy of soil amendments against plant pathogens has been attributed to enhanced antagonism (Rodriguez-Kabana *et al*, 1978; Morgan-Jones and Rodriguez-Kabana, 1985; Hoitink and Fahy, 1986), heat resulting from decomposition (Hoitink *et al*, 1976; Sussman, 1982; Yuen and Raabe, 1984), toxicity (Linford *et al*, 1938; Hollis and Rodriguez-Kabana, 1966;

Walker, 1969; Gilpatrick, 1969; Papavizas and Lewis, 1971; Sonoda, 1977; Walker, 1971; Schippers and Bauman, 1973; Smith, 1976), and/or improved host resistance due to improved nutritional status of host plants (Alexander, 1977; Nakasaki *et al*, 1985; Tsdale *et al*, 1985).

Antagonism includes competition (Clark, 1968) hyperparasitism (Alexander, 1976; Hunter *et al*, 1977; Lockwood, 1977; Mankau, 1980;), predation (Baker and Cook, 1974), antibiosis (Gottlie and Shaw, 1970) and cross protection (Deacon, 1973; 1976; Asher, 1978; Baker *et al*, 1978, Guttenridge and Slope, 1978; Wong and Siviour, 1979). Although it is difficult to introduce antagonists in new environments, preparations, such as alginate pellets, vermiculate-bran and bran germlings actively growing hyphae on wheat bran, are promising (Lewis and Papavizas, 1985; 1986; Sikora *et al*, 1990).

Decomposition products with toxic effects against nematodes include ammonia, ethylene, carbon dioxide, organic acids, dimethyl sulphide and dimethyl disulphide (Gilpatrick, 1969; Papavizas and Lewis, 1971; Walker, 1971 Schipper and Bauman, 1973; Smith, 1973; Sonoda, 1977).

2.4 Soil Solarisation

Soil solarisation, the heating of moist soil to fatal or near fatal temperatures to soil borne pathogens with solar irradiation trapped by polythene films (Dawson, 1965), has been used to control some fungal soil-borne pathogens (Grinstein *et al*, 1979; Katan *et al*, 1980; Tjamos and Faridis, 1980; Pullman *et al*, 1981) and weeds (Horowitz, 1980). Successful control of nematodes, including *Pratylechus thornei* Cobb on potato (Grinstein *et al*, 1979), *Heterodera carotae* Jones and *Ditylenchus dipsaci* (Kuen) Filipjev (Greco and Brandonisio, 1990) *Globodera rostochiensis* (La Mondia and Brodie, 1984), *Meloidogyne hapla*(Stapleton and De Vay, 1984) and *Bursaphelenchus seani* Giblin and Kaya (Giblin-Davis and Verkade, 1988), using soil solarisation has been reported.

Efficacy of soil solarisation depends on selective enhancement of biological activities (Katan, 1981), sub-lethal or lethal thermal heat (Bigelow, 1921; Smith, 1923; Farrell and Rose, 1967; Precht *et al*, 1973; Lund, 1975), and toxicity due to accummulation of volatile gases such as carbon dioxide, ammonia and ethylene (Horowitz and Regev, 1980; Ashworth and Genoa, 1982; Greenberg *et al*, 1984). Lethal heat kills pathogens directly (Lund, 1975) and sub-lethal heat weakens them (Precht *et al*, 1973). Weak pathogens are highly vulnerable to antagonism and have too low innoculum potential for effective establishment in the host (Papavizas and Lumsden, 1980). Essential elements such as Ca^{++} and Mg^{++} accummulate in the solarised soils to the benefit of the host plants (Katan, 1976; Chen and Katan *et al*, 1980). Solarisation can, however, lead to selective proliferation of harmful soil flora, including pathogens (Katan, 1980).

CHAPTER 3

MATERIALS AND METHODS

3.1 General Techniques

3.1.1 Planting and maintenance of a banana field.

Planting materials, maiden suckers or corm splits, were obtained from *P. goodeyi*-infested farmers fields. A sucker or corm-split was planted in a 30-cm-depression at the centre of cattle manure (70kg) (TARO, 1981-84) and top soil (70kg) mixture contained in a 60-cm deep and 90-cm-diametr hole. Completely Randomised or Randomised complete block designs (Steel and Torrie, 1960) with 3, 5, or 6 replicates was used. Spacing between plants within a row and between rows was 3.5m.

Pruning and desuckering were done using machettes and local digging tools, "vihosho", respectively, three times a year. Desuckering ensured that each stool consisted of a a mother plant, a daughter and a grand daughter.

Yield parameters measured included height, pseudostem girth, number of leaves per plant and bunch weight. Height was measured from ground level to the inter-section point of petioles of two last open leaves by using a calibrated pole. Girth was measured on the stem one metre above the ground level using a measuring tape. The bananas were harvested at a maturity stage referred to as "bursting full" (Simmonds, 1966), when one or two fingers on the proximal hand of the bunch had burst and even began to ripen.

3.1.2 Soil Sampling

Soil sampling was done with a 6-cm-diameter and 30-cm-long soil auger to a depth of 30-cm. Five soil cores were taken from each plot (experimental unit) at every sampling time. The cores were mixed thoroughly and a sub-sample of 300 cc was taken for nematode extraction.

3.1.3 Nematode extraction from the soil

Nematodes were extracted from the soil by using the modified Jenkins centrifugal-floatation technique (Jenkins, 1964; Byrd *et al.*, 1966; Gibbins and Grandison, 1967). In this method, 100cc. of soil were put in a basin with two litres of water. The mixture was agitated and allowed to settle for 15 seconds. The mixture was passed through a sieve of 72-mesh and caught in a second basin. It was agitated again, allowed to settle for 15 seconds and passed through another sieve of 325-mesh. The contents of the latter sieve were back-washed into a beaker from which it was transferred to a centrifuge tube and centrifuged at 2000 rpm. for three minutes. The supernatant was discarded because at that point the nematodes were embedded in the pellet. A sugar solution (3:7, sugar:water) was poured into the the centrifuge tube and the nematodes re-suspended using a stirring rod . The nematode suspension was re-centrifuged at 2000 rpm. for 15 seconds . Nematodes, then in the supernatant , were poured onto a sieve of 325-mesh. The pellet was discarded and the nematodes were back-washed from the sieve with a stream of water into a vial. Using a pipette , 1ml of the nematode suspension was put into a Hawksley's slide and nematodes counted under a compound microscope.

3.1.4 Banana Root sampling

The local digging tool referred to in section 3.1.1, was used to make a 30cm-long trench per stool. The trench was made 30-cm away from the base of the mother plant and directly opposite the daughter sucker. All the roots encountered were collected in a plastic bag and taken to the laboratory for indexing root damage (necroses) and nematode extractions.

3.1.5 Necrosis Indexing and Nematode extraction from banana roots.

Roots were washed with water to remove all the soil and other debris before splitting them longitudinally. Root necrosis was assessed using a 0-5 scale, where 0 = no lesions root and 5 = more than 75-100% of root tissue being necrotic. After scoring , the roots were cut into 1-cm. pieces, and 10g of well-mixed-root pieces were used for nematode extraction by the marceration-sieving method (Taylor and Loegering, 1953) in which each sample was macerated in 100mls. of water in a blender for 20 seconds. The suspension was passed through a 72 mesh sieve resting over a 325 mesh sieve. The contents of the coarse sieve were discarded while those of the finer sieve were back washed with a gentle jet of water from a rubber tube connected directly to a water tap into a beaker. The suspension was then raised to a convenient volume that ensured minimum turbidity. As in the case of soil nematode suspensions, one ml. of each sample was pipetted into a Hawksley's counting slide and nematodes counted under a compound microscope. Total numbers of nematodes in 100g. roots were then computed and the data were subjected to analysis of variance (ANOVA), correlation statistic, mean separation and regression tests.

3.2 Host Range Tests

Two tests, 1 and 2 , were conducted at Agricultural Research Institute (A.R.I), Maruku, Tanzania (Appendix 1) to determine the host-range of the lesion nematode, *P. goodeyi*, between February 1990 and January 1992. Test 1 was conducted in a field which had banana plants for four years. The test was initiated one month after the banana plants had been up-rooted. Test 2 was conducted in a banana field next to field test 1. Seventy six locally available plant species (Table 2) were used in the host range test. The soil texture, hydrogen ion concentration (pH) and percentage organic matter (Peters, 1965; Day, 1965; Peech, 1965; Banwart *et al*, 1972) for the two fields are presented in table 6. The fields were naturally infested with *P. goodeyi* and small numbers of *Meloidogyne incognita*, *Hoplolaimus sp.*, *Tylenchus sp.* and *Criconema sp.*

In test 1 each species was planted in a 3-metre-long row which constituted a plot. Each plot had between 5 and 20 plants at spacing of 15 - 60-cm between plants,depending on the natural sizes of the plants species at maturity. Spaces between rows was 3-metres. A completely randomised block design with 6 replicates was used. Spacing between blocks was 4 metres. In test 2, each plant species was planted in the rhizosphere of banana stools in a completely randomised design with three replicates.

Sampling was done at 60 and 360 days in test 1 and at 60 days in test 2. At maturity, seeds of annual crops were harvested and replanted almost immediately to ensure continued presence of the plant species in the plot. For small type plants such as *Galinsoga perviflora* Cav., 10 whole plants were uprooted at random from each plot using a trowel during sampling. Soil was gently shaken off roots before putting them in plastic bags. Larger plants were normally few in their plots, as such 10 roots were obtained from different plants within each plot. The plants, if perennial, were left to continue for subsequent sampling. Nematodes were extracted as explained in section 3.1.5.

Table 2: Seventy six plant species used in the host range test of *P. goodeyi*

Plant species	Growth cycle	Uses
Amaranthus graecizans L.	annual	weed
Amaranthus hybridus L.	perennial	food
Ananas comosus (L.) Merr.	perennial	food
Arachis hypogea L.	annual	food
Argeratum conyzoides L.	annual	weed
Bidens pilosa L.	annual	weed
Bothriocline tomentosa S.M.	perennial	medicinal
Brassica oler. acephala L.	biennial	food
Brassica oleracea L.	biennial	food
Cajanus cajan Mill.	biennial	food
Caliandra calothyrsus L.	perennial	fodder
Capsicum annuum(L.) Bell.	perennial	spice
Carica papaya L.	perennial	food
Cicer arietinum L.	annual	food
Coffea arabica L.	perennial	drink
Coffea robusta Linden	perennial	drink
Colocasia esculenta Sch.	perennial	food
Commelina benghalensis L.	perennial	weed
Crotolaria orchroleuca L.	annual	fodder
Curcubit moschta Duch.	annual	food

Table 2: Continued..

Plant species	Growth cycle	Uses
Cymbopogon citrata Sch.	perennial	spice
Desmodium tortuosum DC.	annual	weed
Digitaria sclarum Chiov.	perennial	weed
Discorea cayanesis L.	perennial	food
Elettaria cardamomum Mat.	perennial	spice
Eleucine coracona Gaertn.	annual	food
Eragrostis bluephalalunus L.	perennial	weed
Erigeron floribundus S.& B.	annual	weed
Eucalyptus robusta Smith	perennial	timber
Fuerstia africana T.C.E.F.	perennial	medicinal
Galinsoga perviflora Cav.	annual	weed
Gossypium hirsutum L.	annual	linen
Gynura scandens O. Hoff.	perennial	medicinal
Hybiscus asper Hoohf.	perennial	weed
Hybiscus esculentus L.	annual	food
Hyperrhenia rufa Stap.	perennial	weed
Ipomea batatas (L.) Lam.	perennial	food
Kalanchoe prittwitzii Eng.	perennial	medicinal
Lactuca taracifolia Sch.	perennial	weed
Leucaena leucocephala L.	perennial	fodder
Lycopersicon esculentum Ml.	annual	food

Table 2: Continued..

Plant species	Growth cycle	Uses
Mangifera indica L.	perennial	food
Manihot esculenta Cranz	biennial	food
Musa sapientum L.	perennial	food
Nicotiana tabacum L.	annual	smoke
Ocimum suave L.	perennial	weed
Oldenlandia herbacea Roxb.	perennial	medicinal
Oxalis corniculata L.	perennial	weed
Passiflora edulis Sims.	annual	food
Pennisetum clandestinum C.	perennial	fodder
Pennisetum purpureum L.	perennial	fodder
Persea americana Mill.	perennial	food
Phaseolus vulgaris L.	annual	food
Phylanthes nigrum Sch.& Th.	perennial	weed
Physalis peruviana L.	perennial	weed
Pisum sativum L.	annual	food
Plectranthus barbatus Ben.	perennial	medicinal
Ricinus comunis L.	biennial	medicinal
Rutidea fuscescens Hiern.	perennial	medicinal
Saccharum officinarum L.	perennial	food
Senecio handensis S.Moore	perennial	medicinal
Sesamum alatum Thonn.	perennial	weed

Table 2: Continued..

Plant species	Growth cycle	Uses
Sesbania sesban D.	perennial	fodder
Setaria sphacelata St.& Hub.	perennial	fodder
Solanum melongena L.	annual	food
Solanum nigrum L.	annual	weed
Solanum tuberosum L.	annual	food
Sorghum vulgare Pers	annual	food
Tagetes minuta L.	annual	weed
Tephrosia bracteolata G.& P.	perennial	weed
Tridax procumbens L.	annual	medicinal
Tripsacum laxam Nash.	perennial	fodder
Vigna unguiculata Walp.	annual	food
Voandzeia subterranea Thon.	annual	food
Zea mays Sturt.	annual	food
Zingiber officinarum Rosc.	perennial	food

3.3 Fallowing and Soil Solarisation Test

A field naturally infested with *P.goodeyi* was used to investigate effects of fallowing and soil solarisation on population changes of the lesion nematode at A.R.I- Maruku, Tanzania between 1990 and 1992. Treatments are given on table 3. Polythene films of gauges (G) 250, 500, and 1000 were mounted on wooden frames (Fig. 1) and used to heat the soil in an attempt to increase efficiency of the fallowing. Temperatures were recorded at soil surface and at a depth of 15cm on areas covered by the polythene film chambers. Treatments were clean fallow, weed fallow, and grass mulch fallow,and in combination with polythene films, 250G, 500G and 1000G (Table 3). Predominant weeds in the fallow treatment were *Digitaria sclarum* L., *Galinsoga perviflora* L., *Bidens pilosa* L., *Commelina benghalensis* L., and *Cyperus rotundus* L. Other weeds are given under table 3.

