Organic amendments for control of root-knot nematode (*Meloidogyne incognita*) on ginger

G.R. Stirling
Plant Pathology Branch, Queensland Department of Primary Industries, Meiers Road, Indooroopilly, Queensland 4068

Abstract

Poultry manure and sawdust (24, 36 or 48 t/ha) were incorporated into soil with urea (0–1800 kg nitrogen/ha) and their effects on yield of ginger and populations of *Meloidogyne incognita* were compared with those of nematicide programmes involving ethylene dibromide and/or fenamiphos. The pre-plant nematicide treatments proved inadequate but improved nematode control was achieved when these treatments were followed by post-plant applications of fenamiphos. Total yields in soil amended with poultry manure or sawdust plus urea were greater than in non-amended soil and equal to or greater than those in the best nematicide treatments. The yield increase for poultry manure appeared to be due in part to its beneficial effects on soil fertility. Both amendments provided good control of root-knot nematodes, with significantly fewer rhizomes being discarded at late harvest from the amendment treatments than from the untreated and some nematicide-treated plots. Addition of the highest rates of urea to soil produced ammonium-nitrogen concentrations of more than 1000 μg/g soil, but no measurable effect on root-knot nematode populations or the degree of nematode damage.

Introduction

Numerous reports from many countries have shown that crop losses from plant-parasitic nematodes can be reduced by adding organic materials to soil (Muller and Gooch 1982). Although the mode of action of organic amendments against nematodes is complex and not yet fully understood, they undoubtedly improve the nutritional status and water-holding capacity of soil so that general plant health and tolerance to nematode attack is improved. Also, amendments appear to stimulate the activity of a range of parasites and predators of nematodes, while the decomposition of some materials results in the release of a number of nematicidal compounds.

In Queensland, most growers of ginger (*Zingiber officinale* Roscoe) routinely apply large quantities of organic matter (e.g. cover crops, poultry manure, sawdust, mill mud) and some claim to obtain a degree of nematode control from these materials. However, this is largely seen as a secondary benefit, the primary aim being to improve soil structure and soil fertility. This situation may change if ethylene dibromide (EDB), the most widely used nematicide on ginger, is removed from the market because of health and environmental considerations. Since the alternative chemicals are much more expensive, nematicides will become a more significant cost in ginger production. Growers may then wish to maximise the nematicidal effectiveness of organic amendments and perhaps use them to reduce the cost of their nematode control programmes.

Recent work in the USA (Mian and Rodriguez-Kabana 1982 *a*;*b*; Rodriguez-Kabana 1986) has shown that the nematicidal effect of decomposing organic manures is partly due to the production of ammonia and that their effectiveness is therefore related to nitrogen (N) content. Urea is also a good nematicide when applied at levels in excess of 300 mg N/kg soil (Rodriguez-Kabana and King 1980) and can be used to increase the nematicidal effectiveness of an amendment (Huebner *et al.* 1983).

To determine whether these results could be applied in the Queensland ginger industry, a field experiment was set up to examine the effectiveness of sawdust and poultry manure, two commonly used amendments with widely differing N contents, in controlling root-knot nematode (*Meloidogyne incognita* (Kofoid & White) Chitwood on ginger. The experiment also aimed to determine whether the nematicidal activity of these two amendments could be enhanced by the addition of urea.

Methods

The experiment was conducted on 0.4 ha of brown, clay-loam soil on a property approximately 20 km south of Gympie, Queensland. Ginger had been grown in the field 2 years previously and a crop of oats (4 t dry matter/ha) was ploughed in 3 weeks prior to the commencement of the experiment. To ensure that root-knot nematode was present throughout the trial site, *M. incognita* collected previously from the site was multiplied on tomato plants in the glasshouse and galled roots were spread over the soil surface on 2 July 1987. After the inoculum was incorporated with a rotary-hoe, a soil sample consisting of 20 cores (each 100 mL) was collected to determine the pre-treatment nematode density.

