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Nematode Control in Apple Replants

AP019

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QLD Department of Primary Industries

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SUMMARY OF RESULTS

1. When trees were removed 12 months prior to replanting, nematode numbers were lower and replanted apple trees grew better than if trees were removed 3 months prior to replanting.
2. Solarization of soil during the intercrop period gave no better nematode control than bare fallow.
3. A rotation crop of Sorghum x Sudan grass cv. Jumbo provided more dry matter than *Dolichos*, but *Dolichos* was a better host of *Pratylenchus jordanensis*.
4. When the rotation crops were incorporated with urea (1 800 kg/N/ha), nematode populations were reduced to almost non-detectable levels. The use of animal manures and urea had a similar effect.
5. Once apple trees were replanted, the effects of non-chemical treatments on nematode populations tended to dissipate within twelve months unless an organic mulch was maintained around the trees.
6. A pre-plant application of methyl bromide, fenamiphos applied via trickle irrigation and carbofuran applied as a controlled release granule gave good nematode control.
7. Trees on the more vigorous rootstock (779) were larger than on MM106.
8. Methyl bromide and organic mulches increased tree size compared with untreated plots.
9. Factors other than lesion nematode appeared to be involved in the apple replant disease complex.

APPLICATION OF RESULTS

1. Successful non-chemical systems for managing lesion nematode on apples will involve:
 - i) Removal of trees at least 12 months prior to replanting.
 - ii) A pre-plant management strategy which reduces nematode populations at planting. For example,
 - a suitable rotation crop incorporated into soil with urea
 - bare fallow
 - application of animal manure \pm urea.
 - iii) Choice of an appropriate rootstock.
 - iv) Maintenance of a layer of organic mulch around trees.
2. Lesion nematode can be controlled chemically with methyl bromide followed by non-volatile nematicides applied either as control release formulations or via the irrigation system.

HORTICULTURAL RESEARCH AND DEVELOPMENT CORPORATION

FINAL REPORT OF PROJECT

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Ref. No.: 89/1

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4. DURATION

Commencement Date: July 1987
Completion Date: June 1990
Date of Final Report: December 1990.

5. NON-TECHNICAL SUMMARY

Since fumigant nematicides are being phased from use in Australia because of health and environmental considerations, this project aimed to develop alternative methods of nematode control for use in apple replant situations. Various treatments, including soil solarization, fallowing, cover crops, vigorous rootstocks, animal manures and nematicides were therefore tested in experiments carried out at Granite Belt Horticultural Research Station, Applethorpe, Queensland. The results suggested that animal manures and organic matter produced by cover crops could both be used to control lesion nematode, provided additional nitrogen was applied at a rate of at least 900kg N/ha. Although long-term nematode control was not as good as was achieved with some nematicides, the plant growth responses were as good or better than all treatments except methyl bromide. Several nematicide treatments, including methyl bromide, fenamiphos applied via trickle irrigation and controlled release formulations of carbofuran gave excellent nematode control.

APPENDIX 1

TECHNICAL REPORT

(1) PROJECT OBJECTIVES

To develop nematode - management strategies for apples which can be used as an alternative to the fumigant nematicides.

(2) REPORT

Introduction

Orchardists in the Granite Belt district of Queensland have long been concerned with the failure of apple replants to grow satisfactorily in land where apples have been grown previously. Severely affected trees make little shoot growth in the first year, despite the best of care, and rarely develop into trees worth their place in the orchard (Colbran, 1979). Similar replant problems are common in other apple growing areas of Australia and overseas and accumulated research indicates that lesion nematode (*Pratylenchus penetrans*) is one of the main causal factors (Jaffee *et al.*, 1982).

In the past, *P. penetrans* generally has been controlled in replanted apple orchards by pre-plant fumigation, but recent decisions by health authorities to remove some of the fumigant nematicides from the market have meant that there are now no satisfactory means of controlling lesion nematode on apples. This project therefore aimed to investigate a number of alternative nematode management strategies for apple replant situations. All these strategies had shown promise in other nematode/crop systems, but had never been tested on apples under Australian conditions. Fallow is recognised as a useful method of controlling nematodes (Anon, 1969), while preliminary work has indicated that soil solarization can alleviate replant problems in citrus (Wehner and Kotze, 1985) and increase growth of replanted peach and walnut seedlings (Stapleton and DeVay, 1982). Non-volatile nematicides tend to have a limited effective life in soil, but their efficacy on perennial crops can be increased by applying them at frequent intervals through an irrigation system (Radewald *et al.*, 1985) and perhaps by applying them as controlled release formulations (Wright, 1981). Organic amendments have often been used to control nematodes (Muller and Gooch, 1982), and their nematicidal effectiveness can be enhanced by the addition of nitrogen (Rodriguez-Kabana, 1986).