In grass mulched treatment, *Hyperrhenia rufa* was spread evenly on clean plots to 15-cm unsettled thickness. A carbofuran treatment was included in which the chemical was sprinkled evenly by hand on clean plots and worked into the soil with a rake. Banana plots were also included to serve as controls. A completely randomised design with 5 replicates was used and the experimental units were 2x1.5-metre plots separated by 4 metre alleys.

At sampling time, five cores were taken randomly from every plot to a depth of 30-cm with a 6-cm wide and 30-cm long soil auger. The cores were mixed thoroughly before taking a sub-sample of 300-cc for nematode assays as described in section 3.1.3. If necessary, the nematodes were preserved in 10% formalin before counting them in a Hawksley's slide under a compound microscope. Temperatures (Table 4) in the Polythene films were measured using uni-therm DTL 70 thermometer.

Table 3: Treatments used in the Fallowing and Solarisation Test.

Clean fallow
[1]Weed fallow.
Clean fallow + mulch (*Hyperrhenia rufa*).
Clean fallow + Polythene film 250G.
Clean fallow + Polythene film 500G.
Clean fallow + Polythene film 1000G.
Banana alone.
Clean fallow + carbofuran (450g/plot).

[1]Weed species were:- *Eragrostis bluepharlaglunus* L., *Erigeron floribundus* S.& B., *Cyperus rotundus* L., *Oldenlandia herbacea* Roxb., *Paspalum obiculare* Forst., *Argeratum conyzoides* L., *Celosia laxa* L., *Commelina beghalensis* L., *Phyllanthes amarus* L., *Senecio vulgaris*, *Sonchus oleracea* L., *Bidens pilosa* L., *Cynodon dactylon* L., *Triumferatta rhomboidea* Jacq., *Digitaria sclarum* Chiov., *Chenopodium opulifolium* Schrad. and *Amaranthus spinosa* L.

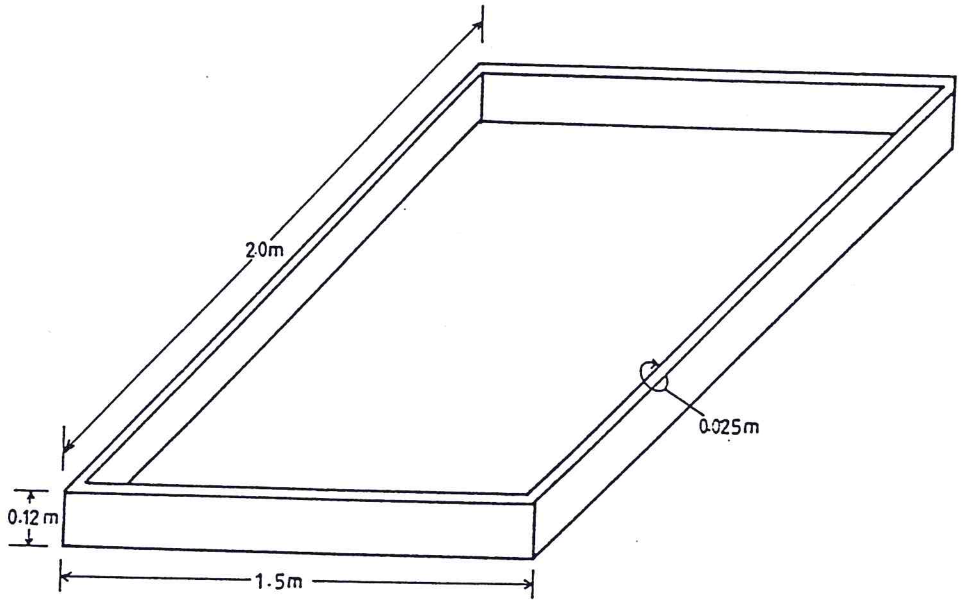


Figure 1: Wooden frame used for mounting polythene films for soil solarisation. Fallowing and solarisation test

Table 4: [1]Mean Temperatures (^{0}C) as recorded at soil surface and at depth of 15-cm. inside the polythene film chambers from 9.30 am to 6.00 pm.

Temperatures	Mean	Range
Ambient air temperature	26.1	23.5-28.5
Ambient ground level Temperature	27.1	25.0-37.0
Polythene 250G	53.4	33.0-66.0
Polythene 500G	57.4	37.0-68.0
Polythene 1000G	60.7	34.0-78.0
Polythene 1000G 15-cm underground	27.9	24.5-31.0

[1]Five-day means

3.4 Clean Planting Material Test

3.4.1 Field Test

A field test was initiated at A.R.I.- Maruku, Tanzania in 1990 to determine efficacy of hot water treatment, heating using solar irradiation (solarisation), paring and carbofuran in freeing banana planting materials of the lesion nematode, *P.goodeyi*. The test was established in a virgin land. The soil texture, hydrogen ion concentration and percentage organic matter were determined and are summarised in table 6. There was no *P.goodeyi* in the field initially but small numbers of *Meloidogyne incognita*, *Criconema sp.*, and *Hoplolaimus sp.* were detected.

Treatments used in this test are presented in table 5. One metre high suckers and corm splits obtained from fields infested with *P. goodeyi* were used in the test. Paring involved trimming roots from planting materials and peeling off all infested tissues to a depth of 1-cm from the surface. Hot water treatment consisted of immersing planting materials in water maintained at 55 ^{0}C in water bath for 20 minutes (Loos and Loos, 1960). The solarisation treatment invo treatment involved trapping of solar energy solarisation box (figure 2) for sterilizing planting material at 65 ^{0}C for 20 minutes. Another treatment involved dipping planting materials in a chemical suspension of-1kg carbofuran 5G in 20 litres of water for 3-hours.

Treated and untreated controls were planted in 60-cm deep and 90-cm wide holes filled with a mixture of 70kg of cattle manure and 70kg of top soil. Each treatment was replicated six times in a randomised complete block design. A plot consisted of 6-plants in two rows. Spacing between plants was 3.5m while the plots were separated by 4-metre alleys.

Ten soil samples were taken at random for determination of initial populations of *P. goodeyi* using the modified Jenkins' centrifugal-floatation method (Jenkins, 1964; Byrd *et al*, 1966; Gibbins and Grandison, 1967). Nematodes were preserved in 10% formalin before counting in a Hawksley's slide under a compound microscope.

Root samples were collected periodically (from two stools every sampling time) for nematode extraction and necrosis indexing as per section 3.1.5. Performance of bananas in each plot was monitored by recording germination, pseudostem girth, plant height and bunch weight.

Table 5: Treatments used in the Clean planting material and solarisation Test.

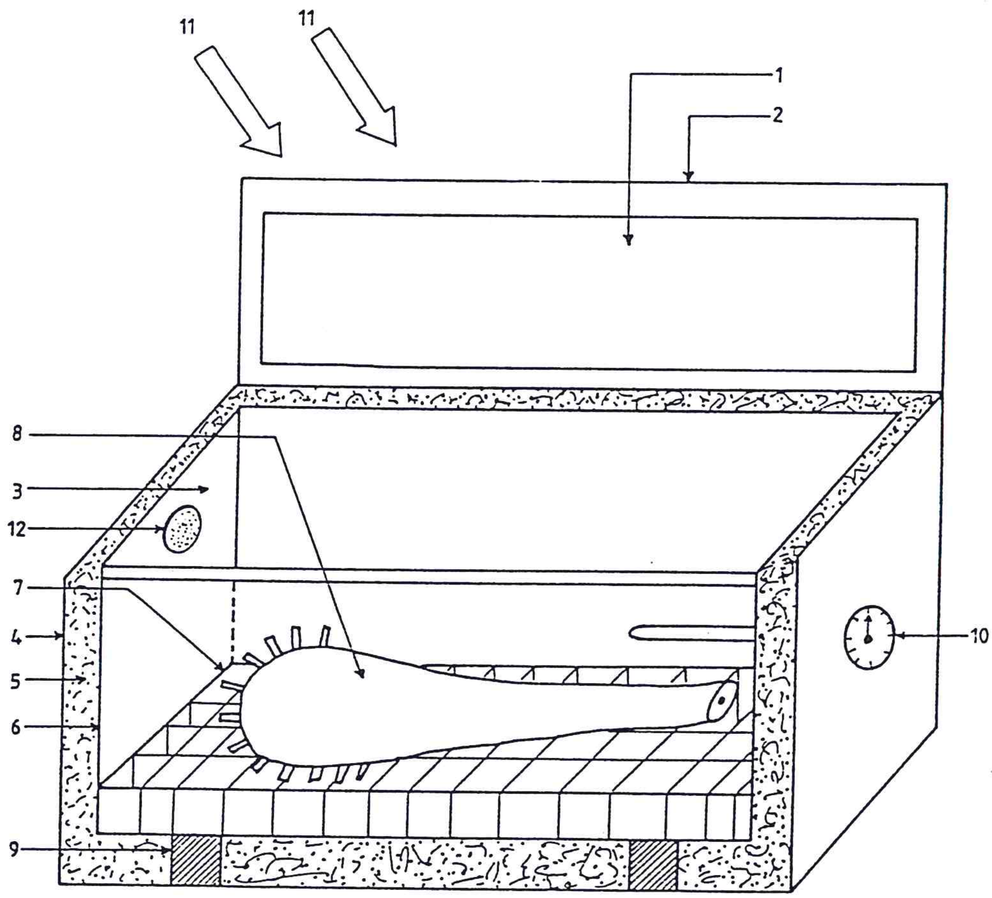
Non-pared suckers
Non-pared suckers + Carbofuran dip (1kg in 20-1.of water)
Pared sucker
Non-pared sucker + Hot water (55 ^{0}C)
Non-pared sucker + Solarisation
Pared sucker + Hot water
Pared sucker + Solarisation
Pared sucker + Carbofuran dip (1kg in 20-1. of water)
Non-Pared corm split
Non-Pared corm split + Carbofuran dip (1kg. in 20-1.water)
Pared corm split
Non-Pared corm split + Hot water
Non-Pared corm split + Solarisation
Pared corm split + Hot water
Pared corm split + Solarisation
Pared corm split + Carbofuran dip (1kg in 20-1.of water)

Table 6: Mechanical analysis, organic matter and nutrient contents of soil from the field used for Clean Planting Material Test.

Soil properties	Mean	Range
% Sand	79.2	76.0-82.0
% Silt	15.0	14.0-16.0
% Clay	5.8	4.0-8.0
pH	5.1	4.8-5.3
% O carbon	5.7	4.8-6.4
C/N	13.2	11.0-14
% P (ppm)	6.3	4.0-9.0
Conductivity (mhos)	6.5	3.7-9.6
Mg (mg/100g)	0.2	0.0-0.7
Na (mg/100g)	0.09	0.07-0.12
K (mg/100g)	0.9	0.4-1.7
Ca (mg/100g)	1.0	0.4-2.9

3.4.2 Functioning of the Solarisation Box

The wooden covers (2) and glass (3) [Figure 2] are opened and a sucker (8) placed on the weld-mesh platform (7). Then the glass cover (3) is closed and the box oriented to receive maximum sunlight directly by the mirror (1) reflection. The black inner surfaces of the metal lining (6) absorbs and transforms the sun irradiation into heat. When temperature inside the box reaches 65 ^{0}C, as read on the metal thermometer (10), the wooden cover is closed to cut off sunlight. The vent (12) may be opened to lower temperatures in cases of excessive heat. The temperature is maintained at 65 ^{0}C for 20 minutes when the box is opened, the sucker removed and another one put in its place to continue with the solarisation. Best time to use the solar box proved to be between 10.30 am. and 5.00 pm. (Table 7).



Scale:- 1cm = 10cm

Legend:- 1-mirror, 2-wooden cover, 3-clear double glass cover, 4-wooden box, 5-space filled with heat resistant material, 6-metal lining with inner black surfaces, 7-weld -mesh platform, 8-planting material to be treated, 9-support for metal lining, 10-thermometer, 11-sunlight, 12-vent

Figure 2: Solarisation box for banana planting material (sectioned to reveal details inside). Clean planting material test

Table: 7 [1]Mean Temperatures (^0C) recorded inside and outside the solarisation box from 9.00 am to 5.30 pm.

Temperatures	Mean	Range
Ambient (air)	26.2	22.0-30.0
Above solarisation box floor	75.9	32.0-100.0
Solarisation box floor.	76.7	30.0-106.0

[1]Mean of five days

3.5 Soil Amendment and Mulching Test.

A field test was initiated at the Agricultural Research Institute, Maruku, Tanzania in 1990 to investigate effects of different soil amendments and mulching on the populations and pathogenicity of *Pratylenchus goodeyi* on banana cultivar Nyoya, a common East African highland cooking banana. Besides *P. goodeyi*, the field was naturally infested with low populations of *Meloidogyne incognita* , *Helicotylenchus multicinctus*, *Hoplolaimus angastalatus* and *Radopholus similis*. The treatments used in the test are shown in table 8.

