INTEGRATED NEMATODE CONTROL ON COTTON IN SOUTH AFRICA: PRESENT STATUS

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Abstract

Research on the control of nematodes on cotton at TCRI was devoted to various aspects of integrated nematode management. Long- and short-term research objectives for laboratory, greenhouse and field research have been identified and are currently being pursued. The most economically important nematodes needing attention are *Meloidogyne incognita* race 4 and various *Pratylenchus* and *Paratrichodorus* spp. Chemical control remains the most important means of nematode control, to such an extent that chemicals are almost abused. Various new nematicides and application techniques have been evaluated in field trials. Germplasm with genetic resistance to *M. incognita* race 4 has been identified and is being incorporated into cotton breeding lines. A nematode-tolerant line has been selected for commercialization and yield and quality characteristics are being monitored further at different localities. A commercially available biological control agent for nematodes, *Paecilomyces lilacinus*, is presently being evaluated for incorporation in an integrated pest management programme, with adaptations to be made for improved application techniques and nematode control on annual field crops with suboptimum environmental conditions. Host plant suitability was determined for numerous rotational crops under greenhouse conditions. Long-term field trials are being done with selected oat and wheat cultivars to determine the shift of nematode species and populations under different cropping regimes. Proper agronomical and field practices and water management strategies are advocated by extension and research officers in order to establish the basic principles and available control measures within an integrated nematode control system.

Introduction

Nematodes of importance in the Southern African cotton production areas include the root-knot nematodes, *Meloidogyne incognita* race 4 and *M acronea* (especially Malawi), stubby root nematode, *Paratrichodorus* spp, lesion nematodes, various *Pratylenchus* spp, reniform nematode, *Rotylenchulus parvus, R. reniformis*, dagger nematode, *(Xiphinema* spp) and others (Luc *et al*., 1990). The major nematode pest of cotton in South Africa is *M incognita*, especially in light sandy soils (Kleynhans, 1991; van Wyk 1985) and research emphasis is placed on various methods to reduce the negative effects of this nematode on cotton yield.

Lack of large areas of arable land and water shortage leading to intensive cropping systems, poorly managed in many cases, are the main causes for extremely high root-knot nematode populations in combination with other plant parasitic nematodes, present in certain cotton production areas. Light sandy soil, high temperatures and poor water quality (especially pH) causing early breakdown of nematicides, also aggravate the problem.

During the past few years, research on the control of nematodes on cotton was intensified, covering all aspects of integrated nematode management, ie, chemical and biological control, host plant resistance, crop rotation and sound agricultural practices, including proper water management (Greeff 1993). Nematode control not only needs to be part of the greater Integrated Pest Management (IPM) programme for insects, pathogens and other pest organisms, but also needs to improve the economics of cotton production in general.

Discussion

Crop Rotation

A selection of wheat and oats cultivars serving as poor or nonhosts of *Meloidogyne incognita* race 4, was done in the greenhouse. These wheat and oats cultivars, compared to other rotational crops are listed in Table 1, indicating the root gall index (nematode damage to plant) and reproduction factor, RF (plant effect on nematode) for each crop and cultivar.

Based on the greenhouse information, a long-term crop rotation trial was initiated at Vaalharts Experimental Station, to determine whether the selected crops and cultivars can be used effectively to reduce the root-knot nematode population in the field. Cotton, cv Tetra, was planted on the same plots for two summer seasons with a winter planting of the wheat cultivars, SST 825, Kariega, Marico, Palmiet and the oats cultivars, Perdeberg and Maluti, compared to bare fallow plots, in between. The fluctuation of the plant parasitic nematodes over the seasons was monitored regularly. As expected, the density of the total nematode population, including *Meloidogyne, Pratylenchus*, *Paratrichodorus* and *Xiphinema* spp, increased on the cotton, planted during the first season (Figures 1 and 2). *A P. teres* population increased in the cotton roots with *M. incognita* and represents the largest percentage of nematodes occurring in the roots (Figure 2).