Materials and methods

Experiment 1. A field trial was established on a 16 year old close-planted apple site on the Granite Belt Horticultural Research Station at Applethorpe, Queensland. The soil was a grey sandy loam (87% sand, 8% silt, 5% clay) with an impermeable clay horizon at approximately 30cm depth. In June 1987, root and soil samples were taken around the existing apple trees to determine the nematode distribution throughout the site. The area was then divided into six equal blocks each containing 24 plots 4.2 m long and 2 m wide. The trees in three randomly chosen blocks were removed in June 1987 and 12 pre-plant treatments of animal manures, cover crops with and without urea applications, soil solarisation and fallow were applied to six replicate plots in October 1987. The

two cover crops used were a sorghum x sudan grass hybrid cv. Jumbo and *Dolichos lablab* cv. Rongai, and they were planted at the following seeding rates: Jumbo, 10 kg/ha; Dolichos, 21.6 kg/ha. When Jumbo and Dolichos were used together they were seeded at 5 kg and 21.6 kg/ha respectively. The cover crops were side dressed with 80 kg nitrogen/ha as urea in December and January, and were ploughed in during February. Feedlot and fowl manures were incorporated into soil in October 1987 at rates of 100t (dry matter)/ha. Half the manured plots also received 1800kg nitrogen/ha as urea. Soil solarisation plots were wetted to field capacity and covered with transparent polythene sheets (50 mm thick) from October 1987 to June 1988. Temperatures in solarized and unsolarized plots were recorded with a Grant Squirrel^(R) data logger at depths of 5 and 15 cm. Fallow plots were covered with black woven polyethylene sheeting from July 1987 to June 1988 to prevent weed growth. In April 1988, soil cores were collected from each plot for nematode analysis.

In the three blocks where trees were removed in April 1988, manures and fumigants were applied following tree removal. Manures were applied as described previously while ethylene dibromide (EDB), 1,3-dichloropropene (1,3D as Telone II^(R)) and metham sodium (Vapam^(R)) were injected into soil with tyned fumigation equipment. Vapam plots were sealed with plastic sheeting and EDB and 1,3D plots sealed by soil surface rolling. Methyl bromide was dispensed from canisters under plastic sheeting. Specific details of all treatments are listed in Table 1 and treatments were set out in a randomized block design with six replicates. In July 1988, soil from all 144 plots was sampled and tested for nematodes by pot bioassay prior to tree planting. In plots treated with fenamiphos, Nematicur, 400^(R) was applied 4 times each growing season at about 6 weeks intervals. The chemical was applied through the trickle irrigation system with an Amiad^(R) injector.

Prior to planting, the whole trial site received a basal fertilizer of agricultural lime (1t/ha) and superphosphate (1t/ha). The apple trees used for the experiment were cultivar Delicious on the semi-dwarf rootstock MM106. The rootstocks were propagated in stool-beds, dipped in Nematicur 400 (2.5ml/litre water) and then planted in a fumigated nursery bed. They were budded in autumn and then grown in the nursery for a further year. Prior to field planting, trees were graded for size and roots were retreated with Nematicur 400 as above. In July 1988, five trees were planted 0.7m apart in each plot. All trees were fertilised through the irrigation system at 2 to 3 weekly intervals with urea and muriate of potash to deliver 40 grams of nitrogen and 15 grams of potassium per tree in the first year and double these quantities in the following year. Tree butts were drenched with PCNB (0.75g per tree) in mid-November and mid-January to prevent tree losses from *Sclerotium rolfsii*. The middle tree in each plot was removed in November 1988, the outside trees in July 1989, while the final trees were removed during the winter of the following year. Soil samples were collected for nematode analysis by taking ten soil cores to a depth of 20cm with a 2cm diameter sampling tube. Nematodes were extracted from 200 ml soil on a Whitehead tray. However, in situations where low nematode numbers were expected and it was important to know whether nematodes were infective, populations were measured by a pot bioassay. Soil (800 ml) was placed in a 10cm pot and five Dolichos seedlings were grown for 1 month. Nematodes were then extracted from roots by misting. Root samples (approx. 100g) were taken from trees as they were removed from soil and nematodes were extracted by misting. Tree size was assessed by measuring the amount of new growth on trees 4, 12, and 24 months after planting and also by measuring girth at 12 and 24 months.