Percentages of carbon (C) and Nitrogen (N) and C:N ratios of some of the organic amendments are presented in table 9. Each planting hole was filled with top soil mixed with half rate (Table 8) of one of the soil amendments before planting. A week later, one metre high suckers with 15-20-cm corm girth were planted (one per hole). The remaining half rates (Table 8) of amendments were spread and worked into the soil 30-cm around the respective plants. Experimental units or plots were separated by 5-metre alleys. Each treatment was replicated three times in a randomised complete block design (Cockran and Cox, 1957; Steel and Torrie, 1960). Roots and soil samples were periodically collected for nematode extraction and necrosis indexing as explained in section 3.1.5.

Crop performance was assessed by recording, for each stool, the number of leaves, number of suckers, height, pseudostem girth (at shooting) and bunch weights. Mulching was done by spreading fresh grass, mostly *Hyperrhenia rufa*, evenly at the rate of 60 tonnes per hactare (about 15-cm thick layer of grass) to the designated plots.

Table 8: Treatments used in Soil Amendment and Mulching Test.

Carbofuran (5G) - 49kg/ha + mulch.
Carbofuran (5G) - 49kg/ha.
Muriate of Potash - 147 kg/ha) + mulch.
Muriate of Potash - 147 kg/ha.
Cattle manure - 69 tones/ha + mulch.
Cattle manure - 69 tones/ha.
Chicken manure - 69 tones/ha + mulch.
Chicken manure - 69 tones/ha.
Saw-dust - 69 tones/ha + mulch.
Saw-dust - 69 tones/ha.
Compost - 69 tones/ha + mulch.
Compost - 69 tones/ha.
Coffee husks (fresh and dry) - 69 tones/ha + mulch.
Coffee husks - 69 tones/ha.
Lime - 980 kg/ha + mulch.
Lime - 980 kg/ha.
N.P.K. (25:10:10) - 588 kg/ha + mulch.
N.P.K. (25:10:10) - 588 kg/ha.
T.S.P. - 370 kg/ha + mulch.
T.S.P. - 370 kg/ha.
mulch alone (60 tones/ha.
Control (non-amended/non-mulched)

Table 9: Carbon and nitrogen percentages of organic amendments used in the Soil Amendments Test.

Treatments	%C	%N	C:N
Sawdust	37.00	0.18	205.00
Coffee husks	33.00	1.92	17.00
Cattle manure	27.00	2.57	10.50
Chicken manure	*	2.38	*
Mulch (grass)	1.98	0.14	13.94

* Analysis not done

CHAPTER 4

4 RESULTS

4.1 Host Range Test

4.1.1 Field Test 1

Pratylenchus goodeyi was extracted from only 4 and 5 plant species 60 and 360 days after planting, respectively (Table 10). *Musa sp., T. laxam, C. benghalensis, H. rufa* and *P. barbatus* were the plant species that supported the nematode. The lowest and highest numbers of nematodes/100g wet root were extracted from *P. barbatus* and *C. benghalensis*, respectively 60 days after planting (Table 10). The nematode, *P. goodeyi*, was extracted from *T. laxam* only 360 days after planting (Table 10). The plant species, *C. benghalensis* and *H. rufa* supported significantly (P=0.05) more nematodes than other plant species including *Musa sp*, the known host , 60 days after planting (Table 10). *Musa sp.* cv Nyoya, had the highest number of *P. goodeyi* 360 days after planting.

Table 10: [1]Numbers of *Pratylenchus goodeyi* extracted from 100g of fresh wet roots of 76 plant species at 60 and 360 days after planting. Host Range Test 1

	Numbers of *P. goodeyi*	
Plant species	60 Days	360 Days
Commelina benghalensis	2430a[2]	2710c
Hyperrhenia rufa	2240a	9500b
*Musa sp.*cv.Nyoya	680b	57430a
Plectranthus barbatus	500b	790c
Tripsacum laxam	0b	2090c
Others (Table 2)	0b	0c

[1]Numbers are means of six replications

[2]Numbers followed by the same letters within a column are not significantly (P=0.05) different with LSD test

4.1.2 Field Test 2

Only two plant species, *Musa sp* and *C. benghalensis*, supported *P. goodeyi* in this test. *Musa sp* cv nyoya supported significantly (P=0.05) higher numbers of the nematode than those supported by *C. benghalensis* 60 days after planting (Table 11).

Table 11: [1]Numbers of *Pratylenchus goodeyi* extracted from 100g of fresh wet roots of 76 plant species 60 days after planting. Host range test 2

Plant species	*P. goodeyi*
Commelina benghalensis	3200b[2]
Musa sp cv Nyoya	42240a
Others (Table 2)	0c

[1]Numbers are means of three replications.

[2]Numbers followed by the same letters are not significantly (P=0.05) different with LSD test.

4.2 Fallowing and Solarisation Test

Field Test

Numbers of *P. goodeyi* extracted from 100cc of soil are depicted in table 12 and fig.3. The treatments had significant effect on the numbers of *P. goodeyi* only 200, 300 and 400 days after treatment application the treatments. The highest and lowest preplant populations of *P. goodeyi* were 59 and 12 nematodes/100cc of soil, respectively (Table 12). The nematode was not recovered from weed fallow, polythene 1000G, polythene 250G or carbofuran-treated plots 300 and/or 400 days after treatment application. *Pratylenchus goodeyi* was recovered from all treatments except from clean fallow plots 500 days after treatment application. Although the numbers of the nematode/100cc of soil were not significantly different 400 and 500 days after treatment application, plots with banana had some of the highest numbers of the nematode (Table 12 and Fig.3).

Fluctuations in populations of *P. goodeyi* during the time of the experiment are illustrated in fig.3. Except for the time period between 300 and 400 days after treatment application, there was a decline in populations of the nematode in clean fallow plots. Populations of the nematode increased only between 0 and 200 days and between 400 and 500 days after planting in the banana plots. Decline in nematode populations in other plots was followed by an increase in the populations 400 days after treatment application (Fig. 3).

Table 12: [1]Mean numbers of *Pratylenchus goodeyi*/100cc of soil on 0, 200, 300, 400 and 500 days after treatment application. Fallowing and soil solarisation Test.

[2]Treatments	Days after treatment application 0	200	300	400	500
Banana	14	243a[3]	32ab	12a	33
Mulch (*H.rufa*)	17	7c	47a	4ab	21
Clean fallow	34	22b	14b	14a	0
[4]Poly500G	42	27bc	4b	9b	3
Carbofuran	59	13c	0b	0b	14
Poly1000G	28	10c	0b	0b	14
Poly250G	14	8c	9b	0b	2
Weed fallow	20	9c	0b	0b	5
	NS[5]				NS

[1]Mean numbers of five replications.

[2]Repliated five times

[3]Numbers with the same letters in the same column are not significantly (P=0.05) different with LSD test.

[4]Polythene film

[5]Not significantly (P=0.05) different with LSD test.

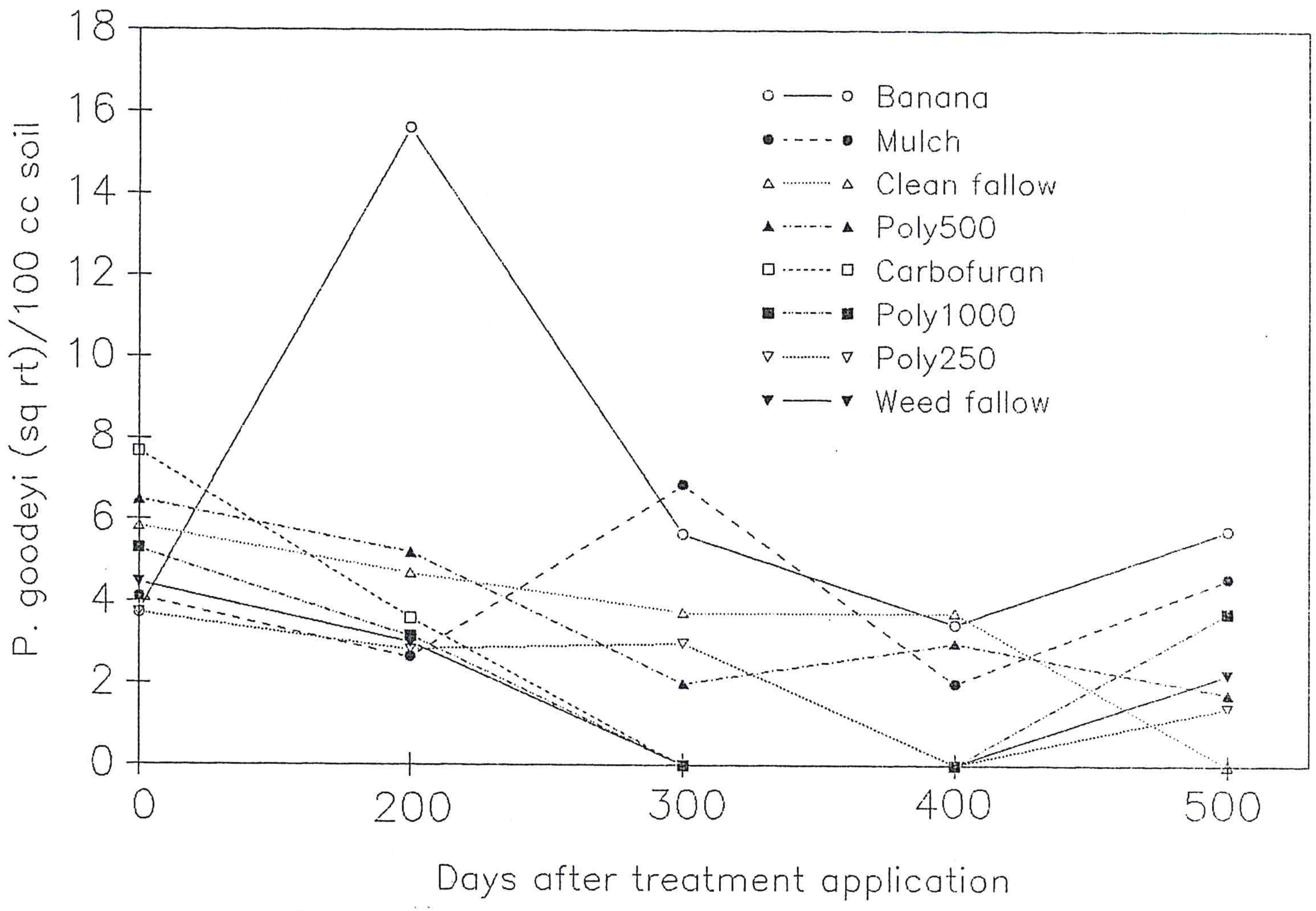


Figure 3: Populations of *Pratylenchus goodeyi*/100cc of soil on 0, 200, 300, 400 and 500 days after treatment application. Fallowing and soil solarisation Test.

4.3 Clean Planting Material Test

Results of the Clean planting material test are depicted in tables 13-22. Numbers of *P. goodeyi* were significantly ($P < 0.05$, Appendices 10-19) different 300, 450 and 650 days after planting (Table 13). Plants grown from non-pared suckers supported the highest numbers of *P. goodeyi* throughout the time of the experiment (Table 13). Plants grown from suckers supported more *P. goodeyi* than those grown from corms in most cases. The lowest numbers of *P. goodeyi* 650 days after planting, were obtained from plants whose planting materials, corms, were subjected to paring-solarisation treatment (Table 13). Correlation coefficients (r) of the correlation statistic of numbers of *P. goodeyi* on banana plant parameters were not significant 300 and 650 days after planting (Table 20).

Planting materials significantly ($P=0.05$) differed in their ability to germinate (Table 14). Non-pared, non-pared-carbofuran, pared, or pared hot water-treated suckers had some of the best germination. Non-pared solarised corms had the poorest germination. Corms had, generally, poorer germination than that of suckers (Table 14).

Table 13: [1]Mean Numbers of *P. goodeyi*/100g fresh roots 300, 450 and 650 days after planting. Clean Planting Material Test.

[2]Treatments	Day 300	Day 450	Day 650
Non-pared sucker	3333a[3]	1400a	29767a
Non-pared sucker+Carbofuran	0b	200b	5525ab
Pared sucker	0b	700ab	5027ab
Non-pared sucker+Hot water	0b	0b	2375b
Non-pared Sucker+Solarisation	675ab	360b	4258b
Pared sucker+Hot water	0b	0b	2800b
Pared sucker+Solarisation	955ab	0b	833b
Pared sucker+Carbofuran	0b	0b	4438b
Non-pared corm	0b	180b	12017ab
Non-pared corm+Carbofuran	700ab	0b	11593ab
Pared corm	0b	105b	6225ab
Non-pared corm+Hot water	525b	95b	1533b
Non-pared corm+Solarisation	0b	85b	8233ab
Pared corm+Hot water	0b	0b	2300b
Pared corm+Solarisation	0b	0b	542b
Pared corm+Carbofuran	0b	0b	2558b

[1]Mean of six replicates
[2]Replicated six times
[3]Numbers followed by the same letter(s) are not significantly (P=0.05) different with LSD test.

Plants were harvested at significantly (P=0.05) different times (Table 14) indicating that the treatments influenced plant maturation differently. Non-treated corms and non-treated suckers took the longest and shortest time period to mature, respectively (Table 14). Correlation coefficients of the correlation test of numbers of days to harvest on banana plant parameters were significant (P=0.05) (Table 20).