During the winter, most of the oats and wheat cultivars and the lower temperatures, decreased the *Meloidogyne* spp population (Figure 3). *Meloidogyne* spp juveniles were not detected in any of the fallow plots. Six weeks after the establishment of the winter crops, no root-knot nematodes were found in the plots planted to the wheat cultivars,

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:112-116 (1999)
National Cotton Council, Memphis TN

Kariega and Marico and the oats cultivar Perdeberg. Six weeks later, the root-knot nematode population remained low in the roots of the wheat and oats cultivars, but all the other nematode spp were well established. The *Pratylenchus* spp, population increased in all the plots, even in the plots left fallow. This could be attributed to a large number of weeds which developed in the trial, with the weeds serving as alternative hosts for the nematodes. No significant differences were found in the biomass of the various wheat and oats cultivars, with the oats cultivar, Maluti, having the highest biomass and the wheat cultivar, SST 825, the highest seed mass (Figure 4).

The following summer season, the population density of the ecto- and endo-parasitic nematodes increased again in the soil planted to cotton and in the cotton roots itself, but not quite to the same levels as were found in the initial cotton crop. The average yield of the 1997/98 season cotton crop was low due to a very late planting date and some soil compaction. but the highest seedcotton yield was obtained for the plots following the oats cultivar, Maluti, planted during the winter. Plots that were planted to the wheat cultivars Kariega, SST 825, Marico or Palmiet or the oats cultivar, Maluti, had seedcotton yields that were significantly higher than those plots left fallow during the winter (Figure 5).

The average *Meloidogyne* spp numbers for all the plots, irrespective of crops, for the 1997/98 season, indicated some reduction in the population density, compared with the similar sampling period during the 1996/97 season (Figure 6). It is possible that changes in the climatic conditions had a negative effect on the nematodes and continued trial work is needed to determine whether a reduction in the *Meloidogyne* spp population is actually taking place.

At twelve weeks after planting the *P. teres* and other ectoparasitic nematode populations were significantly lower on the cotton roots originating from plots previously planted to the wheat cultivars, Marico, SST 825 and Palmiet, compared to the plots that were left fallow during the winter. A possible population drift towards another nematode spp., such as *Pratylenchus* spp, may also be taking place under these specific cultural practices in certain plots and needs to be monitored. Certain cultivars may be good hosts for the ectoparasitic nematodes, while suppressing *Meloidogyne* spp development. It is a known fact that if one organism is removed from a specific ecological system, a niche is formed for another organism to increase and possibly reach damaging levels. Cultivar selection may become critical in pest management. It is not possible to generalization either and identification of nematode species and races must be confirmed if there is any doubt about symptoms or damage to the cotton roots.

There is no direct financial advantage to leave certain fields to remain fallow during the winter months, but might serve to reduce the nematode populations by depriving the nematodes of a suitable host (including weeds) on which they can feed and multiply.

Host Plant Resistance

The use of host plant resistance to nematodes is an extremely economic option to reduce the negative effect of nematodes on cotton. The long-term objective of the nematode resistant breeding programme at the ARC-TCRI is the establishment of suitable cotton cultivars, adapted according to agronomical requirements, for specific cotton production areas. Due to extremely high population densities of *Meloidogyne* spp prevalent in the Vaalharts Irrigation Scheme, immediate attention was given to this area.

Imported cotton germplasm and local lines with possible resistance or tolerance to the root-knot nematode *Meloidogyne incognita* race 4 were evaluated in the greenhouse to select suitable lines to serve as sources of resistance in a breeding programme (Wendt & Greeff 1991). Evaluation was done according to a visually estimated gall index, on a scale of 0 to 5, with 0 indicating no galls on the roots and 5 indicating a high infestation. The reproduction factors of selected commercial cotton cultivars indicate high infestations of *M. incognita* race 4 in the roots (Table 2) compared to resistant material such as M240 and Auburn 634 RNR.

The imported breeding lines with promising nematode resistant trends to South African conditions and root-knot nematode spp, were planted in a breeding block, highly infested with root-knot nematodes. Stringent selections were made and all susceptible material was removed from the breeding block. Direct selections from this material, without hybridization, was used for further development.