The experiment consisted of 32 treatments each allocated to four replicate plots 7 m × 3.66 m, in a randomised block design. Sawdust containing 0.1% N and poultry manure (2.2% N) were applied at 24, 36 and 48 t dry matter/ha in factorial combination with urea at 300, 600, 900 and 1800 kg N/ha (for sawdust) or 0, 300, 600 and 900 kg/ha (for poultry manure). There were two untreated controls and four nematicide treatments, namely EDB (110 kg/ha); EDB (110 kg/ha) preplant + fenamiphos (2 × 10 kg/ha) postplant; fenamiphos (11kg/ha) preplant; and fenamiphos (11 kg/ha) preplant + fenamiphos (2 × 10 kg/ha) postplant. Two nematicide/organic treatments consisted of the EDB + fenamiphos treatment in combination with either sawdust (48 t/ha) + urea (1800 kg N/ha) or poultry manure (48 t/ha) + urea (900 kg N/ha). The organic treatments were applied on 7 July 1987 and incorporated immediately by rotary hoeing to a depth of about 10 cm. One and 7 weeks later, soil was collected with a spade from eight points in each plot at a depth of 5–15 cm and a 300 mL subsample retained for nutrient analysis. Ammonium (NH_4^+-N) and nitrate (NO_3^--N) were determined 1 and 7 weeks after application of the amendments and pH, electrical conductivity, Cl^-, bicarbonate-extractable P, and K^+ were determined at 7 weeks with methods described by Bruce and Rayment (1982). At the latter sampling time, an additional 1 L soil was collected from each plot as described previously, and added to 10 cm pots. Tomato plants grown in the soil were used as root-knot bioassays by harvesting them 1 month later and counting the number of galls per root system.

On 28 August 1987, prior to bedding up for planting, EDB was injected into the appropriate plots with tined fumigation equipment. A broadcast application of basal fertiliser (375 kg/ha superphosphate, 188 kg/ha Crop King Q7 (K) (10.9% N, 2% P, 21.1% K) and 3.75 t/ha lime was also applied to the whole trial site. The area was then bedded up so that plots 7 m in length and consisting of a bed 1.4 m wide were formed in the centre of the original 3.66-m-wide plots. Nemacur 10G (10% fenamiphos) was then sprinkled on the surface of appropriate plots and incorporated to a depth of 5 cm with a rotary tiller.

The experiment was planted with ginger on 20 September 1987 with seed pieces that had been inspected visually for absence of root-knot nematode. The cleanliness of the planting material was checked by potting a sample of 50 seed pieces individually in sterile sand and observing the roots for galling after plants had grown in a glasshouse for 4 months. After planting, the area was managed in a manner typical of the Queensland ginger industry (Whiley 1974). Nemacur 10G was sprinkled over the appropriate plots on 4 December 1987 and 2 March 1988.

Early harvest yields were obtained on 1 March 1988 by hand pulling a 2 m length of each plot and recording the weight of rhizomes. A second 2 m length of plot was late-harvested on 8 August 1988 and the rhizomes were separated into marketable product and those normally discarded because of infection by either *Fusarium oxysporum* Schlecht. ex Fr.f. sp. *zingiberae* Trujillo or root-knot nematodes. Both marketable and discarded yields were recorded.

Soil samples for nematode analysis were obtained from each plot on 12 January 1988 and 8 August 1988 by combining ten cores taken with a 2-cm-diameter tube at depths of 0–15 cm. Nematodes were extracted from 200 mL subsamples with a Whitehead tray (Whitehead and Hemming 1965). At early harvest, a sample of roots was taken from each plot and galling caused by root-knot nematode was rated as follows: 0 = no galls; 1 = 1–25% of the roots galled; 2 = 26–50%; 3 = 51–75%; 4 = 76–99%; 5 = 100% of the roots galled. Rhizomes were not assessed for root-knot nematode damage at early harvest because no damage was apparent. At late harvest, samples of 15 pieces of rhizome from each plot were assessed individually and rated for root-knot nematode damage on a 0–3 scale, where 0 = no damage; 1 = slight surface bumpiness, with the surface of the rhizome still intact; 2 = distinct lumps, with some surface cracking over some of the rhizome and 3 = severe distortion and surface cracking over most of the rhizome, with some rotting associated with the cracking.