Although all plants were of the same cultivar, numbers of hands at maturity were significantly (P=0.05, Appendix 13) different (Table 14). Plants from non-pared + hot-water, carbofuran-treated suckers and non-pared-solarised corms had the highest and lowest numbers of hands/bunch, respectively (Table 14). Plants from non-pared sucker plus hot water, non-pared sucker plus carbofuran and pared sucker plus carbofuran treatments gave 15.87, 11.11 and 9.94% increases, respectively, in the numbers of hands with respect to control, non-pared sucker treatment (Table 15). Reductions in number of hands were associated with plants from other treatments(Table 15). The highest reduction of 39.68% was from plants grown from suckers subjected to paring and solarisation (Table 15). With respect to non-pared corms (control), increases in yield were associated with all treatments, except for the non-pared plus solarisation treatment. Excpt for non-pared corm + solarisation and pared sucker + carbofuran, there was increase in the numbers of hands (Table 16). The highest and lowest increases of 92.10 and 5.26% were associated with non-pared sucker + solarisation and non-pared corm + hot water treatments, respectively (Table 16).

Table 14: [1]Mean numbers of germinated plants/plot, days to harvesting of first crop, hands/bunch and yield of six plants.Clean Planting Material Test.

Treatments	[2]Germn	[3]DHarv	[4]Hands	Yield
Non-pared sucker	6.0a[5]	711e	6.3abcd	198ab
Non-pared sucker+Carbofuran	6.0a	715e	7.0ab	213a
Non-pared sucker	6.0a	715e	6.3abcd	191ab
Non-pared sucker+Hot water	6.0a	706e	7.3a	205a
Non-pared sucker+Solarisation	4.5bc	739cd	4.8efgh	122def
Pared sucker+Hot water	5.5ab	723de	5.7cde	189abc
Pared sucker+Solarisation	2.3de	753bc	3.8gh	107ef
Pared sucker+Carbofuran	6.0a	718e	6.8abc	198ab
Non-pared corm	3.3cd	780a	3.8gh	108ef
Non-pared corm+Carbofuran	4.7ab	740cd	5.3def	159bcd
Non-pared corm	4.3bc	765ab	5.0efg	140de
Non-pared corm+Hot water	3.3cd	750bc	4.0gh	102efg
Non-pared corm+Solarisation	1.8e	767ab	3.7h	67g
Pared corm+Hot water	2.3de	764ab	4.0gh	93fg
Pared corm+Solarisation	2.8de	759bc	4.2fgh	129def
Pared corm+Carbofuran	6.0a	757bc	5.8bcde	152cd

[1]Means of six replicates; [2]Germination; [3]Number of days to harvesting; [4]Number of hands; [5]Values followed by the same letter(s) are not significantly (P=0.05) different with LSD

Table 15: Percentage change (%) in yield (kg) and number of hands after planting in *P. goodeyi* non-infested field. Clean Planting Material Test

[1]Treatments	Yield	% change	Hands	% change
Non-pared sucker+Carbofuran	213a[2]	7.58	7.0ab	11.11
Pared sucker	191ab	-3.54	6.3abcd	0.00
Non-pared sucker+hot water	205a	3.54	7.3a	15.87
Non-pared sucker+solarisation	122def	-38.38	4.8efgh	-23.81
Pared sucker+Hot water	189abc	-4.55	5.7cde	-9.52
Pared sucker+Solarisation	107ef	-45.90	3.8gh	-39.68
Pared Sucker+Carbofuran	198ab	0.00	6.8abc	9.94
Non-pared corm	108ef	-45.45	3.8gh	-39.68
Non-pared corm+Carbofuran	159bcd	-19.90	5.3def	-15.87
Pared corm	140de	-29.29	5.0efg	-20.63
Non-pared corm+Hot water	102efg	-48.48	4.0gh	-36.51
Non-pared corm+solarisation	67g	-66.16	3.7h	-41.27
Pared corm+Hot water	93fg	-53.03	4.0gh	-36.51
Pared corm+Solarisation	129def	-34.85	4.2fgh	-33.33
Pared corm+Carbofuran	152cd	-23.23	5.8bcde	-7.94
[3]Control	198ab		6.3abcd	

[1]Replicated six times
[2]Numbers followed by the same letters in the same column are not significantly (P=0.05) with LSD test.
[3]Non-pared sucker.

Significant (P=0.05) differences were detected in banana bunch weights, the yield (Table 14). The highest and lowest yields were obtained from plants whose planting materials had been subjected to hot water and solarisation treatments, respectively. Plants from corms had inferior performance to that of plants grown from suckers (Table 14). Except for plants grown from untreated sucker, non-pared sucker plus carbofuran, non-pared sucker plus hot water and pared sucker plus carbofuran, plants from other treatments had relatively high yield (Tables 15-17).

In comparison with the control (plants grown from non-pared suckers), yield increases of 7.58 and 3.54% were associated with non-pared suckers plus carbofuran and non-pared sucker plus hot water treatment, respectively (Table 15). Reduction in yield of up to 66.16% was recorded from plants grown from suckers that had been subjected to solarisation alone (Table 15). Except for pared sucker + carbofuran, non-pared corm + hot water and pared corm + hot water treatments increases in yield of between 12.96 and 97.22% were associated with the other treatments (Table 16).

There were significant (P = 0.05) negative and positive relationship between number of *P. goodeyi* and plants grown from non-pared plus carbofuran and pared suckers, respectively (Table 21). Paring plus carbofuran treatments significantly suppressed pathogenic effects of *P. goodeyi* as indicated by the significant r values in table 22.

Table 16: Percentage change (%) in yield (kg) and numbers of hands after planting in *P. goodeyi* non-infested field. Clean Planting Material Test

[1]Treatments	Yield	% change	Hands	% change
Non-pared sucker+Carbofuran	198ab[2]	83.33	6.3abcd	65.79
Pared sucker	213a	97.22	7.0ab	84.21
Non-pared sucker+hot water	191ab	76.85	6.3abcd	65.79
Non-pared sucker+solarisation	205a	89.82	7.3a	92.10
Pared sucker+Hot water	122def	12.96	4.8efgh	26.32
Pared sucker+Solarisation	189abc	75.00	5.7cde	50.00
Pared Sucker+Carbofuran	107ef	-0.93	3.8gh	0.00
Non-pared corm	198ab	83.33	6.8abc	78.95
Non-pared corm+Carbofuran	159bcd	47.22	5.3def	39.47
Pared corm	140de	29.63	5.0efg	31.58
Non-pared corm+Hot water	102efg	-5.56	4.0gh	5.26
Non-pared corm+solarisation	67g	37.96	3.7h	-2.63
Pared corm+Hot water	93fg	- 13.89	4.0gh	5.26
Pared corm+Solarisation	129def	19.44	4.2fgh	10.53
Pared corm+Carbofuran	152cd	40.71	5.8bcde	52.63
[3]Control	108ef		3.8gh	

[1]Replicated six times
[2]Numbers followed by the same letters in the same column are not significantly (P=0.05) with LSD test.
[3]Non-pared corm

Blowdowns were significantly (P=0.05) different 650 days after planting (Table 17). The highest blowdowns were in plots with plants from pared suckers (Table 17). Pooled correlation coefficients of blowdowns with plant parameters were not significant (Table 20).

Plants developed significantly (P=0.05) different levels of root necrosis 350, 450 and 650 days after planting (Table 17). Plants grown from non-pared suckers had the most severe root damage 450 and 650 days after planting. Plants from hot water-treated corms had the least damaged root systems 450 and 650 days after planting (Table 17). The least damaged root systems were those of plants from solarised corms 350 days after planting (Table 17). Correlation coefficients of the correlation test of necrosis indices on banana plant parameters, except blowdown and days to harvest, were significant 650 days after planting (Table 20).

Plant girths were significantly (P=0.05) different 450 and 650 days after planting (Table 18). Plants from carbofuran-treated suckers and solarised corms had consistently the largest and smallest pseudostems, respectively (Table 18). Pseudostems of plants from corms tended to be smaller than those of plants from suckers (Table 16).

Plant heights were significantly (P=0.05) different throughout the time period of the experiment (Table 19). Plants from carbofuran, hot water treated suckers had some of the tallest plants (Table 19).

Table 17: [1]Mean numbers of blowdown and [2]necrosis Indices 300, 350, 450 and 650 days after planting. Clean Planting Material.

	Blowdowns	Necrosis Indices			
	Days	Days after planting			
[3]Treatments	650	300	350	450	650
Non-pared sucker	0.3abc	0.0	0.25abc	1.67ab	2.33a[4]
Non-pared sucker+[5]Carbof	0.0c	0.0	0.15abc	1.47a	1.98ab
Pared sucker	0.8a	0.0	0.52abc	0.78ab	2.00ab
Non-pared sucker+[6]Hw	0.3abc	0.0	0.12bc	1.00ab	1.98ab
Non-pared sucker+[7]solar.	0.7ab	0.0	0.38ab	1.10ab	1.68abc
Pared sucker+Hw	0.0c	0.0	0.15abc	0.85ab	2.28a
Pared sucker+ Solar.	0.0c	0.0	0.30abc	1.37a	1.73abc
Pared sucker+Carbof.	0.2bc	0.0	0.20abc	1.57a	1.78abc
Non-pared corm	0.0c	0.0	0.08bc	1.20ab	1.75abc
Non-pared corm+Carbof.	0.0c	0.0	0.05bc	0.92ab	1.80abc
Pared corm	0.2bc	0.0	0.03bc	0.97ab	2.23a
Non-pared corm+Hw	0.2bc	0.0	0.08bc	0.42b	1.23c
Non-pared corm+Solar.	0.0c	0.0	0.00c	1.02ab	1.45bc
Pared corm+Hw	0.0c	0.0	0.20abc	0.73ab	1.47bc
Pared corm+Solar.	0.0c	0.0	0.12bc	0.72ab	1.43bc
Pared corm+Carbof.	0.0c	0.0	0.07bc	0.70ab	1.77abc

[1]Mean of six replicates; Necrosis Indices based on 1-5 scale, where 1=Clean roots and 5=more than 75% of root cortex lesioned; [3]replicated six times, [4]Values followed by the same letter(s) in the same column are not significantly (P=0.05) different with LSD test; [5]Carbofuran; [6]Hot water; [7]Solarisation.

Table 18: [1]Mean plant girths 450 and 650 days after planting. Clean Planting Material.

	Girth (cm)		
	Days after planting		
[2]Treatments	450	650	650R[3]
Non-pared sucker+Carbofuran	57a[4]	66abc	63abc
[5]Control	61a	69a	68a
Pared sucker	59a	66abc	67ab
Control	57a	67ab	65abc
Non-pared sucker+hot water	38c	53bcde	50def
Control	53ab	60abc	61abcd
Non-pared sucker+solarisation	17e	56abcd	41fg
Control	56a	65abc	62abc
Pared sucker+Hot water	25de	33fg	34gh
Control	43bc	58abcd	56bcde
Pared sucker+Solarisation	34cd	52cde	48ef
Control	24de	45def	41fg
Pared Sucker+Carbofuran	13e	29g	32gh
Control	16e	31fg	30h
Non-pared corm	24de	39efg	42fg
Control	37c	60abcd	54cde

[1]Mean of six replicates
[2]Replicated six times
[3]Second crop
[4]Numbers followed by the same letters are not significantly (P=0.05) different with LSD test
[5]Non-pared sucker

Table 19: [1]Mean plant heights 450 and 650 days after planting. Clean Planting Material.

	Height (cm)		
	Days after planting		
[2]Treatments	450[3]	650[3]	650R[4]
Non-pared sucker+Carbofuran	241ab	365ab	303bc
[5]Control	265a	389a	337a
Pared sucker	237ab	381ab	296bc
Control	202ab	390a	310ab
Non-pared sucker+hot water	176abc	302bcd	229d
Control	226ab	349ab	285bc
Non-pared sucker+solarisation	48def	300bcd	175e
Control	195ab	372ab	310ab
Pared sucker+Hot water	68def	193e	134f
Control	127cdef	323abc	274c
Pared sucker+Solarisation	140bcdef	322abc	235d
Control	154abcd	247cde	212d
Pared Sucker+Carbofuran	19f	168e	123f
Control	38ef	182e	156ef
Non-pared corm	58def	225de	219d
Control	141bcde	347ab	284bc

[1]Mean of six replicates, [2]Replicated six times, [3]First crop [4]Second crop, [5]Numbers followed by the same letters are not significantly (P=0.05) different with LSD test, [6]Non-pared sucker.

Table 20: Correlation coefficients (r) of numbers of *Pratylenchus goodeyi*, root necrosis or blowdowns on banana plant parameters. Clean Planting Materials Test.

Parameters	*P. goodeyi* Days 300	*P. goodeyi* Days 650
Girth	0.260	0.043
Height	0.189	0.108
Yield	0.156	0.047
Blowdowns	0.161	0.050
Necrosis Indices	0.310	0.480
Germination	0.140	0.087
Days to harvest	-0.291	0.150
Numbers of Hands	0.080	0.042
	Necrosis Indices Days 300	**Necrosis Indices Days 650**
Blowdowns	0.003	0.199
Germination	0.282	0.680**
Days to harvest	-0.375	-0.543
Yield	0.390	0.723**
Number of hands	0.368	0.636**
Height	0.280	0.656**
Girth	0.380	0.713***
	Blowdowns Days 450	**Blowdowns Days 650**
Girth	0.416	0.363
Height	0.489	0.380
Germination	0.386	-
Days to harvest	-0.449	-
Yield	0.263	-
Number of hands	0.313	-
	Days to Harvest Days 450	**Days to Harvest Days 650**
Girth	-0.899***	-0.856***
Height	-0.865***	-0.839***
Yield	-0.877***	-
Number of hands	-0.874***	-
Germination	-0.792***	-

*, **, *** significant at P=0.05, 0.01 and 0.001,

respectively

Table 21: Correlation coefficients (r) of *P. goodeyi* versus necrosis indices[1], yield (kg) and numbers of blowdowns per treatment. Clean Planting Material Test.