Experiment 2. A second field trial was established at a site with a similar soil type and cropping history to that used for experiment 1. In April 1988, root and soil samples were collected from around the existing trees to determine the nematode distribution throughout the site. Trees were then pulled, the area was ripped in two directions, roots were removed, agricultural lime (1t/ha) and superphosphate (1t/ha) was broadcast, and the soil was worked into planting rows 5m apart. The site was then divided into 72 plots each 6.3 m long that were designed to accommodate trees planted 1.05 m apart. Each plot contained five datum trees and had two pollinator trees at either end. Twelve treatments (Table 7) were then applied in a randomized block design with six replicates. Manure and mulch treatments were applied in May 1988 and maintained annually. Telone II and methyl bromide were injected into soil with tyned fumigation equipment and the soil sealed by rolling and polyethylene sheeting respectively. Two months later, soil samples were collected and nematode populations in each plot determined by pot bioassay. Trees were planted in July 1988 and carbofuran granules were sprinkled in a 1m wide strip along the tree row. Nematicur 400 was applied four times from September to March each year by metering the chemical into the trickle irrigation system. In the first year, the drippers were near the base of each tree and 1.25ml Nematicur was applied per application per dripper. In later years, the application rate per dripper remained the same, but the irrigation line was moved so that there was a dripper on each side of a tree. Tree butts were drenched with PCNB (0.75g/tree) in November and January of the first year to prevent losses from *Sclerotium rolfsii*. After planting, trees were fertilized through the irrigation system at 2-3 weekly intervals with urea or nitram and muriate of potash to deliver 40g of nitrogen and 15g of potassium per tree per year, increasing to 80g and 30g respectively in the second year.

After one year, three alternate datum trees were removed and top growth, girth and nematode populations in roots were determined. This left two datum trees 2.1m apart in each plot and two pollinator trees at either end for the remainder of the experiment. Soil samples for nematode analysis and girth measurements were collected from these trees in the following year. The procedures for sampling and for processing the samples were the same as for experiment 1. Trees were grown on two rootstocks (Table 7) and were produced in the same way as for experiment 1. The scion variety was Delicious Hi-early and the pollinator variety was Granny Smith.

Results

Two *Pratylenchus* species (*P. penetrans* and *P. jordanensis*) were present in both trial sites but they were difficult to identify at the magnifications used for counting. Since 50% of the adults of *P. penetrans* are males whereas *P. jordanensis* does not have males, and the proportion of males in the samples was never more than 1%, the latter species was considered to be predominant. At the site of the first experiment, composite root samples collected from each plot before the original apple trees were removed showed that the trial site contained an average of 68 *P. jordanensis*/g dry weight apple roots, and that population density did not vary significantly across the trial area.

In plots where cover crops were grown, plots containing Jumbo or Jumbo + Dolichos yielded significantly more dry matter than those planted to Dolichos alone (Table 2). Jumbo was the dominant plant species in mixed plantings, accounting for about 98% of the dry matter produced. Although both cover crops

hosted *P. jordanensis*, numbers were significantly higher following Dolichos than following Jumbo. Two months after the cover crops had been ploughed in, nematode numbers in soil had declined substantially but were still significantly higher than in fallowed or solarized plots (Table 3). Addition of nitrogen to manures or cover crops reduced the number of *P. jordanensis* in soil and in several cases, this difference was significant. These difference due to nitrogen were often detectable a further 3 months later, at the time apples trees were replanted (Table 4).

In plots where trees had been removed 12 months previously, samples collected at the time of planting and bioassayed using Dolichos showed similar trends in nematode numbers to those samples collected in April. However, even in the best treatments infective nematodes were present. Nematode populations were generally much higher in plots where the old apple trees had been removed more recently. All treatments except EDB and poultry manure significantly reduced nematode numbers compared to the untreated fallow, but only methyl bromide and Vapam reduced nematodes to almost non-detectable levels (Table 4).

