Nematology, 2002, Vol. 4(3), 381-386

Effects of some crop management practices on reproduction of *Meloidogyne javanica* on *Brassica napus*

Rod W. MCLEOD [1,*], Christopher C. STEEL [1] and John A. KIRKEGAARD [2]

[1] *National Wine and Grape Industry Centre, Charles Sturt University, P.O. Box 588, Wagga Wagga, 2678, NSW, Australia*
[2] *CSIRO Plant Industry, G.P.O. Box 1600, Canberra, ACT 2601, Australia*

Received: 14 August 2001; revised: 3 December 2001
Accepted for publication: 3 January 2002

Summary – The effects of seed treatments with pesticides, soil temperature at sowing, cutting of plants with and without glyphosate herbicide, root disruption and age of crop at inoculation on reproduction of *Meloidogyne javanica* on *Brassica napus* were investigated. When inoculated at sowing, plants grown from fodder rape cv. Rangi seed treated with fenamiphos (0.35 g a.i. per 100 g) and from fodder swede cv. Highlander seed with a coating including imidacloprid had fewer galls than plants from seed untreated or treated with omethoate (0.7 g a.i. per 100 g). When nematode inoculation was delayed until 4 weeks after sowing, omethoate and the imadacloprid treatments had no effect while fenamiphos (0.7 g a.i. per 100 g seed) suppressed galling but also impaired seedling emergence and induced chlorosis. Green manure rape plants cvs Rangi and Humus transplanted into infested soil in the field in mid-autumn (soil temperature 17°C) remained nematode and gall-free, but tomato cv. Grosse Lisse plants were heavily galled. All three cultivars were gall-free when transplanted and grown in early winter (soil temperatures 8-14°C). Cutting off the tops of cv. Rangi plants at from 6 to 11 weeks after sowing and inoculation had no effect on egg production compared to that on intact plants. Predominant nematode stages in cut plants ranged from developing juveniles to egg-laying females. Application of glyphosate to freshly cut stems had no effect on egg production at any stage. Infesting soil with roots of cv. Rangi, finely chopped while nematodes in them were still juveniles, resulted in a low incidence of infection of bioassay tomato plants compared with infesting soil with rape roots chopped later, when females and females with eggs predominated. Young females in tomato roots laid eggs despite fine chopping of the roots. When cv. Rangi plants were inoculated at 3, 5 and 7 weeks after sowing, the 7-week-old plants were the least invaded and fewer eggs were produced on the 5 and 7-week-old plants than on the 3-week-old ones.

Keywords – cutting, herbicide, insecticide, inter-row crops, nematicide, rotation crops, seed treatment.

Meloidogyne spp. are amongst the less important pests of brassica crops in temperate climates (Anon, 1996). This may be because brassica crop species are intermediate rather than good hosts of common root knot nematodes, and are generally grown over the cool season and so escape infection and damage (Ahuja & Singh, 1990; McLeod & Warren, 1993). However, when *Brassica napus* L. crops are grown repeatedly in rotations or as inter-row cover crops over autumn-winter in warm climates, *Meloidogyne* spp. can invade and reproduce, increasing infection of later crops (Johnson *et al*., 1992; McLeod *et al*., 1995). Full-scale nematicide treatment of auxiliary crops, such as cover or break crops, would be uneconomic, but reduction of pest build-up could justify low-cost measures that inhibit nematode reproduction on such crops. Application of pesticide on seed at sowing is a low-cost option and has been tried for nematode control, but has not been widely adopted, one problem being short duration of control (Rodriguez-Kabana *et al*., 1977; Hussey, 1978; Singh *et al*., 1983). The extent of *Meloidogyne* reproduction depends on crop host status, but is also influenced by cropping practices, some of which could be varied to modify parasite increase. Soil temperature at sowing is an important determinant of infection (Thomason, 1962; Roberts *et al*., 1981; Ahuja & Singh, 1990; Pung *et al*., 1992). Cutting off top-growth and application of herbicides affect reproduction on already infected plants (Osman & Viglierchio, 1981; Van Biljon, 1996). Time of incorporating infected crops into soil (by ploughing) also affects reproduction. LaMondia (1996) showed that incorporating tobacco crops (*Nicotiana tabacum* L.) at 3 to 6 weeks old reduced subsequent *Globodera tabacum*

* Corresponding author, e-mail: patmcl@bigpond.com

levels more than later incorporation. Autumn-winter crops at an advanced stage may be exposed to infection by J2 hatching as temperatures rise in spring. Jadhav and Kurundkar (1991) found that *M. incognita* produced fewer eggs on okra plants (*Abelmoschus esculentus* (L.) Moench) inoculated at from 6 to 10 weeks after sowing than on plants inoculated at 2 to 4 weeks.