Treatments[2]	*P. goodeyi* Necrosis	Yield	Blowdowns
Non-pared sucker	0.12175	-0.1390	-0.02660
Non-pared sucker+Carbofuran	-0.77126*	0.25475	0.00000
Pared sucker	0.77409*	-0.43146	-0.39661
Non-pared sucker+Hot water	-0.56139	0.62431	0.54422
Non-pared Sucker+Solarisation	0.66026	0.54170	-0.36653
Pared sucker+Hot water	-0.08745	-0.20353	0.00000
Pared sucker+Solarisation	0.53377	0.13748	0.00000
Pared sucker+Carbofuran	-0.17208	-0.51673	-0.37508
Non-pared corm	0.72519	0.00000	0.00000
Non-pared corm+Carbofuran	0.26824	0.37320	0.00000
Pared corm	0.39862	-0.36960	-0.21001
Non-pared corm+Hot water	0.45006	-0.38245	-0.31227
Non-pared corm+Solarisation	0.49621	0.26747	0.00000
Pared corm+Hot water	-0.05729	-0.06688	0.00000
Pared corm+Solarisation	0.29377	0.31280	0.00000
Pared corm+Carbofuran	0.18319	0.45537	0.00000

*Significant at $P = 0.05$
[1]Replicated six times
[2]Based on 1-5 scale, where 1=No lesions and 5=More than 75% of root cortex lesioned

Table 22: Correlation coefficients (r) of necrosis indices versus yield (kg) and numbers of blowdowns and blowdowns versus yield per treatment. Clean Planting Material Test.

	[2]Necrotic indices		
[1]Treatments	Yield(kg)	Blowdowns	[3]Bd vs Yd
Non-pared sucker	0.52467	-0.12251	-0.59783
Non-pared sucker+Carbofuran	-0.58986	0.00000	0.00000
Pared sucker	-0.76265*	-0.64777	0.09242
Non-pared sucker+Hot water	-0.02893	-0.48872	0.79155*
Non-pared Sucker+Solarisation	-0.08202	-0.05658	-0.14713
Pared sucker+Hot water	-0.68111	0.00000	0.00000
Pared sucker+Solarisation	0.80560*	0.00000	0.00000
Pared sucker+Carbofuran	0.53016	-0.07804	-0.29888
Non-pared corm	0.00000	0.00000	0.00000
Non-pared corm+Carbofuran	-0.20785	0.00000	0.00000
Pared corm	-0.60207	-0.29848	-0.07632
Non-pared corm+Hot water	-0.26133	-0.59440	-0.24495
Non-pared corm+Solarisation	0.24200	0.00000	0.00000
Pared corm+Hot water	-0.16713	0.00000	0.00000
Pared corm+Solarisation	0.33096	0.00000	0.00000
Pared corm+Carbofuran	0.8918***	0.00000	0.00000

*, **, *** Significant at P = 0.05, 0.01 and 0.001, respectively, [1]Replicated six times, [2]Based on 1-5 scale, where 1=No lesions and 5=More than 75% of root cortex lesioned, [3]Blowdown versus yield

4.4 Soil Amendment and Mulching Test

The results and associated ANOVA tables are presented in tables 23-36 and appendices 20-29, respectively. Numbers of *P. goodeyi* were significantly (P=0.05) different only 200 and 800 days after planting (Table 23). Plants grown in lime plus mulch - treated soil supported significantly (P=0.05) more nematodes than those grown in other soils 200 days after planting. Carbofuran plus mulch or coffee husks plus mulch - treated soils supported plants with the highest and second highest numbers of *P. goodeyi* 800 days after planting (Table 23). Some of the low numbers of *P. goodeyi* were obtained from plants grown in lime or N.P.K. plus mulch - treated soils (Table 23). Except for lime plus mulch and lime treatments, there was no significant difference in numbers of *P. goodeyi* from corresponding treatments non-amended plus mulch and amended treatments (Table 23). Nematode population build-up was higher in mulched than in non-amended soils except for the compost and N.P.K. treatments (Table 24).

Necrosis indices were significantly (P=0.05) different 200 and 600 days after planting (Table 25). Plants grown in soil treated with chicken manure + mulch had the lowest root damage (Table 25) 200 days after planting. The highest necrosis index was associated with plants grown in coffee husk amended soil (Table 25) 200 days after planting.

Table 23: [1]Mean numbers of *Pratylenchus goodeyi*/100 g fresh wet banana roots 0, 200, 400, 600, and 800 days after planting. Soil amendment and Mulching Test.

	P. goodeyi in Days				
Treatments	0	200	400	600	800
Carbofuran + mulch	1814	25608b[2]	25334	8513	72883a
Carbofuran	5441	16373b	60933	920	18183ab
M. Potash + mulch	6200	19020b	25867	16787	48867abc
M. Potash	3291	9872b	8333	7987	60417abc
Cattle m. + mulch	5391	16271b	48533	3880	38360abc
Cattle m	3476	9988b	14800	3060	16767abc
Chicken m. + mulch	6460	19381b	44467	2240	10617c
Chicken m.	4977	14922	8333	19767	6000c
Sawdust + mulch	10350	31150b	61333	36053	26300abc
Sawdust	8537	25611b	25800	26233	27400abc
Compost + mulch	5751	17253b	9600	4267	28583abc
Compost	11253	34028b	39867	2633	62083abc
Coffee h + mulch	5832	17496b	75933	4800	72260ab
Coffee husks	3711	14133b	21067	7080	14573bc
Lime + mulch	12025	148404a	38400	7673	18383abc
Lime	3024	9072b	30000	1387	6290c
N.P.K. + mulch	2316	6947b	56800	9293	6900c
N.P.K.	7988	23965b	52733	7633	23000abc
T.S.P. + mulch	3526	10577b	30067	2387	53583abc
T.S.P.	3337	6497b	27400	4540	17733abc
No amend.+ mulch	5495	46485ab	8733	41613	62340abc
No amend.+ no mulch	607	13821b	48267	9100	23367abc
	[3]NS		NS	NS	

[1]Means of six replicates
[2]Numbers followed by the same letters in the same column are not significantly (P=0.05) different with LSD test
[3]Non significant

Table 24: [1]Mean numbers of *Pratylenchus goodeyi*/100g fresh wet banana roots 200, 400, 600 and 800 days after planting. Soil amendments and Mulching Test.

	P. goodeyi	
Treatments	Mulch	No mulch
Carbofuran	33085	24102
M. Potash	27635	21655
Cattle m	26761	11154
Chicken m.	19176	12256
Sawdust	38709	26264
Compost	14901	35653
Coffee husks	42622	14213
Lime	53215	11687
N.P.K.	19985	26833
T.S.P.	21654	12420
No [2]amend.+ no mulch	39793	23639

[1]Means of six replications

[2]Amendment

Table 25: [1]Mean numbers of blowdowns and [2]necrosis indices on 200 and 600 days after planting in *Pratylenchus goodeyi*-infested field. Soil amendment and Mulching Test.

	Blow down		Necrosis indices	
Treatments	Day 200	Day 600	Day 200	Day 600
Carbofuran + mulch	0.0	0.3	2.4abcd[3]	2.4abcde
Carbofuran	0.0	1.0	2.7abcd	3.3ab
M. Potash + mulch	0.0	0.3	2.9abcd	1.9de
M. Potash	0.0	1.0	3.6ab	3.3ab
Cattle m. + mulch	0.0	2.0	3.0abc	2.7abcde
Cattle m	0.0	1.7	2.9abcd	2.8abcd
Chicken m. + mulch	0.0	1.0	1.7d	2.7abcd
Chicken m.	0.0	0.7	2.1cd	2.7abcd
Sawdust + mulch	0.0	1.7	2.3bcd	3.0abcd
Sawdust	0.0	2.0	2.7abcd	3.1abc
Compost + mulch	0.0	1.0	3.4abc	2.4abcde
Compost	0.0	0.3	2.1cd	2.7abcde
Coffee husks + mulch	0.7	0.7	2.1cd	2.3bcde
Coffee husks	0.7	1.3	3.7a	3.2ab
Lime + mulch	0.0	0.0	2.2cd	2.0cde
Lime	0.0	1.0	2.8abc	3.1abc
N.P.K. + mulch	0.0	0.7	2.3bcd	1.7e
N.P.K.	0.3	1.0	3.3abc	2.8abcd
T.S.P. + mulch	0.0	0.7	2.5abcd	2.6abcde
T.S.P.	0.0	0.3	2.7abcd	2.6abcde
No amend. + mulch	0.3	1.0	2.8abcd	2.7abcde
No amend. + no mulch	0.0	0.0	3.4abc	3.5a
	[4]NS			

[1]Means of six replicates.
[2]Based on 0-5 scale, in which 0 = no lesions and 5=more than 75% of a root being necrotic.
[3]Numbers followed by the same letter in the same column are not significantly (P=0.05) different with LSD.
[4]Non significant.

Root systems of plants grown in soils treated with N.P.K. plus mulch or muriate of potash were less damaged than most of the root systems 600 days after planting (Table 25). Plants grown in non-amended-non-mulched soils had the most damaged root systems 600 days after planting (Table 25). Between corresponding treatments (amended plus mulch and amended alone) significant (P=0.05) difference in root damage was detected only in N.P.K. plus mulch and N.P.K. treatments 600 days after planting (Table 25).

Blowdowns were not significantly different 200 and 600 days after planting (Table 25). The blowdowns were, recorded only in coffee husks and/or mulch-treated soil and non - amended, mulched soils 200 days after planting (Table 25). There were no blowdowns in soils treated with lime plus mulch, and non-amended soil 600 days after planting. The worst blowdowns were in cattle manure or sawdust, mulch-treated soil 600 days after planting (Table 25). Only 2.25% (r^2 = 0.0225, r = 0.15) and 0.04% (r^2 = 0004, r = -0.02) variation in the blowdowns was ascribed to *P. goodeyi* 200 and 400 days after planting, respectively (Table 36). Root necrosis accounted for only 2.89% (r^2 = 0.0289, r = -0.17) and 0.64% (r^2 = 0.0064, r = -0.08) variation in the blowdowns (Table 26).

Table 26: Correlation coefficients (r) of numbers of *Pratylenchus goodeyi*, [1]necrosis or blowdowns on banana plant parameters. Soil Amendment and Mulching Test.

Plant Parameters	*P. goodeyi* Days after planting 200 r	400 r
Blowdowns	0.15	-0.02
Root necrosis	-0.17	-0.08
First yield	-0.05	-0.14
second yield	0.07	-0.01
Number of suckers	-0.12	-0.20
Plant height	-0.01	-0.15
Pseudostem girth	-0.12	0.02
Days to first harvest	-0.13	-0.28
Days to second harvest	0.47*	0.18

	Root Necrosis Days after Planting 200 r	600 r
Blowdowns	0.18	0.21
First yield	-0.42*	-0.28
Second yield	-0.28	-
Number of suckers	-0.06	-0.41
Plant height	-0.26	-0.55*
Pseudostem girth	-0.07	-
Days to first harvest	-0.17	-
Days to second harvest	0.26	-

	Blowdowns Days after Planting 200 r	600 r
First yield	0.14	-0.45*
Second yield	0.22	-0.22
Number of suckers	0.28	-0.06
Plant height	-0.09	-0.17
Pseudostem girth	0.17	-0.20
Days to first harvest	0.20	-0.17
Days to second harvest	0.06	0.19

*Significant at P=0.05, [1]Based on 1-5 scale where 1=No lesions and 5=More than 75% of root cortex lesioned.

Banana pseudostem girths are shown in table 27. There were significant (P=0.05) difference in the girths only 200, 400 and 700 days after planting. The largest and smallest pseudostems were those of plants grown in coffee husks plus mulch and T.S.P. - treated soils, respectively, 200 days after planting (Table 27). Chicken manure plus mulch or N.P.K. plus mulch - treated soils supported plants with the largest pseudostem 400 days after planting (Table 27). Pseudostems of plants grown in N.P.K. - treated soil were significantly (P = 0.05) smaller than those of plants grown in N.P.K. plus mulch - treated soil 400 days after planting. Chicken manure plus mulch and lime - treated soils supported plants with the largest and smallest pseudostems, respectively, 700 days after planting (Table 27).

Plant heights were significantly (P = 0.05) different only 400 and 600 days after planting (Table 28). There were no significant difference in plant heights of plants grown in soils treated with amendments plus mulch and those grown in soils treated with amendment alone, except for lime plus mulch and lime treatments 600 days after planting (Table 28). Plants grown in potash, compost, compost plus mulch or carbofuran-treated soils were relatively tall compared with others. The shortest plants were those grown in N.P.K., T.S.P. or lime-treated soils (Table 28). *P. goodeyi* had no effect on plant height as indicated by non-significant r values of -0.01 and -0.15 (Table 26). Only 0.01% (r^2=0.0001) and 2.25% (r^2 = 0.225) of the variation in height was ascribed to *P. goodeyi* 200 and 400 days after planting, respectively.

Table 27: [1]Mean banana pseudostem girths (cm) 30, 100, 200, 400, 600 and 700-[2]R after planting. Soil amendment Test.