Field evaluation was done in replicated trials on highly infested soil at the Vaalharts Experiment Station, for the past four seasons. Auburn 634 RNR, a single plant selection and M 240, which are resistant lines, performed well in terms of tolerance to root-knot nematode attack. A single line, selected from the imported line, N 9311, performed best in terms of yield and tolerance to root-knot nematode (Table 3). On average it was found that for this selection 61.8 % of the plant population had gall indices below 2 (on a scale of 0 -5) compared to 20.0 % and 4.5 % for Tetra and Acala 1517/70. This selection, with a yield potential of 4400 kg/ha, G O T higher than 39 % and fibre properties within acceptable norms, has reached the point where larger plantings and seed multiplications have been initiated. Uniformity and purity of seed are being monitored at Rustenburg and Vaalharts. Every effort will be made to expedite the registration and release of this line, under the name, Gamka.

During the 1997/98 season, a similar replicated field trial was planted for the first time at Weipi, where Gamka yielded 4488 kg/ha. The fibre length for Gamka was 30.1

mm and had a micronaire value of 4.5. The new cultivar will be further evaluated under various agronomical practices at different localities during the following season.

The nematode resistant breeding programme will continue in order to improve nematode resistant characteristics of existing material.

The possible integration of a nematode tolerant line into an integrated nematode management system necessitates some economic evaluation of these proposed changes in normal cotton production. Selected cost factors were estimated to compare a standard commercial cultivar Tetra and the nematode tolerant cotton cultivar, Gamka, was made. At an estimated price of R 2.50 per kg seedcotton, the proposed increase of 1570 kg/ha by planting a nematode tolerant cultivar such as Gamka, could be valued at R 3 925.00 per ha higher income for the producer.

In order to control early sucking pests on cotton, it would be advisable to plant with a systemic pesticide such as aldicarb, but probably at a lower dosage, implicating a production cost saving of at least R 100.00 per ha. The use of a fumigant, for example EDB, would not be necessary, resulting in a further saving in the order of R 478.80 per ha (total saving of R 578.80/ha).

Chemical Control

Chemical control is the more conventional method of nematode control being used in South Africa, due to the availability of the nematicides. Since the profitability of cotton is marginal, especially under rain-fed conditions, reducing the population densities of damaging nematode species must be economical. Various registered and experimental chemicals are being evaluated and re-evaluated to give improved chemical control. Aldicarb has been used on a wide scale for the control of nematodes and early season sucking pests, but extreme soil and other environmental conditions have a negative effect on the efficacy of the product. Producers therefore requested the evaluation of follow-up nematicide treatments to extend the period of nematode control.

Since the 1994/95 season chemical agents were evaluated under greenhouse conditions, followed by field trials and the more successful products or product combinations are listed in Table 4. Only EDB, aldicarb and fenamiphos are presently registered in South Africa for general use prior to or at planting of cotton.

The best treatment as far as root-knot nematode control is concerned, is fumigation with EDB or the use of aldicarb GR followed by oxamyl EC under high nematode pressure. Treatment with fenamiphos GR followed by oxamyl EC is an option where the density of the root-knot nematode population is less critical. The highest yield and income throughout the different seasons were achieved with aldicarb followed by oxamyl EC and EDB followed by aldicarb.

In the situation where *Meloidogyne* spp populations have reached such dimensions on cotton that normal row treatments with contact/systemic chemicals such as fenamiphos or aldicarb no longer give proper control, it is being advised to rotate with a fumigant such as ethylene-dibromide (EDB). The application technique of a chemical is absolutely critical to its efficiency. Specific environmental conditions are required and the application equipment must be in good functioning order. Detailed instructions, based on numerous years of experimental data, are given on container labels and must strictly be adhered to. Irregular use of chemicals lead to additional and unnecessary production costs and continuous communication with producers is necessary to improve nematode management.