Four months after planting, nematode numbers in apple trees were relatively low, but populations had increased by the time trees were 12 months old (Table 5). At this time, the depression of nematode numbers due to the addition of nitrogen was still apparent in some of the cover crop treatments and nematode populations remained relatively low in fallow and solarized plots. The nematode was no longer under control in Vapam - treated plots and nematode numbers were low only in plots treated with methyl bromide or fenamiphos. Trees generally grew better in manure-treated plots and sometimes this showed as a significant increase in girth and top dry weight (Table 6). However methyl bromide was the only outstanding treatment, as top growth and girth at 24 months had more than doubled compared with untreated plots.

In the second experiment, composite samples collected before work commenced showed that *P. jordanensis* was distributed throughout the experimental area at a population density similar to the site for experiment 1.

Bioassay results from samples taken immediately prior to planting showed that the methyl bromide treatments had given good control of lesion nematode whereas 1,3D was ineffective (Table 8). Other treatments had either not been applied or had not been in place for long enough to show an effect. At the end of the first year, the nematode control due to methyl bromide had largely been lost and carbofuran and fenamiphos were the only treatments giving good nematode control (Table 9). However, differences in nematode numbers between nematicide-treated and untreated plots had largely disappeared by the end of the second year (Table 10). Nematode populations on 779 rootstock were slightly higher than on MM106 and sawdust and feedlot manure mulch also provided some nematode control, particularly on the less vigorous rootstock (Tables 9,10). Rootstock had an effect on tree growth but the only treatment to markedly increase shoot dry weight and girth was methyl bromide (Tables 9,10).

Discussion

In sites where old apple trees were removed 12 months before new trees were replanted, lesion nematodes multiplied on cover crops and populations were higher than in fallowed plots during the period prior to replanting. However,

when urea was incorporated into soil when the cover crops were ploughed in, lesion nematode populations were reduced to insignificant levels. The addition of urea to manure treatments also had a similar effect. This confirmed the nematicidal effect of high rates of nitrogen (Rodriguez - Kabana, 1986) and showed that applications of nitrogen with a utilizable carbon source can provide useful nematode control in acid soils. The effect of nitrogen is thought to be due to the production of nematicidal quantities of NH_3 and because NH_3 concentration is dependent on soil pH, nitrogen sometimes fails to control nematodes in acid soils (Stirling, 1989).

Solarization has been found to reduce numbers of plant-parasitic nematodes in surface layers of soil (Porter and Merriman, 1983, 1985, McSorley and Parrado, 1986; Barbercheck and Von Broembsen, 1986) but in this experiment, solarization provided no better control than the fallow treatment. Since soil temperatures under plastic in December, January and February were raised by only 6°C and a temperature of 37°C was exceeded on average for 7 and 5 hours each day at 5 and 15 cm respectively, the lack of an effect was probably due to the relatively low temperatures that were reached. Much higher temperatures tend to occur under plastic in areas which have less cloud cover in summer (Porter and Merriman, 1983).

When old trees were removed only 3 months before replanting, nematode populations were much higher at planting, probably because there was insufficient time for nematodes to die of starvation. Because of time constraints, few non-chemical options are available in this situation, but manures with and without additional nitrogen did decrease nematode populations. Both methyl bromide and Vapam gave excellent initial nematode control whereas EDB and 1,3D did not. The failure of the latter treatments and the poor long-term control from methyl bromide in experiment 2 was unexpected, as all three chemicals are excellent nematicides and have been successfully used in apple replant situations for many years. Perhaps the soil was not sealed adequately, or the fumigants were not applied evenly to the plot because of the difficulties involved in fumigating small plots with equipment designed for broad-scale use.

Once trees were planted, the effects of the various treatments on nematodes tended to dissipate, but some difference remained at 4 and 12 months. Methyl bromide, carbofuran and fenamiphos were the only treatments to provide high levels of nematode control, the results with fenamiphos confirming preliminary results (Stirling and Dullahide, 1987) which suggested that drip irrigation was an ideal vehicle for applying this chemical. The results with a controlled-release formulation of carbofuran were encouraging. However, it is not yet known whether the loss of efficacy in the second year was due to premature leaching of the active ingredients from the granule. Enhanced microbial degradation is sometimes a problem with carbofuran (Felsot *et al.*, 1981; Harris *et al.*, 1984; Read 1983; 1986). The poorer long-term control with methyl bromide in the second experiment compared with the first was possibly due to the different method of application used.