	Girth (cm)					
	Days after planting					
Treatments	30	100	200	400	600	700-R
Carbofuran + mulch	24	25	30bcde[3]	59abc	47	31abc
Carbofuran	25	25	30bcde	58abcd	39	40a
M. Potash + mulch	26	25	32abcd	57abcd	41	39a
M. Potash	22	24	29cde	55abcd	35	27abc
Cattle m. + mulch	24	27	34abc	44d	45	29abc
Cattle m	21	28	35abc	58abcd	44	32abc
Chicken m. + mulch	24	27	30bcde	69a	58	36ab
Chicken m.	23	28	35abc	62abc	50	30abc
Sawdust + mulch	21	24	29cde	57abcd	46	27abc
Sawdust	25	26	30bcde	52abcd	34	23bc
Compost + mulch	23	28	36ab	64ab	50	36ab
Compost	24	29	34abc	57abcd	48	31abc
Coffee husks + mulch	25	27	37a	63abc	58	32abc
Coffee husks	23	24	32abcd	52abcd	36	25abc
Lime + mulch	24	25	30bcde	58abc	47	35ab
Lime	26	24	27de	54abcd	40	19bc
N.P.K. + mulch	22	26	32abcd	64ab	52	32abc
N.P.K.	23	23	30bcde	50cd	39	28abc
T.S.P. + mulch	24	30	34abc	62abc	53	36ab
T.S.P.	23	23	25e	55abcd	39	29abc
No amend. + mulch	22	22	26de	58abcd	49	28abc
No amend. + no mulch	23	27	32abcd	58abcd	46	32abc
	[4]NS	NS			NS	

[1]Means of six replicates
[2]Second crop
[3]Numbers followed by the same letter in the same column are not significantly (P=0.05) different with LSD test
[4]Non sgnificant.

Table 28: [1]Mean banana plant heights (cm) 30, 100, 200, 400, and 600 days after planting in *P. goodeyi*-infested field. Soil amendment and Mulching Test.

	Height (cm)				
	Days after planting				
Treatments	30	100	200	400	600-[2]R
Carbofuran + mulch	124	165	215	253abc	198abc[4]
Carbofuran	135	166	216	248bc	265a
M. Potash + mulch	121	179	232	271ab	224ab
M. Potash	142	143	183	274ab	167bc
Cattle m. + mulch	127	179	229	278c	210ab
Cattle m	127	193	234	248bc	215ab
Chicken m. + mulch	139	193	222	301ab	224ab
Chicken m.	128	181	224	286ab	219ab
Sawdust + mulch	117	155	210	240bc	181abc
Sawdust	138	165	211	261ab	151bc
Compost + mulch	135	186	261	327a	237ab
Compost	138	200	223	291ab	197abc
Coffee husks + mulch	122	159	229	306ab	208ab
Coffee husks	124	145	204	269ab	153bc
Lime + mulch	127	153	197	275ab	228ab
Lime	135	178	191	277ab	106c
N.P.K. + mulch	128	184	198	301ab	211ab
N.P.K.	106	167	187	247bc	168bc
T.S.P. + mulch	137	191	221	281ab	212ab
T.S.P.	117	140	182	276ab	185abc
No amend. + mulch	112	140	187	274ab	224ab
No amend. + no mulch	131	192	205	273ab	188abc
	[3]NS	NS	NS		

[1]Means of six replicates
[2]Second crop
[3]Non significant
[4]Values followed by the same letter in the same column are not significantly different with LSD test.

There were significant (P = 0.05) differences in leaf lengths and breadths 200 days after planting (Table 29). Leaves of plants grown in soils amended with cattle manure alone and in mulched, non-amended soils were the tallest and the shortest, respectively (Table 29). Except for T.S.P. plus mulch and T.S.P. alone treatments, no significant differences were detected in leaf lengths of amendment treatment and the corresponding amendment plus mulch treatments (Table 29). Plants grown in compost - mulched soils, T.S.P. amended or non-amended soils had the widest and the narrowest leaf breadths, respectively. Plants grown in amended and the corresponding amended, mulched soils were not significantly different.

Suckering was highest in coffee husk-mulch, cattle manure-mulch or cattle manure treated soils in most cases. Suckering was poor in soils treated with carbofuran plus mulch, saw-dust, saw-dust plus mulch or lime. Suckering was also poor in non-amended soil (Table 30). The nematode, *P. goodeyi*, had no significant effect on suckering (Table 30). It caused only 1.44% ($r = 0.0144$) and 4% ($r^2 = 0.04$) variation in suckering.

Banana plants grown in soils treated with compost plus mulch, carbofuran and muriate of potash took the longest time to mature (Table 31). Days to flowering and harvesting of second crop were not significantly different (Table 31).

P. goodeyi had a significant ($P = 0.05$, $r = 0.47$) (Tables 26 and 34) effect on yield only in the second harvest in which it caused a yield reduction of 22.09% ($r^2 = 0.2209$).

Weights of banana bunches were significantly ($P = 0.05$) different for both first and second crops (Table 31). Bunch weights of the first crop were higher than the corresponding weights of the second crop (Table 31). In the first crop, some of the heaviest bunches weighing more than 100 kg/plot, were from plants grown in soils treated with chicken manure plus mulch, compost plus mulch, chicken manure, coffee husks plus mulch or lime plus mulch (Table 31). Weights of the heaviest bunches were significantly ($P = 0.05$) different from weights of bunches of plants grown in soils treated with carbofuran and/or mulch, muriate of potash, cattle manure and/or mulch, saw-dust and/or mulch, compost, coffee husks, lime, N.P.K., T.S.P. and/or mulch and non - amended and/or mulched soils (Table 31).

Table 29: Mean banana leaf lengths and breadths 200 days after planting in *Pratylenchus goodeyi*-infested field. Soil Amendment and Mulching Test.

	Leaf	
Treatments	Length (cm)	Bredth (cm)
Carbofuran + mulch	110cdef	48b
Carbofuran	114abcdefg	51ab
M. Potash + mulch	117abcdefg	51ab
M. Potash	105defg	47b
Cattle m. + mulch	124abcdef	55ab
Cattle m	139a	55ab
Chicken m. + mulch	114abcdefg	48b
Chicken m.	122abcdef	54ab
Sawdust + mulch	103efg	48b
Sawdust	111cdefg	46b
Compost + mulch	135ab	59a
Compost	137ab	56ab
Coffee husks + mulch	120abcdefg	58ab
Coffee husks	126abcde	53ab
Lime + mulch	111cdefg	50ab
Lime	114abcdefg	49ab
N.P.K. + mulch	122abcdef	52ab
N.P.K.	122abcdef	49ab
T.S.P. + mulch	129abcd	55ab
T.S.P.	100fg	45b
No amend. + mulch	96g	45b
No amend. + no mulch	121abcdefg	49ab

[1]Means of six replicates .
[2]Values followed by the same letters are not significantly (P=0.05) different with LSD test.
[3]Non-significant.

Table 30: [1]Mean numbers of banana suckers /stool 200, 300 and 400 days after planting in *Pratylenchus goodeyi*-infested field. Soil amendment and Mulching Test.

	Days after planting		
Treatments	200	300	400
Carbofuran + mulch	0.0e[2]	1.1ghij	3.3def
Carbofuran	0.5de	1.8bcdefghi	5.3abcd
M. Potash + mulch	0.5de	1.7cdefghij	3.6cdef
M. Potash	0.6cde	1.4defghij	2.3f
Cattle m. + mulch	1.8a	2.9ab	4.8abcde
Cattle m	1.8a	2.2bcdefg	5.8abc
Chicken m. + mulch	0.9abcde	2.5abc	5.3abc
Chicken m.	1.5abc	2.3bcde	5.0abcde
Sawdust + mulch	0.0e	1.3efghij	2.7ef
Sawdust	0.5de	1.1ghij	3.2ef
Compost + mulch	0.7bcde	2.5abc	6.0ab
Compost	1.6ab	2.0bcdefgh	5.0abcde
Coffee husks + mulch	1.8a	3.6a	4.8abcde
Coffee husks	1.2abcd	2.3bcde	2.8ef
Lime + mulch	0.3de	1.2efghij	4.2bcdef
Lime	0.3de	0.7ij	2.6ef
N.P.K. + mulch	0.2de	1.7cdefghij	4.8abcde
N.P.K.	0.3de	0.9hij	3.4cdef
T.S.P. + mulch	0.5de	1.9bcdefgh	6.7a
T.S.P.	0.2de	0.7ij	2.8ef
No amend. + mulch	0.2de	1.2efghij	3.6bcdef
No amend. + no mulch	0.6cde	1.3efghij	4.6abcdef

[1]Means of six replicates

[2]Numbers followed by the same letters in the same column are not significantly (P=0.05) different with LSD test

Some of the lightest bunches were from plants grown in cattle manure plus mulch, saw-dust or lime treated soils (Table 31). Between corresponding treatments, significant (P = 0.05) differences in bunch weghts were detected only between lime plus mulch and lime treatments (Table 31).

Between amended and non-amended + mulch treatments, significant differences (P=0.05) were detected in bunch weight and yield, from plants grown in chicken manure or non amended soil in the first crop (Tables 32 and 33). Chicken manure resulted in 50.68% and 11.11% increases in banana yield in the first and second crops, respectively (Table 33). Reductions of 12.33, 15.07 and 10.96% were associated with plants grown in carbofuran, saw dust and lime-treated soils,in the first and second crops, respectively (Table 33). Performance of plants grown in lime - treated soil was also inferior in the second crop (Table 28). The second crop performance was inferior to that of the first crop in most cases (Tables 32 and 33).

Table 31: [1]Mean Yield (kg), days to flowering and harvesting of first and second banana crops. Soil amendments and Mulching Test.

Treatments	Yield (kg) First crop	Yield (kg) Second crop	Days to Harvest First crop	Days to Harvest Second crop	Days to [4]Flower Second crop
Carbofuran + mulch	84bcdef[2]	63abcd	616ab	747	683
Carbofuran	64efg	63abcd	633a	720	654
M. Potash + mulch	93abcdef	70abcd	605ab	694	648
M. Potash	80cdefg	45bcd	630a	722	665
Cattle m. + mulch	51g	45bcd	607ab	729	653
Cattle m	83bcdef	64abcd	597ab	698	618
Chicken m. + mulch	120a	88ab	597ab	694	591
Chicken m.	110abc	60abcd	613ab	704	614
Sawdust + mulch	71defg	50bcd	604ab	702	660
Sawdust	62fg	40cd	566b	726	643
Compost + mulch	113ab	96a	635a	701	627
Compost	87bcdef	54abcd	598ab	704	613
Coffee husks + mulch	109abc	58abcd	610ab	701	643
Coffee husks	81bcdefg	40cd	584ab	703	636
Lime + mulch	103abcd	76abc	585	689	639
Lime	65efg	32d	606ab	725	661
N.P.K. + mulch	91abcdef	62abcd	599ab	703	643
N.P.K.	81bcdefg	62abcd	594ab	731	661
T.S.P. + mulch	95abcd	74abcd	598ab	698	618
T.S.P.	85bcdef	54abcd	599ab	712	660
No amend. + mulch	86bcdef	50bcd	594ab	759	677
No amend. + no mulch	73defg	54abcd	608ab	711	650
		[3]NS		NS	NS

[1]Means of six replications
[2]Numbers followed by the same letter in the same column are not significantly (P. 0.05) different with LSD test.
[3]Non significant
[4]First crop took an average of 549 days to flowering

Between amended plus mulch and non amended plus non mulched treatments, significantly (P = 0.05) higher in yields were associated with plants grown in chicken plus mulch, compost plus mulch or coffee husks plus mulch-treated soils in the first crop (Tables 32 and 33). Yield increases of 64.38, 54.79 and 49.32% were associated with plants grown in soils treated with chicken manure plus mulch, compost plus mulch and coffee husks plus mulch, respectively in the first crop (Table 33). thes treatments resulted also in yield increases of up to 77.78% in the second crop (Table 33). Crop performance in the second crop was poorer than the one of the first crop (Table 33).

Reductions of between 2.74 and 30.14% were associated with plants grown in saw dust plus mulch or cattle manure plus mulch-treated soil (Table 33).

Table 32: Percentage change (%) in yield (kg), bunch weight, after planting in a *Pratylenchus goodeyi*-infested field. Soil Amendments and Mulching Test.

[1]Treatments	1st Crop yield	% Change	2nd crop yield	% Change
Carbofuran	64efg[2]	-12.33	63abcd	16.67
[3]Control	73defg		54abcd	
Murate potash	80defg	9.59	45bcd	-16.67
Control	73defg		54abcd	
Cattle manure	83bcdef	13.70	64abcd	18.52
Control	73defg		54abcd	
Chicken manure	110abc	50.68	60abcd	11.11
Control	73defg		54cd	
Saw dust	62fg	-15.07	40abcd	-25.93
Control	73defg		54abcd	
Compost	87bcdef	19.18	54abcd	0.00
Control	73defg		54cd	
Coffee husk	81bcdefg	10.96	40abcd	-25.93
Control	73def		54abcd	
Lime	65efg	-10.96	32d	-40.74
Control	73defg		54abcd	
[4]NPK	81bcdefg	10.96	62abcd	14.81
Control	73defg		54abcd	
[5]TSP	85bcdef	16.44	54abcd	0.00
Control	73defg		54abcd	

[1]Replicated three times, [2]Numbers followed by the same letters are not significantly (P=0.05) different with LSD test, [3]No amendment + no mulch, [4]Nitrogen-Phosphorus-Potasium (20:10:10), [5]Triple superphosphate

Table 33: Percentage change (%) in yield (kg), bunch weight, after planting in a *Pratylenchus goodeyi*-infested field. Soil Amendment and Mulching Test.