We directed our research to looking at the effect of some potential low-cost control options on reproduction of *M. javanica* on *B. napus* cvs Rangi and Humus. The following were studied: treatment of seed with pesticides; soil temperature at sowing; cutting tops of an infected crop with or without herbicide treatment; mechanically damaging infected roots and the importance of late exposure of the crop to infection.

Materials and methods

General

Meloidogyne javanica (Treub) Chitwood, originally from grape (*Vitis vinifera* L.) and maintained on tomato (*Lycopersicon esculentum* Mill.) cv. Grosse Lisse, was used throughout and J2 inocula were prepared as described by McLeod and Steel (1999). Experiments generally included the fodder rape (*Brassica napus* L. ssp. *oleifera biennis*) cv. Rangi. Some experiments included one or more of the following: fodder swede turnip (*B. napus* L. ssp. *rapifera*) cv. Highlander, green manure rape (*B. napus* ssp. *oleifera biennis*) cv. Humus and tomato cv. Grosse Lisse. A soil made up of equal parts by volume of coarse sand and peat was used in all pot experiments and glasshouse temperatures were 15-30°C. Washed roots were boiled for 5 min in lactoglycerol containing 0.05% methyl blue (Bridge *et al*., 1982) to stain nematodes. Numbers of eggs on root systems were estimated by shaking roots in 1% sodium hypochlorite for 4 min and retaining eggs on 25 μm aperture sieves (McLeod & Steel, 1999).

Pesticide seed treatments

Experiment 1: efficacy when inoculated at sowing

The experiment compared four treatments: cv. Rangi seed untreated (control), cv. Rangi treated with omethoate, and with fenamiphos; and fodder swede cv. Highlander coated with Superstrike®. Omethoate (Bayer Australia Limited, Pymble, NSW, Australia) is used as a seed dressing for control of insect and mite damage in cereal, pastures and brassica oilseed crops. Fenamiphos (Bayer Australia Limited) is a widely used nematicide. The Superstrike seed coating (Wrightson Seeds, Sydney, NSW, Australia) contains the insecticide imidacloprid (Gaucho®, Bayer Australia Limited), the fungicide thiram and molybdenum trace element, within a thin fertiliser base. Fodder swede cv. Highlander is a slightly better host for *M. javanica* than rape cv. Rangi (McLeod & Steel, 1999). Le-mat® (290 g/l omethoate) was applied at 2.4 ml in 5 ml water to 100 g seed (0.7 g a.i.), equivalent to the rate specified for treatment of brassica oilseed crops. A slurry of fenamiphos was prepared by soaking 7 g of Nemacur Granular Nematicide® (5% fenamiphos, *i.e.*, 0.35 g a.i./100 g seed) in 20 ml water overnight and blending for 10 min in a Waring blender. The 100 g lots of seed quickly imbibed the fluid applied and were spread on paper towel and left to air-dry overnight. Next day, 20 seeds/pot were sown in six 20 cm diameter pots and the soil immediately inoculated with 1000 J2 per pot. Treatments were placed in six randomised blocks, ten seedlings were allowed to grow per pot. Galls on five plants per pot were counted 5 weeks after inoculation.

Experiment 2: efficacy when inoculated 4 weeks after sowing

The aim of this experiment was to assess the persistence of seed-applied treatments. The treatments were the same as in the previous experiment, except that fenamiphos was applied at double the previous rate (14 g of Nemacur, 0.7 g a.i./100 g seed, in 20 ml water). Approximately 70 seeds/plot were sown outdoors in *Meloidogyne*-free soil, in 1 m single row plots arranged in five randomised blocks. Ten days after sowing, emerged seedlings were counted. Four weeks after sowing, three seedlings from each plot were transplanted to a 15 cm diameter pot and the soil inoculated with 1000 second stage juveniles (J2)/pot. Nine weeks after sowing (5 weeks after inoculation) plants were uprooted and numbers of galls on the plants in each pot counted.