The data obtained were subjected to analysis of variance, and to a factorial analysis to show the effects of the organic treatments and urea. In the latter analysis, results for sawdust, poultry manure and non-amended soil were obtained from treatments 1–12, 13–24 and 25–30, respectively (see Table 2).

Results

The addition of organic amendments to soil had a marked effect on soil chemical analyses (Table 1). Poultry manure did not affect pH, but increased electrical conductivity, Cl^-, P and K^+, while NH_4^+-N and NO_3^--N levels increased in proportion to the amount of amendment applied. The addition of urea in combination with poultry manure caused a significant increase in NH_4^+-N levels, the degree of increase being dependent on the amount of urea applied. One week after application, NH_4^+-N levels were greater than 1000 μg/g in several treatments, but 6 weeks later they had declined markedly. Increased NO_3^--N levels at this time indicated that some of the NH_4^+-N had been nitrified to NO_3^--N. Because treatments containing sawdust without urea were not included in the experiment, the effects of sawdust were confounded with those of urea. However, sawdust with urea tended to decrease pH and increase electrical conductivity, and had little effect on levels of Cl^-, P or K^+. As the amount of urea added with sawdust increased, effects on NH_4^+-N and NO_3^--N were similar to those observed with poultry manure.

Inspection of the crop during the growing season indicated that the ginger grew normally in all plots except those treated with sawdust plus 1800 kg N/ha, where plant density was reduced and leaves showed symptoms of chlorosis and marginal necrosis. Marketable yield at early harvest did not differ

Table 1 Soil chemical analyses in non-amended (NA) soil and in soil amended with poultry manure (P) or sawdust (S) in combination with various amounts of nitrogen.

Treatment no.	Treatment Amendment (t/ha)	Nitrogen (kg/ha)	NH_4^+-N (μg/g) 1 wk	7 wk	NO_3^--N (μg/g) 1 wk	7 wk	pH	EC (ms/cm)	Cl^- (μg/g)	P (μg/g)	K^+ (m equiv/100 g)
1	S24	300	270	9	24	98	5.6	0.31	19	30	0.55
2	S24	600	614	68	19	136	5.1	0.51	29	36	0.64
3	S24	900	566	49	25	144	5.3	0.58	45	41	0.61
4	S24	1800	1153	268	22	213	5.1	0.84	21	39	0.59
5	S36	300	318	5	21	63	5.5	0.25	23	36	0.60
6	S36	600	564	52	22	149	5.1	0.51	22	35	0.60
7	S36	900	542	77	22	188	5.3	0.66	20	40	0.66
8	S36	1800	1345	368	25	199	5.3	0.83	21	38	0.64
9	S48	300	212	7	24	56	5.8	0.24	29	43	0.57
10	S48	600	578	39	25	159	5.3	0.55	18	36	0.86
11	S48	900	537	73	23	157	4.9	0.57	22	33	0.71
12	S48	1800	1564	292	22	177	5.3	0.78	23	34	0.56
13	P24	0	163	4	42	95	6.1	0.44	102	170	1.44
14	P24	300	291	16	39	151	5.8	0.58	92	141	1.06
15	P24	600	797	21	38	231	5.7	0.85	105	222	1.36
16	P24	900	1028	86	47	215	5.9	0.94	96	243	1.23
17	P36	0	222	11	40	113	6.0	0.59	131	237	1.78
18	P36	300	389	21	45	162	5.9	0.68	140	211	1.52
19	P36	600	992	20	56	215	5.7	0.92	120	199	1.60
20	P36	900	1053	37	89	234	5.8	0.99	119	240	1.62
21	P48	0	308	9	51	161	6.3	0.76	186	291	2.29
22	P48	300	518	6	58	196	6.2	0.81	158	330	1.84
23	P48	600	1292	17	84	291	6.2	1.10	173	345	2.25
24	P48	900	1000	79	83	278	6.0	1.17	187	250	1.65
25[A]	NA	0	14	3	18	16	6.0	0.10	21	36	0.55
26[A]	NA	0	8	4	20	19	6.0	0.11	20	34	0.55
27[A]	NA	0	12	1	16	19	6.0	0.11	21	35	0.53
28[A]	NA	0	50	5	21	25	5.8	0.13	29	41	0.58
29[A]	NA	0	21	3	18	21	6.0	0.12	22	36	0.59
30[A]	NA	0	11	2	17	14	6.1	0.32	18	37	0.58
31	S48	1800	2067	410	16	172	5.3	0.80	30	41	0.55
32	P48	900	1195	71	95	234	6.0	1.11	195	321	2.15
LSD ($P=0.05$)			411	111	22	49	0.4	0.18	31	90	0.39