[1]Treatments	1st Crop yield (kg)	% Change	2nd Crop yield (kg)	% Change
Carbofuran+mulch	84bcdef[2]	15.07	63abcd	16.66
M.potash+mulch	93abcdef	27.40	70abcd	29.63
Cattle mn+mulch	51g	-30.14	45bcd	-16.67
Chicken [4]mn+mulch	120a	64.38	88ab	62.96
Saw dust+mulch	71defg	-2.74	50bcd	-7.41
Conpost+mulch	113ab	54.79	96a	77.78
Coffee [5]hs+mulch	109abc	49.32	58abcd	7.41
Lime + mulch	103abcd	42.10	76abc	40.74
[6]NPK + mulch	91abcdef	24.66	62abcd	14.81
[7]TSP + mulch	95abcd	26.67	74abcd	37.04
[3]Control	73defg		54abcd	

[1]Replicated three times, [2]Numbers followed by the same letters are not significantly (P=0.05) different with LSD test, [3]No amendment + no mulch' [4]Manure, [5]Husks, [6]Nitrogen-Phosphorus-Potasium (20:10:10), [7]Triple superphosphate,

Table 34: Correlation coefficients (r) of numbers of *Prtylenchus goodeyi* on banana yields (kg) of first and second crops. Soil Amendment and Mulching Test.

[1]Treatments	Crops First r	Crops Second r
Carbofuran + mulch	-0.97263	0.00000
Carbofuran	-0.63609	-0.98998
M. Potash + mulch	0.41626	-0.86603
M. Potash	-0.96650	0.02272
Cattle m. + mulch	0.16182	0.97309
Cattle m	0.25567	0.12390
Chicken m. + mulch	0.79881	0.91808
Chicken m.	-0.90469	-0.11972
Sawdust + mulch	-0.85065	-0.59308
Sawdust	0.29574	0.53514
Compost + mulch	-0.52174	-0.49433
Compost	-0.46066	0.60169
Coffee h + mulch	0.45196	-0.95843
Coffee husks	0.73913	0.91799
Lime + mulch	-0.25118	-0.91766
Lime	0.87713	-0.27796
[2]N.P.K. + mulch	-0.51930	-0.77930
N.P.K.	0.99955**	1.00000***
[3]T.S.P. + mulch	-0.64567	0.10355
T.S.P.	0.97836	0.22096
No amend.+ mulch	-0.93600	0.99847*
No amend.+ no mulch	0.64442	-0.42610

*, **, *** Significant at P=0.05, 0.01, and 0.001 levels, respectively;
[1]Replicated three times
[2]Nitrogen-Phosphorus-Potasium (20:10:10)
[3]Triple superphosphate

Table 35: Correlation coefficients (r) of [1]necrosis indices on first banana crop yield. Soil Amendment and Mulching Test.

[2]Treatments	r
Carbofuran + mulch	-0.18898
Carbofuran	0.96725
M. Potash + mulch	-0.98198
M. Potash	-0.37115
Cattle manure + mulch	-0.95222
Cattle manure	0.77691
Chicken manure + mulch	0.97754
Chicken manure	-0.66285
Sawdust + mulch	-0.88736
Sawdust	0.31917
Compost + mulch	0.22074
Compost	0.99222*
Coffee h + mulch	-0.97516
Coffee husks	0.99834
Lime + mulch	-0.50000
Lime	-0.13653
[3]N.P.K. + mulch	-0.39736
N.P.K.	0.99960**
[4]T.S.P. + mulch	0.10931
T.S.P.	-0.99340*
No amend.+ mulch	0.88032
No amend.+ no mulch	0.68202

*, **, *** Significant at P=0.05, 0.01, and 0.001 levels, respectively;
[1]Based on 0-5 where 0=No lesions and 5=More than 75% of root cortex is lesioned, [2]Replicated three times
[3]Nitrogen-Phosphorus-Potasium (20:10:10)
[4]Triple superphosphate

Table 36: Correlation coefficients (r) of numbers of blowdowns on first and second banana yields (kg), bunch weight. soil Amendment and Mulching Test.

[1]Treatments	First crop r	Second crop r
Carbofuran + mulch	-0.88980	0.00000
Carbofuran	-0.39736	0.50000
M. Potash + mulch	-0.94491	-1.00000**
M. Potash	0.16531	-0.50000
Cattle manure + mulch	-0.00697	1.00000**
Cattle manure	-0.49196	0.24855
Chicken manure + mulch	-0.64046	-0.07509
Chicken manure	0.70047	0.98198
Sawdust + mulch	0.99381*	-0.84299
Sawdust	-0.04120	-0.27735
Compost + mulch	-0.26015	-0.84299
Compost	-0.93427	-0.15554
Coffee h + mulch	-0.92857	-0.99124
Coffee husks	-0.69746	-0.94491
Lime + mulch	-	-
Lime	-0.87944	-0.60999
[2]N.P.K. + mulch	0.32733	0.80296
N.P.K.	0.32733	0.30038
[3]T.S.P. + mulch	-0.98432	-0.98533
T.S.P.	0.59030	-0.86603
No amend.+ mulch	-0.73221	-0.95222
No amend.+ no mulch	-	-

*, **, *** Significant at P=0.05, 0.01, and 0.001 levels, respectively' [1]Replicated three times, [2]Nitrogen-Phosphorus -Potasium (20:10:10), [3]Triple superphosphate

CHAPTER 5

DISCUSSIONS

5.1 Host Range Test

The ability of *P. goodeyi* to parasitize 5 plant species out of 77 species (Table 10), provides the first experimental evidence to the speculation that the nematode has a narrow host range (Loof, 1960; Machon and Hunt, 1985; Gowen and Queneherve, 1990). The inability of *P. goodeyi* to infect most of the plant species used in the host range test, may be ascribed to lack of attraction between the nematode and the plants, production of substances toxic to the nematode (Oostenbrink *et al*, 1957; Rhode and Jenkins, 1958; Uhlenbroek and Bijloo, 1959; Scheffer *et al*, 1962; Winoto, 1969; Giebel, 1972 and 1982), production of growth inhibitory substances by the plants (Daulton and Curtis, 1963; Van Gundy and Kirkpatrick, 1964; Baldwin and Baker, 1970; Endo and Veech, 1970; Fassuliotis, 1970; Griffin and Waite, 1971; Jatala and Russel, 1972) and/or morphological barriers that prevent the nematode from invading the plants (Giebel, 1982). Further work is, however, required to delineate the role of attraction, toxins, inhibitory substances, and morphological barriers in the *P. goodeyi* - plant interaction.

The ability of *T. laxam* to support *P. goodeyi* after the plants were older than 60 days (Table 10) may indicate dependence of susceptibility of this species to plant age. Although plant age is known to influence susceptibility of plants to pathogens (Rees and Platz, 1983; Shabear and Bockus, 1988; Hosford *et al*, 1990; Riaz *et al*, 1991), data from this study do not verify this possibility adequately. Therefore, studies need to be carried out to verify age influence in the *T. laxam* - *P. goodeyi* interaction.

The colonization of only *C. benghalensis* and *Musa sp* (Table 11) in test 2 might have been due to host preference (Dao, 1970; Benard and Laughlin, 1976). All plant species (Table 11) were planted in the rhizosphere of banana plants as was described in section (3.2.1.2). Because of this,the probability for the nematode to choose the most susceptible hosts was high (Wallace, 1973).

Although *P. goodeyi* was reported in Kilimanjaro region, Tanzania, on maize cultivar Kiilima, the nematode did not parasitize the maize cultivar EH 85109. This might have been due to varietal differences and/or existence of *P. goodeyi* biotypes (DuCharme and Birchfield, 1956; Dropkin, 1988; Huttel and Yaegashi, 1988). These possibilities, however need to be tested.

The narrow host-range of *P. goodeyi*offers an opportunity for developing an effective cultural control strategy involving fallowing, crop rotation and intercropping. For effective management such a package should ensure that fields are free of hosts *P. goodeyi* such as *C. benghalensis, H. rufa, P. barbatus, and T laxam*. Intercropping is a common practice in Bukoba District, Tanzania. Since *Tagetes minuta* is abundant in most areas it may be encouraged to grow in banana fields to lower the nematode populations. This plant may not only help in suppressing *P. goodeyi,* but also the notorious nematodes such as *Meloidogyne incognita, Radopholus similis Helichotylenchus multicintus and Hoplolaimus angustalatus* (Gowen and Queneherve, 1990).

Appropriate utilisation of non-host plants would be economically feasible and attractive to farmers whose meagre resources have been overstretched by the current economic crisis in many third world countries.

5.2 Fallowing and Solarisation Test

The general decline in the populations of *P. goodeyi* in clean fallow plots (Fig.3) indicates poor survival of the nematode in the absence of the host plants. This trend confirms the obligate parasitism of the nematode (Blake, 1969). The decrease of P. *goodeyi* populations in banana rhizosphere could have been due to the colonization of banana roots by this nematode. In contrast, the increase in *P. goodeyi* populations in the first 200 days (Fig 3) of the experiment in the plant's rhizosphere could be ascribed to low availability of infection courts, roots.

The increase in *P. goodeyi* populations only 400 days after treatment application in carbofuran, polythene films, 250, 500, and 1000G, mulch and weed plots may imply poor residual effects that might have promoted high efficacy of the treatments in reducing *P. goodeyi* populations before 400 days after planting (Fig.3). Translucent polythene films increase soil temperature (Mbugua, 1990; Gristein *et al*, 1979; Giblin-Davis and Verkade, 1988), soil moisture (Sharmar and Nene, 1990), and soil nutrient status and texture (Wilson *et al*, 1985; Hullugalle *et al*, 1991). Changes in soil temperature, moisture, nutrient status and texture can enhance antagonism (Miller and Waggoner, 1963; Stapleton and De Vay, 1984), and accumulation of toxic substances (Miller and Waggoner, 1963; Stapleton and De Vay, 1984). Enhanced antagonist, lethal levels of toxic substances and heat might have caused the initial decline in the populations of *P. goodeyi*. These possibilities, however, need to be verified experimentally. The decline in *P. goodeyi* populations in the fallow plots might have been due to the inability of the nematode to parasitise the weed plants (Table 2).

These results indicate that the use of clean fallow and soil solarisation are promising management strategies for the control of *P. goodeyi*. Although information on economic threshold is lacking in these results, the data in Fig 3 reveal that a two year fallow period can reduce populations of the nematode to levels which may be below the injurious threshold. Because of the poor residual effects of soil solarisation, repeated solarisation may be necessary for it to have effective long-term impact on nematode populations. Shading effect of banana plants, however, may make this control measure impractical, except when plants are still young. In view of this, a combination of clean fallow and soil solarisation would, perhaps, be more effective if adopted in the control of the nematode.

5.3 Clean Planting Material Test

The significantly (P = 0.05) different *P. goodeyi* numbers among the treatments (Table 13) implies that the treatments have diffent effects on *P. goodeyi*. The differences in numbers of *P. goodeyi* from unpared and pared treatments may be ascribed to differences in initial innoculum density. Paring is known to make planting materials nearly nematode free (Gowen and Queneherve, 1990). The relatively low nematode populations associated with plants whose planting materials were subjected to combination of treatments such as paring plus solarisation, hot water and/or carbofuran , hot water and solarisation indicates that those combinations have more lethal effect on nematodes. These treatments can minimise banana losses due to *P. goodeyi* if adopted.

The increase in yield in only some treatments (Tables 14, 15 and 16) indicate that injurious threshold of the plants varied from treatment to treatment. Pinochet (1988) reported that 10,000-20,000 *Radopholus similis* cause significant yield losses. The losses in banana yields (Tables 14, 15 and 16) associated with *P. goodeyi* at populations smaller than the injurious threshold of *R. similis* imply a relatively high pathogenic potential of *P. goodeyi* in bananas.

5.4 Soil Amendment and Mulching Test

The fact that plants grown in amended soils suffered less root damage than those grown in non-amended soils indicates that the amendments excerted some control against *P. goodeyi*. The control might have been the result of activities of nematophagous micro-organisms (Sayre, 1971; De La Cruz, 1983). Organic amendments reduced *P. goodeyi* populations significantly (P = 0.05) better than the inorganic fertilizers (Table 23) perhaps as a result of direct effect of toxic products of decomposition such as acetic, propionic and butyric acids (Mankau and Minteer, 1962; Desai *et al*, 1969; Mankau and Das, 1974; Castillo, 1985), increased host resistance, increased numbers of nematophagous organisms (Sayre, 1971; De La Cruz, 1983) and/or differences in nutrient quality and quantity. Differences in nutrient qualities and quantities in the amendments might have influenced the operation of plant defence mechanisms differently (Johnson, 1957 and 1959; Hollis and Rodriguez-Kabana, 1966; Sayre *et al,* 1969). There is, however need to determine the mechanisms of soil amendment that suppress *P. goodeyi* populations.

The significantly (P = 0.05) low damage associated with plants grown in chicken manure plus mulch in the early phase (200 days) of the experiment signifies that the treatment had suppressive activity against *P. goodeyi*. It is possible that chicken manure promoted activities of soil micro-organisms that antagonise the lesion nematode more than the other amendments. The effectiveness of the chicken manure activities declined during the later phase of the experiment perhaps due to depletion of toxic decomposition nutrients and toxins (Walker, 1971). Therefore, to be able to sustain its the activities, repeated applications may be necessary.

The high bunch weights of plants grown in soil amended with chicken manure plus mulch, compost plus mulch or coffee husks are an indication of the potential of those organic materials to suppress pathogenic effects of *P. goodeyi*. The decreased yield of second crop was probably a reflection of lowered /or depleted nutrients and/or antagonistic activities against the nematode.

The general tendency of unmulched plants to have higher necrosis scores shows that mulch had improved the plants defence mechanisms probably through promotion of biological control agents, conservation of water or provision of nutrients (Juo and Lal, 1977; Oyeninyi and Agbede, 1980).

The low frequency of blowdown in the first 200 days of the experiment might have been due to nematode populations that were below the injurious threshold level (Miller and Edgington, 1962).

The study has, therefore, established that manipulation of the soil environment by using amendments, particularly chicken manure, compost and coffee husk enhanced activities that adversely affected *P. goodeyi*. The study, however, has not established mechanisms of the amendments against this nematode. Further work, therefore, is required to establish the mechanisms involved.