Infection at autumn and winter temperatures

Autumn planting experiment

Three-week-old seedlings of fodder rape cv. Rangi, green manure rape cv. Humus and tomato cv. Grosse Lisse were transplanted to the field, into *M. javanica*-infested soil, in mid-autumn (15 April). On the same day, soil from the site was put in 15 cm diameter pots. Four pots were planted to each crop and the pots were placed in a glasshouse. Field soil temperature at sowing time, at 15 cm deep, was 17°C. Daily readings until 9

June indicated 15 cm depth soil temperatures consistently below 20°C, and continuous monitoring with a Hobo data logger (Hastings Data Loggers, Wauchope, NSW, Australia) from 9 to 14 June indicated soil temperatures of 9-13°C. At 6 and 10 weeks after planting, roots of 16 plants of each crop from the field and the glasshouse plants were inspected for galls. Pieces of galled roots and lateral roots from gall-free plants were stained and dissected to detect *Meloidogyne*.

Winter planting experiment

In early winter (14 June), tomato, rape cvs Rangi and Humus seedlings were planted into the infested field site as in the autumn planting. Seedlings were protected from frost for 2 weeks by panes of glass placed above them overnight. Soil temperatures from 21 June to 7 August varied between 8 and 14°C. Four plants of each crop were again grown in pots of the same soil in the glasshouse. Roots of 16 field-grown plants of each crop and the glasshouse plants were inspected for galls and processed to confirm presence or absence of *Meloidogyne*, 11 weeks after planting.

Effect of cutting

Soil in four blocks of ten 15 cm diameter pots was inoculated with 1000 J2/pot, sown with seed of rape cv. Rangi and after emergence, thinned to three plants per pot. The stems of plants in one randomly chosen pot from each block were cut through within 1-3 cm of the soil at 6, 7, 9, 10 or 11 weeks from sowing and a 1-2 cm cover of chopped leaf/stem debris was left on the soil surface. At each of these times, galls on the roots of one pot of intact plants were boiled in lactoglycerol stain and dissected to determine stage of nematode development. Numbers of nematode eggs on root systems in pots with cut plants and in one randomly chosen pot of intact plants from each block were estimated 3 weeks after the last cut.

Cutting with glyphosate

Forage rape cv. Rangi plants were grown from seed in J2-infested soil as in the previous experiment, with 35 pots arranged in five blocks. At 6, 7 and 8 weeks after sowing, plants in two pots/block were cut as before and undiluted Glyphosate 360® (Nufarm Limited, Laverton North, Victoria, Australia) herbicide (360 g/l glyphosate as the isopropylamine salt) was immediately painted onto the cut surfaces of stems in one of the two cut-plant pots. Stage of nematode development was monitored as before. Three weeks after the last cut, numbers of eggs were estimated, as previously described. To examine the effect of the glyphosate on hatchability of eggs, five lots of 60 eggs from plants treated with glyphosate at 8 weeks and five similar lots from untreated cut plants were placed in water at 25°C and numbers of hatched J2 counted 8 days later.

Effect of Root damage

In a first experiment, single cv. Rangi plants were grown in 15 cm diameter pots and inoculated with 500 J2/pot at 3 weeks after sowing. Plants from ten randomly selected pots were uprooted 2, 4, 6, 8, and 10 weeks after inoculation. Roots were lightly washed, chopped into lengths of 2-5 cm, mixed into 1 kg of new soil and kept in plastic bags at 25°C. One week after the last uprooting, the soil root mixture from the plastic bags was transferred to 15 cm diameter pots and bioassayed by transplanting 3-week-old tomato seedlings into the soil. The bioassay plants were inspected for galls 5 weeks after transplanting.

A second experiment followed the method of the first, except that plants were uprooted 3, 5 and 7 weeks after inoculation, and stage of nematode development was monitored.

In a third experiment, roots of 6-week-old tomato cv. Grosse Lisse plants, with *M. javanica* at the young female stage but not laying eggs, were chopped and buried in soil in plastic bags, as previously described, and kept at 25°C. Four and 7 days later, root pieces were stained and examined to see if eggs had been laid.

Effect of age of crop at inoculation

Seven 4 × 20 cm tubes and seven 15 cm diameter pots were sown with seed of rape cv. Rangi rape and thinned to one seedling in each container. Repeat sowings were made 2 and 4 weeks later and the sowing treatments arranged in seven randomised blocks. All containers were inoculated with 800 J2/container 3 weeks after the last sowing, when plants were 7, 5 and 3 weeks old. Ten days after inoculation, roots from the tubes were stained and nematodes in them counted, using the maceration and sieving method of Wachtel (1986). Plants in the 15 cm pots were left to grow for 8 weeks after inoculation, when numbers of eggs were estimated.