Biological Control

Natural control of nematodes are continuously taking place in the soil due to the presence of numerous antagonists such as insects, mites, fungi, bacteria, predaceous nematodes, etc. It is important to stimulate the activity of all these natural enemies in the soil, eg by adding large quantities of organic matter which serves as a source of energy. The use of kraal manure, oilseed cake, marigolds, etc, have been evaluated under field conditions. Mycorrhizae and rhizosphere-colonizing bacteria can reduce nematode attack by competing for space and reduce the attraction of nematodes to the roots.

Although nematodes are water animals, plant-parasitic nematodes have protective structures and metabolic adaptions which enable them to survive under extreme climatic and soil conditions. Biological control should take place in a continuous changing environment where both the nematodes and their antagonists are influenced by the plant, the physical environment and other soil microfauna and micro flora. Successful control on a large scale is, therefore, quite difficult to achieve.

Environmentally safer means of control are receiving attention in South Africa. A few biotic products for the control of nematodes, for example, organisms like bacteria and parasitic fungi, are commercially available. In most cases, until recently, these agents could be successfully applied only on a small scale. Biological control has always been included in the total IPM programme, but more specific research could only be initiated recently. Formulations of the commercial products have improved as well, which simplifies the application of large quantities of the antagonists, eg via drip irrigation.

A South African strain of the fungus *Paecilomyces lilacinus*, an effective parasite of nematode eggs, is presently commercialized in order to control nematodes. The parasitism of the eggs will prevent larval development or hatching, leading to a gradual decrease in the nematode population, especially a sedentary endoparasite such as *Meloidogyne* spp with egg masses produced on the outside of the roots and within reach of the fungus. The fungus, in spore form, is presently applied in water suspension at planting time of row crops, eg in planting hole when tomatoes and tobacco are planted. Trials have been done on cotton, but some adaption would be necessary for successful application under flood irrigation.

The incorporation of a biological control agent into an IPM programme must be done at the correct stage or cropping sequence, to have the best effect with regard to controlling the target organism, without disrupting the ecology. Biological control must be seen as a long-term investment to enhance soil conditions and the micro-ecology in general.

Agricultural Practices and Water Management

Various basic agronomical practices are advocated to support proper management of nematode populations. Producers are encouraged to obtain sufficient knowledge of the crop and its production as well as the economic important nematodes, their biology and the host-parasite interaction. Field sampling and diagnostic services are available to determine the distribution and densities of nematode populations for each field planted to cotton. Record keeping of nematode population fluctuations and rotational crops (including cultivars) planted are advocated. The reduction of large populations of plant-parasitic nematodes such as *Meloidogyne incognita* race 4 on cotton, needs dedicated long-term planning for each field. A single control measure such as chemical, or crop rotation alone, would not be sufficient.

Deep cultivation of soil to expose nematodes to harsh climatic conditions, on a regular basis, will reduce population densities. Sanitation on all farming levels must be implemented. The removal of infested roots from the field at the end of the season to be burnt will assist to reduce egg numbers, which are harboured in and around organic matter. Contamination of relatively clean fields by not using equipment (unless cleaned) or plant material (eg potatoes) from heavily infested fields needs to be prevented. Clean cultivation and removal of crop residues are important control measures. Timely application of herbicides and regular weeding will prevent the damaging nematodes to maintain high populations on alternative host plants. Incorporation of large quantities of organic matter to enhance biological activity in the soil and improve soil structure must be encouraged.

Water run-off must be restricted to prevent further spread of nematodes through irrigation water. Irrigation water should be stored in a storage dam for some time (at least 24 hours) to allow nematodes to sink to the bottom. Water for irrigation should then be pumped from the upper surface.

Summary

Nematode control is a management problem which actively involves the producer. Management decisions must be made on an ongoing basis. Treatments for different fields may vary according to sampling results, and could be a cost-saving factor. The correct nematode identification is an extremely important factor in the decision making process and producers and plant breeders should make use of diagnostic services on a continuous basis.