It must be emphasised that manipulation f the soil environment in favour of individual resident species, if adopted could overcome the problems associated with adding biocntrol agents to the soil. The complex soil environment usually has a buffering effect against establishment of introductions.

CHAPTER 6

6 CONCLUSIONS

This study has established that:-

i) *Pratylenchus goodeyi* has a narrow host range. The nematode parastised only 5 plant species , *C. benghalensis, H. rufa, P. barbatus*, and *T. laxam* out of 76 plant species planted in naturally *P. goodeyi*-infested fields.

ii) Clean fallow can reduce *P. goodeyi* populations to insignificant levels. A 500-day fallow period reduced numbers of *P.* goodeyi from 32 to 0.

iii) Soil heating (solarisation) using polythene films can reduce *P. goodeyi* innoclum densities to levels perhaps below the injurious threshold. Soil solarisation with 1000G film reduced numbers of *P. goodeyi* from 28 to 10 in the first 200 days of the experiment.

iv) A combination of paring and solarisation, hot water and carbofuran or hot water-solarisation are effective in freeing banana planting material (Suckers and corms of *P. goodeyi*. Yield, bunch weight increase of up to 97.22% were associated with these treatments.

v) Manipulation of the soil environment by addition of amendments enhanced activities such as antagonism that reduced populations of *P. goodeyi*. Amending the soil with chicken manure, compost or coffee husks increased banana (bunch weight) yield to between 10.96 and 50.68% (Table 32).

vi) Treatments with mulching reduced populations of *P. goodeyi* more than treatments without mulch.

These findings are going to make it possible to avoid using hosts of *P. goodeyi* in intercropping systems, use non-hosts in crop rotation systems and disinfect *P. goodeyi* infested field and infected planting materials. The adoption of the findings in management of *P. goodeyi* as components of an IPM package will be a big help to many resource poor farmers (Appendices 4 & 5) and a positive step towards protecting the environment from pollution.

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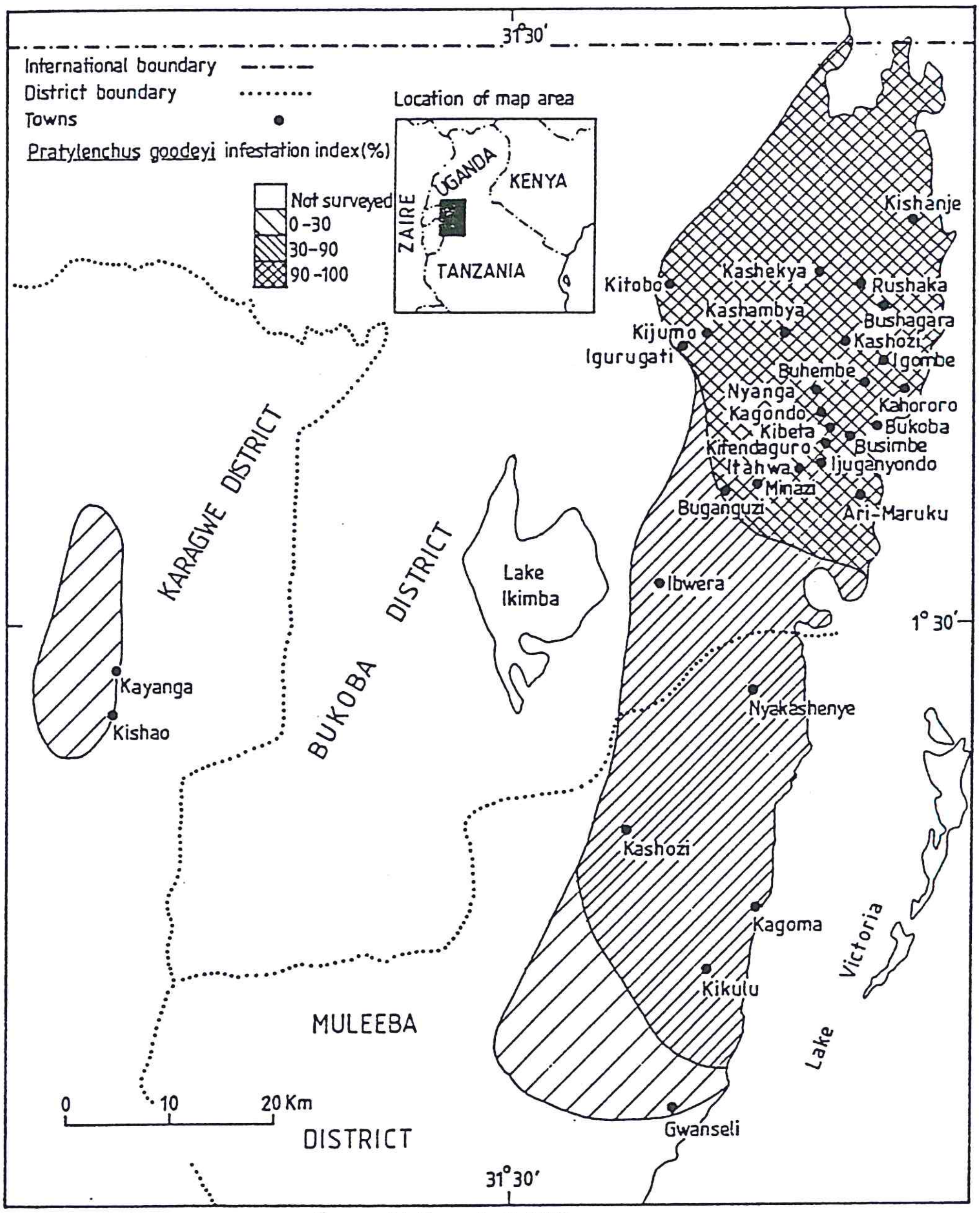
APPENDICES



Source Walker et al, 1984

Appendix 1 Map of Bukoba, Muleba and Karagwe Districts (Tanzania) showing infestation levels of *Pratylenchus goodeyi* on bananas

Appendix 2: Banana roots showing typical *Pratylenchus goodeyi* lesions.

Appendix 3: Cut banana corm showing lesions caused by *Pratylenchus goodeyi*.

Appendix 4: Banana field under good control of nematodes including *Pratylenchus goodeyi* (With near mature bunches)

Appendix 5: Banana field under good control of nematodes including *Pratylenchus goodeyi* (Before flowering)

Appendix 6: Analysis of variance of *P. goodeyi* 647 days after planting. Fallowing and solarisation Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	7	1252.97	178.99	3.00	0.0175
Reps	4	394.60	98.65	1.65	0.1885
Errors	28	1669.40	59.62		
Total	39	3316.97	337.26		

Appendix 7: Analysis of variance of *P. goodeyi* 200 days after planting.Fallowing and solarisation Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	7	2.5×10^5	3.5×10^4	11.48	0.0001
Reps	4	1.5×10^4	3.9×10^3	1.28	0.3005
Errors	28	8.7×10^4	3.1×10^3		
Total	39	3.5×10^5	4.42×10^4		

Appendix 8: Analysis of variance of *P. goodeyi* days after planting. Fallowing and Solarisation Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	7	2.5×10^5	3.5×10^4	11.48	0.0001
Reps	4	1.5×10^4	3.9×10^3	1.28	0.3005
Errors	28	8.7×10^4	3.1×10^3		
Total	39	3.5×10^5	4.2×10^4		

Appendix 9: Analysis of variance of *P. goodeyi* 400 days after planting. Fallowing and solarisation Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	7	1193.92	170.56	2.69	0.029
Reps	4	413.60	103.40	1.63	1.950
Errors	28	1778.40	63.51		
Total	39	3385.92	337.47		

Appendix 10: Analysis of variance of mean numbers of *Pratylenchus goodeyi* 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	4.6×10^9	3.0×10^8	2.02	0.0242
Reps	5	3.1×10^9	6.3×10^8	4.16	0.0022
Errors	75	1.1×10^{10}	1.5×10^8		
Total	95	1.87×10^{10}	1.08×10^9		

Appendix 11: Analysis of variance of necrosis indices 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	1.100	0.07	1.75	0.05
Reps	5	1.1	0.23	5.50	0.0002
Errors	75	3.16	0.04		
Total	95	5.36	0.34		

Appendix 12: Analysis of variance of blowdowns 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	6.00	0.40	2.11	0.018
Replicates	5	1.08	0.21	1.14	0.346
Errors	75	14.25	0.19		
Total	95	21.33	0.40		

Appendix 13: Analysis of variance of number of hands/bunch. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	143.00	9.53	9.20	0.0001
Reps	5	3.25	0.65	0.63	0.6796
Errors	75	77.75	1.03		
Total	95	224.00	11.21		

Appendix 14: Analysis of variance of yield 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	193819.95	12921.33	11.14	0.0001
Reps	5	8028.62	1605.75	1.38	0.2397
Errors	75	86982.04	1159.76		
Total	95	288830.61	15686.84		

Appendix 15: Analysis of variance of girth 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	12862.29	857.48	9.25	0.0001
Reps	5	858.70	171.74	1.85	0.1129
Errors	75	6953.95	92.71		
Total	95	20674.94	112.93		

Appendix 16: Analysis of variance of numbers of germinated plants/ plot 248 days after planting. Clean Planting Material Test

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	16.62	1.10	2.47	0.005
Reps	5	0.35	0.07	0.16	0.977
Errors	75	33.71	0.44		
Total	95	50.68	1.61		

Appendix 17: Analysis of variance of height of second crop 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	8.2×10^5	5.4×10^4	33.29	0.0001
Reps	5	3.6×10^4	7.3×10^3	4.43	0.0008
Errors	75	2.8 x 105	1.6 x 103		
Total	95	1.1×10^6	6.3×10^4		

Appendix 18: Analysis of variance of height 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	5.3×10^5	3.5×10^4	6.47	0.0001
Reps	5	2.2×10^4	4.5×10^3	0.83	0.534
Errors	75	4.1×10^5	5.5×10^3		
Total	95	9.62×10^5	4.5×10^4		

Appendix 19: Analysis of variance of girth second crop 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	1.6×10^4	1.1×10^3	6.55	0.0001
Reps	5	4.4×10^2	89.04	0.53	0.754
Errors	75	1.2×10^4	1.6×10^2		
Total	95	2.8×10^4	1.3×10^3		

Appendix 20: Analysis of variance of Yiel of first crop 650 days after planting. Soil Amendment and mulching Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	5.3×10^5	3.5×10^4	8.88	0.0001
Reps	5	1.5×10^4	3.1×10^3	0.78	0.566
Errors	75	3.0×10^5	4.0×10^3		
Total	95	8.45×10^5	4.2×10^4		

Appendix 21: Analysis of variance of pseudostem girth 450 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	26323.33	1754.88	14.87	0.0001
Reps	5	421.45	84.29	0.71	0.6146
Errors	75	8850.54	118.00		
Total	95	35594.99	1957.17		

Appendix 22: Analysis of variance of time to harvest 650 days after planting. Clean Planting Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	50633.95	3375.59	10.55	0.0001
Reps	5	586.32	117.26	0.37	0.8700
Errors	75	23998.66	319.98		
Total	95	7521.93	3812.83		

Appendix 23: Analysis of variance of mean necrosis indices 470 days after planting. Soil Amendment and mulching Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	21	18.44	0.88	1.90	0.038
Reps	2	0.53	0.27	0.57	0.570
Errors	42	19.44	0.46		
Total	65	38.41	1.61		

Appendix 24: Analysis of variance of mean number of suckers 200 days after planting. Soil Amendment and mulching Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	21	34.32	1.63	3.53	0.0002
Reps	2	0.56	0.28	0.13	0.880
Errors	42	93.73	2.23		
Total	65	128.61	4.14		

Appendix 25: Analysis of variance of mean pseudostem girth blowdowns 700 days after planting. Soil Amendment and mulching Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	21	6564.48	312.59	2.19	0.01
Reps	2	116.46	58.24	0.41	0.66
Errors	42	5989.51	142.00		
Total	65	12670.45	512.25		

Appendix 28: Analysis of variance of mean yield of first crop. Soil Amendment and mulching Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	21	20163.27	960.15	2.53	0.005
Reps	2	2046.39	1023.19	2.69	0.079
Errors	42	15954.27	379.86		
Total	65	38163.93	2363.2		

Appendix 29: Analysis of variance of mean number of hands/bunch of first crop. Soil Amendment and mulching Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	21	27.94	1.33	1.77	0.050
Reps	3	1.73	0.86	1.15	0.32
Errors	42	31.60	0.75		
Total	65	61.27	2.94		

Appendix 30: Analysis of variance of blowdowns 647 days after planting. Clean Material Test.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value	Pr > F
Treatments	15	6.00	0.40	2.11	0.018
Replicates	5	1.08	0.21	1.14	0.346
Errors	75	14.25	0.19		
Total	95	21.33	0.80		

Appendix 31: Meterological data for 1990, 1991 and part of 1992 at A.R.I.-Maruku, Bukoba, Tanzania.

	Total rainfall (mm)			Average temperature (^0C)			Relative humidity (%)		
Months	1990	1991	1992	1990	1991	1992	1990	1991	1992
Jan	177	225	89	25.3	24.3	25.3	73	72	68
Feb	140	107	111	25.7	24.8	25.0	76	71	70
Mar	270	290		25.5	19.3		76	72	
Apr	131	389		25.7	24.1		77	76	
May	240	421		25.6	23.4		75	79	
Jun	29	66		25.6	25.1		64	67	
Jul	6	59		25.7	25.7		64	63	
Aug	8	42		25.8	25.8		65	69	
Sep	48	91		26.0	26.0		64	66	
Oct	287	172		25.1	25.1		70	71	
Nov	216	190		26.7	26.7		70	68	
Dec	296	47		26.5	26.5		72	69	