Despite the differences in numbers of *P. jordanensis* that were apparent in various treatments, tree growth was not related to nematode population density. Methyl bromide produced much larger trees than all other treatments, and the only other growth responses tended to occur in plots which received organic matter and nitrogen. The lack of responses when nematodes were controlled may have been

due to the lack of pathogenicity of *P. jordanensis* to apple (Colbran, 1979). Soil-borne fungal pathogens and other factors therefore appear to be the major factors limiting tree growth at the experimental site.

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Table 1 Treatments applied in an apple replant trial, Granite Belt Horticultural Research Station. Experiment 1.

Trees removed winter 1987

1. Feedlot manure (100 t/ha)
2. Feedlot manure (100 t/ha) + 900 kg N/ha
3. Poultry manure (100 t/ha)
4. Poultry manure (100 t/ha) + 900 kg N/ha
5. Cover crop - Jumbo
6. Cover crop - Jumbo + 1 800 kg N/ha when ploughed in
7. Cover crop - Jumbo + Dolichos
8. Cover crop - Jumbo + Dolichos + 1 800 kg N/ha when ploughed in
9. Cover crop - Dolichos
10. Cover crop - Dolichos + 1 800 kg N/ha when ploughed in
11. Solarization
12. Fallow.

Trees removed April 1988

13. Feedlot manure (100 t/ha)
 14. Feedlot manure (100 t/ha) + 900 kg N/ha
 15. Poultry manure (100 t/ha)
 16. Poultry manure (100 t/ha) + 900 kg N/ha
 17. EDB (150 kg/ha)
 18. Telone II (340 l/ha)
 19. Telone II (340 l/ha), non-irrigated
 20. Methyl bromide (500 kg/ha)
 21. Vapam (500 l/ha) applied by injection and covered with plastic
 22. Nematicur 400 (4. x 1.25 ml/dripper/year)
 23. Fallow
 24. Fallow, non-irrigated.
-

Table 2 Dry matter production from three cover crops and numbers of *Pratylenchus jordanensis* following those cover crops. Experiment 1, February 1988

Cover Crops	Dry Matter (t/ha)	Pratylenchus/ 200 ml soil ^B
Jumbo	13.8	217 (5.4)
Jumbo & Dolichos	12.9 (11.5+1.4 ^A)	211 (5.3)
Dolichos	6.3	423 (6.0)
LSD (P=0.05)	1.9	(0.4)

A Component of dry matter due to Jumbo and Dolichos, respectively

B Equivalent means with transformed means (\log_e (no. nematodes + 1) in parentheses.

Table 3 Effect of organic amendments, incorporation of cover crops with and without additional nitrogen, soil solarization and fallow treatments on numbers of *Pratylenchus jordanensis*. Experiment 1, April 1988.

Treatment	<i>P. jordanensis</i> /200ml soil ^A
1. Feedlot manure	3.1 (1.41)
2. Feedlot manure + N	0.0 (0)
3. Poultry manure	2.4 (1.22)
4. Poultry manure + N	0.0 (0)
5. Jumbo	10.4 (2.44)
6. Jumbo + N	3.3 (1.45)
7. Jumbo & Dolichos	29.7 (3.42)
8. Jumbo & Dolichos + N	3.1 (1.39)
9. Dolichos	13.1 (2.65)
10. Dolichos + N	0.0 (0)
11. Solarization	0.4 (0.37)
12. Fallow	0.6 (0.47)
LSD (P=0.05)	(1.60)

^A Equivalent means with transformed means (\log_e (no. nematodes + 1)) in parentheses.

Table 4 Number of *P. jordanensis* in Dolichos bioassay plants grown in soil collected in July 1988 (immediately prior to planting apple trees) and previously subjected to various treatments. Experiment 1.