Statistical analyses

Results of the seed treatment and slashing experiments were subjected to analysis of variance, with log transformation where needed to normalise the data. Crop age results were analysed using generalised linear modelling. The Genstat 5 statistical program was used and a level of $P \leqslant 0.05$ was required for significance (Anon., 1987).

Results

Efficacy of seed treatments

In experiment 1, galling was reduced on plants from Superstrike coated seed and from seed treated with fenamiphos, but increased after treatment with omethoate (Table 1). In experiment 2, when inoculation was delayed to 4 weeks after sowing, fenamiphos (at twice the previous rate) reduced gall numbers, whereas Superstrike and omethoate treatments had no effect (Table 1). The omethoate and fenamiphos treatments impaired germination/emergence. Fenamiphos treated seedlings showed chlorosis on emergence, but affected seedlings recovered and grew normally.

Galling after autumn and winter planting

The 16 tomato plants transplanted to the field in mid-autumn had numerous root galls with developing *Meloidogyne* when examined 6 and 10 weeks after planting. In contrast, the 16 plants of both rapes were gall-free, and no nematodes were found in their roots. The four glasshouse-grown plants of all three crops had numerous galls, with developing nematodes inside. Winter field transplants were all free of galls when dug 11 weeks after transplanting, whereas all their glasshouse-grown counterparts were severely galled.

Cutting with and without glyphosate

In the initial experiment, tops were cut off plants whose roots contained developing juvenile stages (6 weeks) and subsequently on four occasions as nematodes developed to young females, mature females, females with small egg masses and to females with large egg masses (11 weeks). The experiment with glyphosate covered a similar range of development stages at 6, 7 and 8 weeks when females with eggs were present. Cutting did not alter egg production in either experiment; treatment means ranged from 3530 to 7000 eggs/replicate (initial experiment) and 4840 to 8300 (glyphosate experiment). Mean egg number on plants cut and treated with glyphosate (7100/replicate) was not significantly different from the mean, either of plants that were only cut (6950) or of intact untreated controls (5540). Mean percentage hatch was 78% for eggs from cut plants not treated with glyphosate and 81% from cut and glyphosate-treated plants.

Effects of damaging roots and age of crop at inoculation

The incidence of infection on bioassay plants at 5 weeks after planting was less after cv. Rangi roots were chopped while nematodes were still juveniles (one of ten plants with galls), compared with those grown in presence of roots chopped when later developmental stages were present (five to ten plants with galls). Infected bioassay plants had few, small galls, between ten and 20/plant.

Table 1. *Numbers of* Meloidogyne javanica *galls (detransformed and (log_e) means) at 5 weeks after inoculating, either at sowing or 4 weeks later, on rape (*Brassica napus *ssp.* oleifera*) cv. Rangi and fodder swede (*B. napus *ssp.* rapifera*) cv. Highlander grown from pesticide-treated seed, and effects on seedling emergence.*

Seed treatment (g a.i. per 100 g seed)	Plant cultivar	Inoculated at sowing (n = 6)		Inoculated 4 weeks after sowing (n = 5)		
		Galls on five plants		Seedling emergence (%)	Galls on three plants	
Untreated	Rangi	43	(3.761) b[1)]	42 a	23	(3.151) a
Omethoate (0.696)	Rangi	76	(4.337) a	26 b	28	(3.327) a
Fenamiphos (0.35)	Rangi	20	(3.017) c	–	–	–
Fenamiphos (0.70)	Rangi	–	–	17 b	2	(0.913) b
Superstrike®	Highlander	2	(0.814) d	56 a	31	(3.440) a

[1)] Means with different letters in the same column differ at $P \leqslant 0.05$.

This experiment did not include a control with unchopped roots, so differences between survival of juveniles in young chopped roots compared to similar but intact roots is not revealed. When tomato roots with pre-egg laying females were chopped and buried in soil, females without eggs were present 4 days later, and by 7 days later the females had produced numerous egg masses.

Plants inoculated at 3 and 5 weeks after sowing were invaded similarly at 10 days (treatment means, 43 and 36 nematodes per plant) but plants inoculated 7 weeks after sowing were less invaded (treatment mean, 13 nematodes per plant, $P \leqslant 0.05$). Egg production at 8 weeks on these plants was much less ($P \leqslant 0.05$) on plants inoculated at 5 and 7 weeks (treatment means, 280 and 60 eggs per plant) than on those inoculated at 3 weeks (treatment means, 1220).