[A]Treatments 25–30 do not differ, as nematicides had not yet been applied to treatments 25–28, and treatments 29 and 30 are untreated controls.

significantly between treatments (Table 2). Since almost no disease or nematode damage was observed on rhizomes, marketable yield was approximately the same as total yield. At late harvest, differences in total yield were observed between treatments (Table 2), with plots amended with poultry manure producing the highest yields and untreated and nematicide-treated plots the lowest yields (Table 3). Many rhizomes were discarded because of infection by *F. oxysporum* f.sp. *zingiberae* or because they were damaged by root-knot nematodes (Table 3). In plots amended with sawdust or poultry manure, rhizomes were discarded mainly because of fungal infection whereas losses from non-amended plots were due mainly to nematodes.

The ginger seed used for the experiment was largely free of root-knot nematode, but 2 seed pieces from a sample of 50 grown in sterilised sand had galled roots after 4 months.

Soil samples taken on 2 July 1987 indicated that approximately 75 root-knot nematodes/200 mL soil were present in the field before treatments were applied. Data obtained by tomato bioassay 7 weeks after application of the amendments showed that the amendments had not significantly reduced root-knot nematode numbers compared with untreated plots. In January 1988, numbers of root-knot nematodes in soil were significantly lower in most organically amended and nematicide treatments than in untreated plots (Tables 2 and 3). Although few rhizomes

Table 2 Yields, root-knot nematode populations and nematode damage in non-amended soil (NA), in soil amended with poultry manure (P) or sawdust (S) in combination with various amounts of nitrogen, and following nematicide treatment