Treatment	<i>P. jordanensis</i> / root system ^A
Trees removed winter 1987	
1. Feedlot manure	4.5 (1.71)
2. Feedlot manure + N	4.1 (1.63)
3. Poultry manure	1.5 (0.91)
4. Poultry manure + N	1.6 (0.94)
5. Jumbo	26.5 (3.31)
6. Jumbo + N	7.2 (2.10)
7. Jumbo & Dolichos	51.1 (3.95)
8. Jumbo & Dolichos + N	1.9 (1.06)
9. Dolichos	9.4 (2.34)
10. Dolichos + N	3.5 (1.51)
11. Solarization	2.2 (1.16)
12. Fallow	6.6 (2.02)
Trees removed April 1988	
13. Feedlot manure	14.2 (2.72)
14. Feedlot manure + N	10.8 (2.47)
15. Poultry manure	19.7 (3.03)
16. Poultry manure + N	12.6 (2.60)
17. EDB	23.9 (3.21)
18. 1,3D	18.4 (2.97)
19. 1,3-D ^B	13.6 (2.68)
20. Methyl bromide	0.4 (0.37)
21. Vapam	0.8 (0.60)
22. Fallow ^B	58.2 (4.08)
23. Fallow	49.8 (3.93)
24. Fallow ^B	63.9 (4.17)
LSD (P=0.05) ^C	(1.07)
LSD (P=0.05) ^D	(1.25)

A. Equivalent means with transformed means (\log_e (no. nematodes + 1)) in parentheses.

B. Additional treatments were imposed on these plots after planting apple trees.

C. For comparisons of treatments within 1-12 or within 13-24.

D. For comparisons of any treatment from 1-12 with any treatment from 13-24.

Table 5 Number of *Pratylenchus* in roots of replanted apple trees in soil which had received various treatments before and after planting. Experiment 1.

Treatment	<i>P. jordanensis</i> /g dry wt. roots ^A		
	4 months	12 months	24 months
Trees removed winter 1987			
1. Feedlot manure	0.9 (0.66)	7.6 (2.15)	280 (5.64)
2. Feedlot manure + N	0.1 (0.07)	21.7 (3.12)	111 (4.72)
3. Poultry manure	0.4 (0.31)	30.4 (3.45)	183 (5.21)
4. Poultry manure + N	0.1 (0.08)	21.8 (3.13)	287 (5.66)
5. Jumbo	1.5 (0.90)	65.1 (4.19)	290 (5.67)
6. Jumbo + N	0.8 (0.58)	29.3 (3.41)	206 (5.33)
7. Jumbo & Dolichos	0.9 (0.66)	41.8 (3.76)	310 (5.74)
8. Jumbo & Dolichos + N	0.3 (0.26)	13.3 (2.66)	238 (5.48)
9. Dolichos	0.9 (0.64)	52.6 (3.98)	239 (5.80)
10. Dolichos + N	1.0 (0.71)	7.7 (2.17)	112 (4.73)
11. Solarization	0.1 (0.11)	10.3 (2.42)	210 (5.35)
12. Fallow	0.2 (0.16)	16.6 (2.89)	256 (5.88)
Trees removed April 1988			
13. Feedlot manure	0.6 (0.48)	14.2 (2.72)	96 (4.58)
14. Feedlot manure + N	1.2 (0.80)	15.2 (2.78)	179 (5.19)
15. Poultry manure	0.5 (0.40)	20.6 (3.07)	285 (5.66)
16. Poultry manure + N	1.4 (0.88)	24.9 (3.25)	499 (6.21)
17. EDB	0.7 (0.55)	14.3 (2.73)	168 (5.13)
18. 1,3D	0.6 (0.49)	24.5 (3.23)	279 (5.63)
19. 1,3D, non-irrigated	0.8 (0.61)	30.9 (3.46)	302 (5.71)
20. Methyl bromide	0.1 (0.10)	1.3 (0.81)	81 (4.41)
21. Vapam	1.0 (0.71)	49.0 (3.91)	357 (5.88)
22. Fenamiphos	0.3 (0.25)	1.6 (0.97)	29 (3.41)
23. Fallow	1.3 (0.83)	30.1 (3.44)	275 (5.62)
24. Fallow, non-irrigated	1.0 (0.68)	63.6 (4.17)	265 (5.58)
LSD (P=0.05) ^B	(0.59)	(1.04)	(0.45)
LSD (P=0.05) ^C	(0.78)	(1.10)	(0.45)

A Equivalent means with transformed means (\log_e (no. nematodes + 1)) in parentheses.