Discussion

The seed treatments indicate that such applications could provide cost effective short-term protection from infection by *M. javanica*, at least for crops of intermediate host status. This could be useful in protecting autumn-sown crops until soil temperatures drop low enough to inhibit J2 activity. The effect of Superstrike® coated seed is probably due to the imidacloprid, an insecticide rapidly translocated upwards, which would explain the limited duration of activity against root parasites. Fenamiphos treatment reduced galling, but its effect on emergence and the observation of chlorosis suggest it is unsuitable for seed application. Detrimental effects from seed-applied fenamiphos have been reported before (Rodríguez-Kabána *et al.*, 1977). No explanation can be given for the increased galling on plants grown from omethoate treated seed.

Root-knot development on tomato but not rape cvs Rangi and Humus when these crops were planted in mid-autumn indicates that intermediate hosts can escape attack by *M. javanica* even though soil temperatures permit infection of a good host crop. There are other reports that *M. javanica* and *M. incognita* infection is inhibited when crop species that are generally poor or intermediate hosts are sown in the field when soil temperatures fall below 20°C. *Meloidogyne javanica* did not reproduce on barley (*Hordeum vulgare* L.), rye (*Secale cereale* L.) and oat (*Avena sativa* L.) cultivars sown in autumn with soil temperature below 20°C (Thomason, 1962). Roberts *et al.* (1981) found that *M. incognita* invaded wheat (*Triticum aestivum* L. cv. Anza) sown when soil temperature was 21°C, but not when sown later when soil temperature was 16°C. Ahuja and Singh (1990) observed that cabbage, kohlrabi and cauliflower (*B. oleracea* L.) cultivars escaped infection by *M. incognita* if planted when soil temperatures were below 21°C. The present results provide direct evidence of differential infection of good and intermediate hosts by *M. javanica* when field soil temperatures are below 20°C.

Our results indicate that cutting tops off infected plants 6 weeks or more after sowing and infection, when juvenile development has started, is unlikely to suppress egg production by *M. javanica*. Van Biljon (1996) reported a similar finding for *M. javanica* reproduction on tobacco (*Nicotiana tabacum* L.); the nematode population increased 2.4 to 3.5 times within 3 weeks of cutting plants 3 to 18 weeks after planting. Application of glyphosate to cut stems did not change egg production. In contrast, Osman and Viglierchio (1981) reported that application of glyphosate to leaves of soybean (*Glycine max* L.) reduced galling by *M. incognita*. Levene *et al.* (1998) found the herbicides acifluorfen, bentazon and lactofen applied to soybean leaves inhibited the hatch of eggs of *Heterodera glycines* produced on treated plants. Our results suggest that hatch of *M. javanica* eggs is unaffected by glyphosate application to the cut stems of rape.

It is not clear from the root chopping experiments that chopping young roots containing juveniles contributed to nematode suppression. Juveniles may have starved because of low nutrient reserves in young detached roots whether or not the roots were chopped. Steele (1972) found that *Heterodera schachtii* developed in lateral roots attached to large tap roots of defoliated sugar beet (*Beta vulgaris* L.) but not in detached lateral roots or in roots of young defoliated plants without large tap roots. The experiment with tomato roots confirmed that females initiate and continue egg production despite fine chopping of host roots. Shepperson and Jordan (1957) found that 50% of *M. incognita* females laid eggs during 1 week after removal from host tissue. In experiments by Tzortzakakis and Trudgill (1996), *M. javanica* females isolated in 1 cm pieces of tomato root continued laying eggs. The present results indicate that neither slashing nor the disruption of the roots of an infected crop is likely to inhibit reproduction of *M. javanica* once nematode development is under way.

The crop age experiment results suggest that reproduction on late infected crops will be less significant than on crops infected shortly after sowing. Similarly, *M. incognita* produced more eggs on 2 and 4-week-old inoculated

okra plants than on later inoculated plants (Jadhav & Kurundkar, 1991).

ACKNOWLEDGEMENTS

We thank Mr Robert Soretz for assistance with statistical analyses. Dr Rita Holland's cooperation enabled us to use resources at Macquarie University, Sydney and The Australian Grape and Wine Research and Development Corporation gave financial support.

References

AHUJA, S. & SINGH, J. (1990). Variation in the susceptibility of some cole crops to root-knot nematode *Meloidogyne incognita* at different soil temperatures. *Indian Journal of Entomology* 52, 702-704.