The correct rotational crop, on a cultivar level, must be chosen for each field to reduce high densities if economic important nematode species. When nematode control strategies are planned, it is important to consider optimum planting date, to prevent unnecessary yield loss. Care should be taken that standard or improved cultivation practises must be used in order to contribute to the erradication of nematode populations by means of cultural control or sanitation.

The incorporation of genetic resistant cotton cultivars in an IPM programme must be done with care to ensure the best results and the diversity of nematode populations should be monitored when continuous planting of a resistant cultivar is taking place in a specific field or area. The misuse of resistant cultivars may lead to the untimely loss of such valuable material.

Available nematicides must be administered with care to obtain the optimum effect against high nematode populations. Due to the selectivity of certain nematicides, the rotational use of nematicides may be considered in fields where cotton is planted in monoculture, to prevent the unnessasary build up of a specific nematode genus or specie. The use of environmentally friendly products and biological control agents during or after the cotton planting season, will also assist with nematode control.

With most of the components of IPM available, revolutionary changes in nematode management may now be considered.

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Table 1. Effect of *Meloidogyne incognita* race 4 on selected crops and cultivars evaluated according to root gall index (GI) and reproduction factor (RF) at eight weeks after inoculation.

Crop	Cultivar	GI	RF
Cotton	Acala 1517/70	3.55	3.26
Tomato	Roma	3.85	148.04
Maize	SNK 2220	0.5	9.35
Wheat	Palmiet	1.45	0.88
	Kariega	1.8	0.61
	Marico	1.45	0.6
	SST 825	1.95	0.28
	SST 822	2.45	0.65
Oats	Overberg	2.15	2.53
	Perdeberg	1.2	1.4
	Maluti	0.65	0
	Echidna	2.6	2.48
	Langberg	1.35	10.64
Lucerne	Beryl	1	0.28
	Granada	1	0.51
	Topaz	1.1	0.27
Crotalaria spectabilis	Sunn hemp	0.55	0.27
Crotalaria juncea	Sunn hemp	0.5	0.36
Pennisetum glaucum	Babala (Pearl millet)	0.55	0.23
Rhodes Katambora	Rhodes grass	0.1	0.21
Eragrostis curvula	Love grass	0.2	0.12

Table 2. The effect of *Meloidogyne incognita* race 4 on selected cotton cultivars and lines, according to gall indices and reproduction factors

Cultivar	Gall index	Reproduction Factor
Acala 1517/70	3.03	6.69
Alpha	3.05	9.12
Gamma	3.1	5.23
Tetra	3.05	7.92
K 111	3.4	12.6
DP / AC 90	3.55	3.26
Sicala	3.32	2.79
Komatie	2.75	4.7
OR 27	2.4	3.17
Palala	2.68	2.77
N 9311	1.54	0.72
LA RN 1032	1.72	0.03
Auburn 634 RNR	2.45	0.48
M 240	1.7	0.41

Table 3. Average yield, fibre properties and nematode resistance of the new cotton cv., Gamka, compared to selected standards.

	Yld[a]	Lint %	Lgth	Stgth	M/N	% GI 0-2	GI 0-5
Gamk	3478	40	29.7	20.8	4.2	61.8	2.1
A634	2819	37.9	26.9	20.9	4.8	85.8	1.8
Tetra	1908	39.5	28.3	22.4	4	20	2.9
Acala	1472	37.7	28.5	22.7	3.7	4.5	3.3

All data = Average of four seasons
Yield = Total seed cotton yield/ha
Lgth = Length, mm
Stgth, cN/tex
% GI 0-2 = % of plant population with gall indices between 0 and 2
GI 0-5 = Gall index with 0 = no galls and 5= 80 - 100% infestation of roots with *Meloidogyne* spp.
Gamk = New cultivar, Gamka
A634R = Auburn 634 RNR, resistant standard
Acala = Acala 1517/70, susceptible standard

Table 4. The dosage rate, area treated and time of application for selected nematicides evaluated since 1994.