B For comparisons of treatments within 1-12 or within 13-14.

C For comparisons of any treatments from 1-12 with any treatment from 13-24.

Table 6 Plant Growth of replanted apple trees in soil which had received various treatments before and after planting. Experiment 1.

Treatment	Dry wt. tops (g)			Girth (cm)	
	4 months	12 months	24 months	12 months	24 months
Trees removed winter 1987					
1. Feedlot manure	16.3	30.2	405	3.1	9.4
2. Feedlot manure + N	21.5	46.5	417	4.8	9.5
3. Poultry manure	19.2	61.7	550	4.9	11.4
4. Poultry manure + N	19.1	66.8	531	4.5	10.8
5. Jumbo	15.8	30.8	243	3.0	6.6
6. Jumbo + N	21.4	47.8	442	4.1	9.8
7. Jumbo & Dolichos	15.2	26.3	252	3.4	7.1
8. Jumbo & Dolichos + N	15.8	53.8	444	4.1	10.3
9. Dolichos	14.5	30.9	318	3.2	8.5
10. Dolichos + N	20.0	46.0	465	3.6	9.8
11. Solarization	16.3	46.0	475	4.2	10.0
12. Fallow	14.6	40.5	363	3.4	9.6
Trees removed April 1988					
13. Feedlot manure	16.1	29.2	280	2.8	7.5
14. Feedlot manure + N	16.2	33.2	376	4.0	9.2
15. Poultry manure	15.5	46.8	369	3.8	9.0
16. Poultry manure + N	16.0	63.8	403	4.3	9.4
17. EDB	12.8	25.7	280	2.8	7.6
18. 1,3D	13.2	38.0	235	3.1	6.2
19. 1,3D, non-irrigated	19.3	41.3	280	3.1	7.2
20. Methyl bromide	18.4	85.5	665	5.2	11.5
21. Vapam	15.8	29.5	334	3.4	8.0
22. Fenamiphos	14.6	20.5	398	2.6	9.1
23. Fallow	12.3	22.2	275	2.9	7.1
24. Fallow, non-irrigated	10.4	35.0	267	3.0	6.8
LSD (P=0.05) ^B	4.4	18.6	127	1.1	2.1
LSD (P=0.05) ^C	5.9	19.2	138	1.2	2.2

A Equivalent means with transformed means (\log_e (no. nematodes + 1)) in parentheses.

B For comparisons of treatments within 1-12 or within 13-24.

C For comparison of any treatment from 1-12 with any treatment from 13-24.

Table 7 Treatments applied in an apple replant trial, Granite Belt Horticultural Research Station. Experiment 2.

MM 106 rootstock (semi-dwarf)

1. Methyl bromide (100g/m²)
2. Methyl bromide (50g/m²)
3. 1, 3D (Telone II) at 340 l/ha
4. Carbosulfan controlled release granules (15% ai, 2 year formulation), 5g ai/tree at planting in a band 1m wide.
5. Nematicur 400^(R) - 4 applications per year at 1.25 ml/application/dripper. (ie. 4.5L/ha/annum)
6. Sawdust mulch, 10cm thick and 1.5m wide, centred on the tree row and maintained annually
7. Feedlot manure (100 t/ha) incorporated 2 months prior to planting in a 1.5m band centred on the tree row + annual application of feedlot manure mulch (50 t/ha)
8. Feedlot manure (100 t/ha) incorporated 2 months prior to planting in a 1.5m band centred on the tree row + 50t/ha feedlot manure after one year + sawdust mulch 10cm thick and 1.5m wide, centred on the tree row and maintained annually
9. Untreated

779 rootstock (vigorous)

10. 1, 3D (Telone II) at 340 l/ha
 11. Feedlot manure (100t/ha) incorporated 2 months prior to planting in a 1.5m band centred on the tree row + 50t/ha feedlot manure after one year + sawdust mulch 10 cm thick and 1.5m wide, centred on the tree row and maintained annually
 12. Untreated
-

Table 8 Number of *P. jordanensis* in Dolichos bioassay plants grown in soil collected in July 1988 (immediately prior to planting apple trees) and previously subjected to various treatments. Experiment 2.