Treatment no.	Treatment: Amendment (t/ha)	Treatment: Nitrogen (kg/ha)	Treatment: Nematicide[A]	Early harvest: Marketable yield (kg/2 m)	Late harvest: Marketable yield (kg/2 m)	Late harvest: Discarded yield (kg/2 m)	Total yield (kg/2 m)	January 1988: *Meloidogyne*/ 200 mL soil	March 1988: Root gall rating	August 1988: Rhizome damage rating	August 1988: *Meloidogyne*/ 200 mL soil
1	S24	300	–	19.9	22.2	7.6	29.7	1 (0.64)[B]	1.8	1.0	518 (5.95)[B]
2	S24	600	–	20.2	24.0	9.2	33.2	1 (0.60)	1.3	0.8	396 (5.82)
3	S24	900	–	21.9	28.0	5.8	33.8	41 (3.74)	2.0	0.8	566 (5.51)
4	S24	1800	–	21.5	20.6	10.9	31.6	32 (3.50)	2.3	1.3	283 (5.56)
5	S36	300	–	19.2	22.5	10.9	33.5	19 (2.98)	1.5	1.6	786 (6.53)
6	S36	600	–	17.2	18.1	11.5	29.6	51 (3.95)	1.9	0.6	297 (5.29)
7	S36	900	–	20.6	17.9	13.0	30.8	1 (0.68)	1.3	0.2	38 (3.57)
8	S36	1800	–	15.9	20.9	9.4	30.3	74 (4.32)	3.3	1.7	544 (6.26)
9	S48	300	–	18.0	33.6	5.6	39.1	13 (2.63)	1.5	1.0	433 (5.66)
10	S48	600	–	20.1	21.7	11.2	32.9	6 (1.99)	1.3	0.6	280 (5.37)
11	S48	900	–	21.3	29.9	6.5	36.4	3 (1.49)	2.0	0.8	400 (5.54)
12	S48	1800	–	18.2	15.0	10.3	25.3	11 (2.48)	2.0	1.2	186 (4.31)
13	P24	0	–	17.5	27.8	5.0	32.9	5 (1.84)	2.3	1.1	729 (6.34)
14	P24	300	–	24.7	30.5	6.9	37.4	5 (1.72)	2.0	0.7	428 (5.65)
15	P24	600	–	22.7	28.4	9.7	38.1	2 (1.24)	2.3	1.2	518 (5.69)
16	P24	900	–	22.8	36.2	5.3	41.5	2 (1.20)	1.8	0.6	336 (5.13)
17	P36	0	–	23.2	30.0	9.0	39.0	2 (1.07)	1.5	1.3	868 (6.50)
18	P36	300	–	21.9	28.8	6.5	35.3	2 (1.02)	2.3	0.7	323 (5.44)
19	P36	600	–	22.7	36.1	5.6	41.6	1 (0.97)	1.0	0.8	241 (4.83)
20	P36	900	–	23.3	31.6	4.3	35.9	8 (2.17)	1.8	1.0	471 (5.70)
21	P48	0	–	20.8	26.6	7.1	33.7	2 (1.21)	1.3	0.7	372 (5.43)
22	P48	300	–	24.8	33.4	4.4	37.8	0 (0.00)	1.0	0.6	352 (5.06)
23	P48	600	–	19.3	26.4	7.8	34.2	0 (0.00)	0.5	0.2	396 (5.73)
24	P48	900	–	23.3	36.1	4.4	40.6	4 (1.52)	1.5	0.7	332 (5.50)
25	NA	0	E	20.9	13.5	14.2	27.7	3 (1.26)	1.8	1.3	623 (6.08)
26	NA	0	E+Fb	18.8	25.4	5.6	31.0	5 (1.70)	1.3	1.4	2403 (7.75)
27	NA	0	Fa	21.2	8.5	21.0	29.5	49 (3.90)	3.3	2.0	848 (6.49)
28	NA	0	Fa+Fb	18.9	22.5	9.5	32.0	14 (2.74)	3.5	2.2	1918 (7.44)
29	NA	0	–	18.4	14.4	15.0	29.4	114 (4.75)	2.3	2.0	1238 (6.89)
30	NA	0	–	19.2	7.9	16.7	24.5	63 (4.16)	3.3	2.3	1534 (7.14)
31	S48	1800	E+Fb	20.3	27.5	3.5	31.0	5 (1.86)	1.3	0.6	244 (4.25)
32	P48	900	E+Fb	19.8	33.9	2.7	36.6	0 (0.00)	0.3	0.2	27 (2.71)
LSD (P=0.05)				n.s	12.5	7.9	9.6	(2.65)	1.5	1.0	(1.63)

[A]E = Preplant EDB at 110 kg/ha; Fa = Preplant fenamiphos at 11 kg/ha; Fb = Post-plant fenamiphos, 2 applications each at 10 kg/ha
[B]When transformed data were analysed, equivalent means are presented with transformed means ($\log_e(x+1)$) in parentheses. Otherwise, arithmetic means are given.

in any treatment were damaged by root-knot nematodes at early harvest, there was more root galling in non-amended plots than those treated with sawdust or poultry manure (Tables 2 and 3). At late harvest, root-knot nematode populations and rhizome damage were also higher in non-amended plots (Tables 2 and 3).