Treatment	Dosage (product)	Area treated	Time of application
Untreated control	-	-	-
EDB	30 l/ha	broadcast	2 weeks BP
Aldicarb GR	10 kg/ha	row	At planting
Aldicarb GR + oxamyl EC	10 kg/ha 3.75 l/ha	row row	At planting 6 weeks AP
Fenamiphos GR	15 kg/ha	row	At planting
Fenamiphos GR + Oxamyl EC	15 kg/ha 3.75 l/ha	row row	At planting 6 weeks AP
Fosthiazate GR	15 kg/100 m	row	At planting
Fosthiazate GR + Oxamyl EC	15 kg/100m 3.75 l/ha	row row	At planting 6 weeks AP
EDB +Aldicarb GR	30 l/ha 10 kg/ha	broadcast row	2 weeks BP 6 weeks AP
Aldicarb GR + Aldicarb GR	10 kg/ha 5 kg/ha	row row	At planting 6 weeks AP

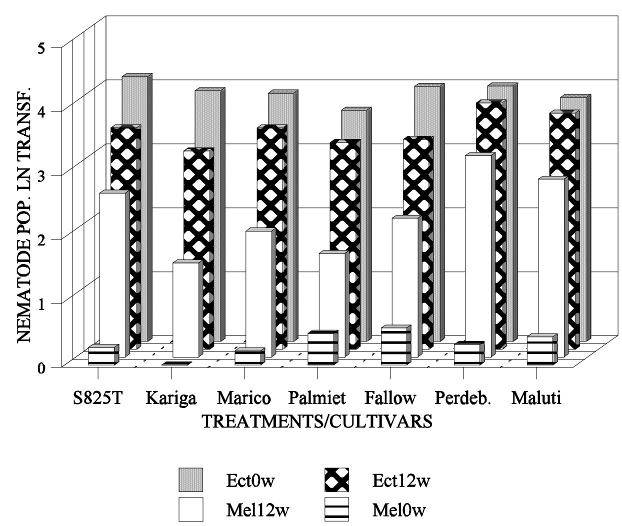

Figure 1. Meloidogyne spp & ectoparasitic nematode populations in soil (250 ml) planted to cotton at 0 & 12 weeks after establishment (1996/7)

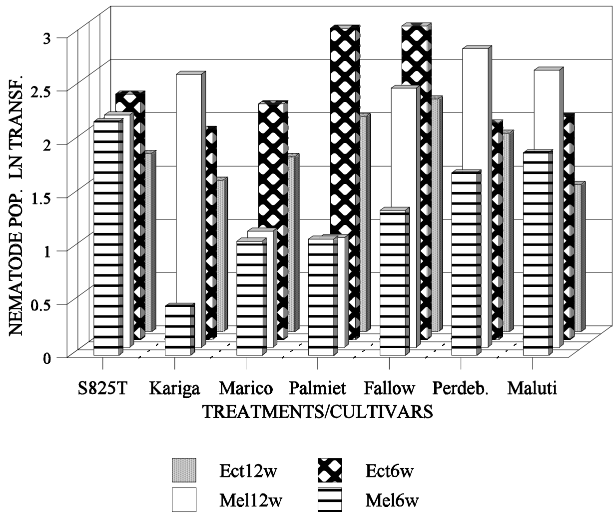

Figure 2. Meloidogyne spp & ectoparasitic nematode populations in cotton roots (10 g) at 6 & 12 weeks after establishment (1996/7).

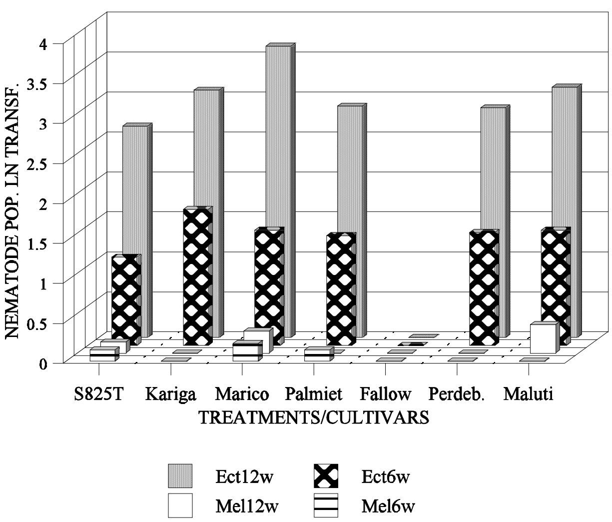

Figure 3. Meloidogyne spp & ectoparasitic nematode populations in wheat & oats roots (10 g) at 6 & 12 weeks after establishment (1997).