Treatment	<i>P. jordanensis</i> /root system ^A	
1. Methyl bromide (100g/m ²)	0.5	(0.35)
2. Methyl bromide (200g/m ²)	0.6	(0.41)
3. 1,3-D	48.8	(3.46)
4. Untreated ^B	114.0	(4.08)
5. Untreated ^B	82.3	(3.52)
6. Sawdust + sawdust mulch	73.5	(3.97)
7. Feedlot manure & feedlot manure mulch	50.0	(3.48)
8. Sawdust & feedlot manure mulch	57.8	(3.99)
9. Untreated	185.3	(4.95)
10. 1,3D	99.7	(4.56)
11. Sawdust & feedlot manure mulch	36.2	(3.41)
12. Untreated	102.5	(4.49)
LSD (P=0.05)		(1.12)

A Equivalent means with transformed means (\log_e (no. nematodes + 1)) in parentheses

B Treatments were imposed on these plots after planting apple trees.

Table 9 Growth and number of *P. jordanensis* in one year old apple trees grown following various soil treatments and removed in July 1989. Experiment 2

Treatment	Dry wt. tops (g)	Added girth (cm) (1988-89)	<i>P. jordanensis</i> /g dry weight root
MM106 rootstock (semi-dwarf)			
1. Methyl bromide (100g/m ²)	86.7	13.3	64.9
2. Methyl bromide (200g/m ²)	88.6	13.6	134.9
3. 1,3-D	47.4	8.6	95.8
4. Carbofuran	42.8	9.6	2.7
5. Fenamiphos	_A	_A	3.5
6. Sawdust & sawdust mulch	49.9	10.8	57.4
7. Feedlot manure & feedlot manure mulch	25.9	7.9	51.6
8. Sawdust & feedlot manure mulch	49.9	10.1	14.6
9. Untreated	32.9	7.6	234.0
779 rootstock (vigorous)			
10. 1,3D	67.2	13.3	97.5
11. Sawdust & feedlot manure mulch	147.4	18.1	103.5
12. Untreated	70.6	14.1	112.7
LSD (P=0.05)	43.1	3.4	118.6

^A Missing data due to phytotoxicity from misapplied urea

Table 10 Growth and number of *P. jordanensis* in two year old apple trees grown following various soil treatments. Experiment 2.

Treatment	Added girth (cm) (1989-90)	<i>P. jordanensis</i> / 200 ml soil
MM 106 rootstock (semi-dwarf)		
1. Methyl bromide (100g/m ²)	13.7	257.1
2. Methyl bromide (200g/m ²)	13.4	217.2
3. 1,3-D	9.4	168.3
4. Carbofuran	11.4	154.5
5. Fenamiphos	_A	68.9
6. Sawdust & sawdust mulch	12.7	155.3
7. Feedlot manure & feedlot manure mulch	_B	74.8
8. Sawdust & feedlot manure mulch	11.1	50.7
9. Untreated	8.4	143.8
779 rootstock (vigorous)		
10. 1,3-D	13.6	204.5
11. Sawdust & feedlot manure mulch	17.1	122.8
12. Untreated	14.5	203.3
LSD (P=0.05)	3.6	n.s.

^A Missing data due to phytotoxicity of misapplied urea

^B Missing data due to phytotoxicity of feedlot manure mulch

3) DETAILS OF INTELLECTUAL PROPERTY ARISING FROM THE PROJECT.

This work involved the first successful uses of a controlled release nematicide for nematode control in Australia. Also, work from the USA on nematode control using organic matter and urea was successfully extended to perennial crops.

4) PUBLICATIONS RESULTING FROM THE PROJECT

Since experiment 2 is continuing, the work will not be published until this experiment is completed.

APPENDIX 2

PROJECT SUMMARY

(1) STATEMENT ON OBJECTIVES

The objectives have largely been achieved: when experiment 2 is completed in June 1993, it should be possible to provide growers with new recommendations for controlling nematodes on replanted apples.

(2) BUDGET

Funding source	1987/88	1988/89	1989/90
ASRRF	3650		
Apple and Pear Industry Research Foundation	3650		
HRDC		3600	2700
TOTAL	7300	3600	2700

(3) ASSESSMENT OF IMPACT

The results of the project should be useful to all sections of the Australian apple industry.

(4) RECOMMENDATIONS ARISING FROM THE PROJECT

The results of this work should not be exploited until the long-term trial (experiment 2) is completed and the results evaluated.