ANON. (1987). *Genstat 5 Reference Manual*. Oxford, UK, Oxford University Press, 749 pp.

ANON. (1996). Guidelines on good plant protection practice. Vegetable brassicas. *Bulletin OEPP* 26, 349-367.

BRIDGE, J., PAGE, S. & JORDAN, S. (1982). An improved method for staining nematodes in roots. *Report of Rothamsted Experimental Station for 1981*, Part 1, p. 171.

HUSSEY, R.S. (1978). Seed treatment for control of *Meloidogyne incognita* on cotton. *Plant Disease Reporter* 62, 287-290.

JADHAV, P.V. & KURUNDKAR, B.P. (1991). Effect of age of okra plants on multiplication of *Meloidogyne incognita*. *Indian Phytopathology* 44, 504-506.

JOHNSON, A.W., GOLDEN, A.M., AULD, D.L. & SUMNER, D.R. (1992). Effects of rapeseed and vetch as green manure crops and fallow on nematodes and soil-borne pathogens. *Journal of Nematology* 24, 117-126.

LAMONDIA, J.A. (1996). Trap crops and population management of *Globodera tabacum tabacum*. *Journal of Nematology* 28, 238-243.

LEVENE, B.C., OWEN, M.D.K. & TYLKA, G.L. (1998). Influence of herbicide application to soybeans on soybean cyst nematode egg hatching. *Journal of Nematology* 30, 347-352.

MCLEOD, R.W. & STEEL, C.C. (1999). Effects of brassica-leaf green manures and crops on activity and reproduction of *Meloidogyne javanica*. *Nematology* 1, 613-624.

MCLEOD, R. & WARREN, M. (1993). Effects of covercrops on inter-row nematode infestation in vineyards. 1. Relative increase of root knot nematode *Meloidogyne incognita* and *M. javanica* on legume, cereal and brassica crops. *The Australian Grapegrower and Winemaker* 357, 28-30.

MCLEOD, R., SOMERS, A. & GENDY, M. (1995). Covercrops and nematodes – some field observations. *The Australian Grapegrower and Winemaker* 381, 53-57.

OSMAN, A.A. & VIGLIERCHIO, D.R. (1981). Herbicide effects in nematode diseases. *Journal of Nematology* 13, 544-546.

PUNG, S.H., BARBETTI, M.J. & SIVASITHAMPARAM, K. (1992). Effect of soil environment on infection of subterranean clover by *Meloidogyne arenaria*. *Australian Journal of Agricultural Research* 43, 87-104.

ROBERTS, P.A., VAN GUNDY, S.D. & MCKINNEY, H.E. (1981). Effects of soil temperature and planting date of wheat on *Meloidogyne incognita* reproduction, soil populations, and grain yield. *Journal of Nematology* 13, 338-344.

RODRÍGUEZ-KABÁNA, R., HOVELAND, C.S. & HAALAND, R.L. (1977). Evaluation of a seed-treatment method with acetone for delivering systemic nematicides with wheat and rye. *Journal of Nematology* 9, 323-326.

SHEPPERSON, J.R. & JORDAN, W.C. (1957). Observations on *in vitro* survival and development of *Meloidogyne*. *Proceedings of the Helminthological Society of Washington* 24, 254.

SINGH, S.P., PANT, V., KHAN, A.M. & SAXENA, S.K. (1983). Attractiveness of *Meloidogyne incognita* larvae to roots of tomato and changes in biochemical content of plants affected by oilcakes and nematicides. *Nematologia Mediterranea* 11, 115-118.

STEELE, A.E. (1972). Development of *Heterodera schachtii* on large rooted crops plants and the significance of root debris as substratum for increasing field infestations. *Journal of Nematology* 4, 250-256.

THOMASON, I.J. (1962). Reaction of cereals and Sudan grass to *Meloidogyne* spp. and the relation of soil temperature to *M. javanica* populations. *Phytopathology* 52, 787-791.

TZORTZAKAKIS, E.A. & TRUDGILL, D.L. (1996). A thermal time based method for determining the fecundity of *Meloidogyne javanica* in relation to modelling its population dynamics. *Nematologica* 42, 347-353.

VAN BILJON, E.R. (1996). The population growth of *Meloidogyne javanica* on cut-off tobacco. *African Plant Protection* 2, 80. [Abstr.]

WACHTEL, M.F. (1986). Resistance and tolerance of grapevine rootstocks to citrus nematode (*Tylenchulus semipenetrans*). *Australian Journal of Experimental Agriculture* 26, 517-521.