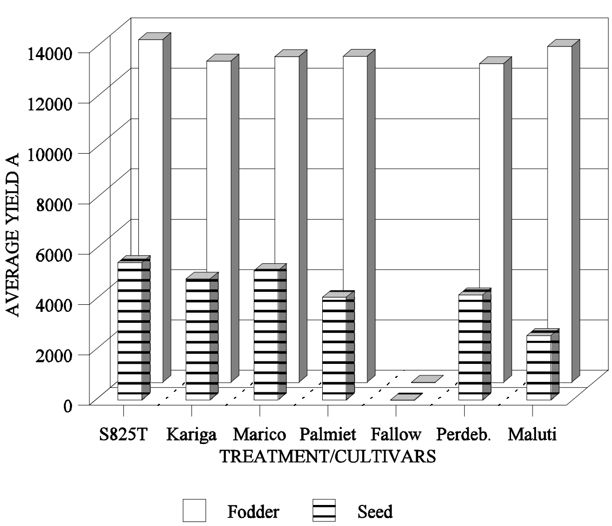

Figure 4. Average seed and fodder yield of wheat and oats rotations (winter, 1997) in a cotton field, prior to a second cotton planting.

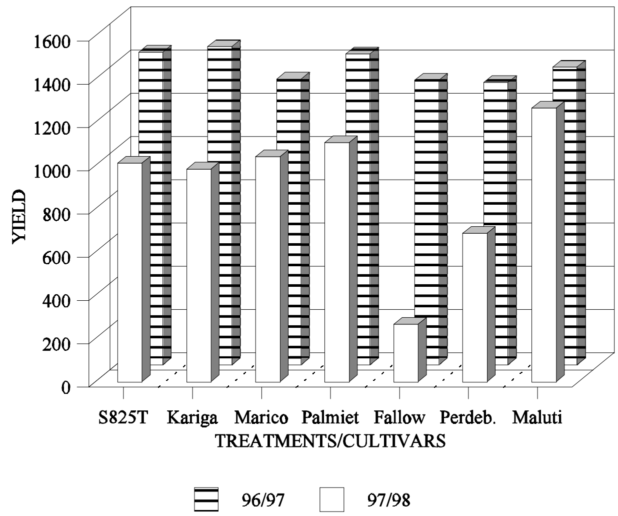

Figure 5. Seedcotton yield for 1996/97 and 1997/98 seasons.

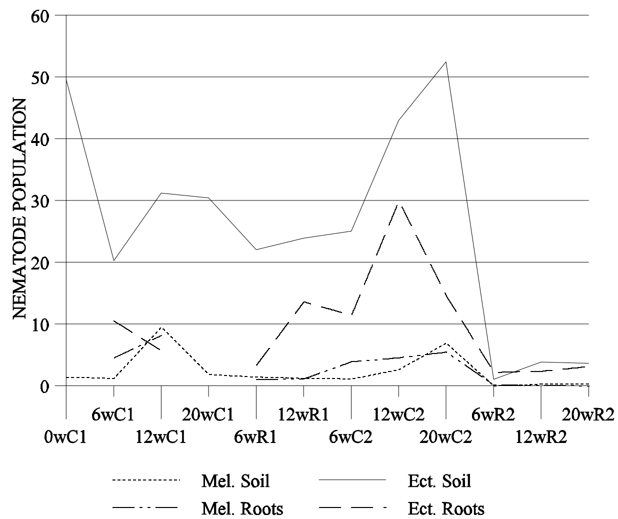

Figure 6. Average nematode population density over time, in soil and roots