A factorial analysis of variance to isolate the effect of adding N from that of the amendments showed that for each amendment there was no significant difference in yield, root-knot nematode populations and nematode damage between the four levels of N. Comparisons of nematicide-treated and untreated plots in non-amended soil showed that nematicides had no significant effects on any of the parameters measured, except that EDB + fenamiphos increased marketable yield (Table 2). When this nematicide treatment was combined with poultry manure + 900 kg N/ha, excellent nematode control and high yields were obtained (Tables 2 and 3).

Discussion

As this experiment aimed to test treatments that may have been of some practical value in controlling root-knot nematode, all possible combinations of sawdust, poultry manure and urea were not included. Treatments containing urea or sawdust alone were omitted because materials with such extreme C:N ratios were likely to be detrimental to plant growth. Urea is phytotoxic at the application rates needed to control nematodes (Rodriguez-Kabana and King 1980; Huebner *et al.* 1983), while sawdust has such a low N content that N deficiency symptoms were likely to result from immobilisation of soil N. Nevertheless, the experimental results clearly showed that total ginger yields in soil amended with poultry manure were greater than in non-amended soil. Poultry manure had a greater effect than sawdust plus urea, possibly because large amounts of N, P and K were added with poultry manure, but the response was not due entirely to nutritional effects.

Table 3 Factorial analysis of data in Table 2, showing effect of organic amendments on yield, nematode populations and nematode damage[A]

	Poultry manure	Sawdust	No amendment	LSD ($P = 0.05$)[B]
Yield data				
Early harvest:				
Marketable yield (kg/2 m)	22.2	19.5	19.5	1.7, 2.1
Late harvest:				
Marketable yield (kg/2 m)	31.0	23.0	15.3	3.6, 4.4
Discarded yield (kg/2 m)	6.3	9.3	13.7	2.3, 2.8
Total yield (kg/2 m)	37.3	32.2	29.0	2.8, 3.4
Nematode data				
Meloidogyne/200 mL soil (January, 1988)	2.1 (1.15)	9.4 (2.34)	20.8 (3.08)	(0.73), (0.93)
Root-gall rating (March 1988)	1.58	1.83	2.54	0.43, 0.53
Rhizome damage rating (August 1988)	0.80	0.94	1.86	0.29, 0.36
Meloidogyne/200 mL soil (August 1988)	447 (5.58)	396 (5.54)	1426 (6.96)	(0.47), (0.57)

[A]When transformed data were analysed, equivalent means are presented with transformed means ($\log_e (x+1)$) in parentheses. Otherwise, arithmetic means are given.
[B]The first figure is to be used for comparisons between sawdust and poultry manure, the second figure for comparisons between sawdust or poultry manure and no amendment.

Both amendments provided some control of root-knot nematode and this was reflected in higher marketable yields at late harvest. Discarded yield was significantly higher with sawdust than with poultry manure, probably because with sawdust, more rhizomes were infected by *F. oxysporum* f.sp. *zingiberae*.

One week after addition of urea to soil, levels of 200 to more than 1000 μg/g of NH_4^+-N were produced, with concentrations generally increasing in proportion to the amount of urea added. Since previous studies had shown that NH_4^+-N was nematicidal at concentrations of 300–600 μg/g soil (Eno *et al.* 1955; Johnson and Shamiyeh 1975; Rodriguez-Kabana *et al.* 1981), some nematode control was expected in many of the plots treated with urea.

The absence of an effect when nematode populations were measured 7 weeks after the urea was applied and later in the experiment, may have been the result of insufficient NH_3 production because of low soil pH. Free NH_3 is nematoxic whereas NH_4^+ is not, and since the direction of the equilibrium between them is pH dependent (Dupleiss and Kroontje 1964), there would have been little free NH_3 at a pH of 4.9–6.2. The lack of nematode control from urea may also have been due to the limited activity of NH_3 at depths below the incorporation zone. Much of the work on the nematicidal effect of NH_3 has been done in pots, where it is possible to incorporate the chemical throughout the soil. In the field, NH_3 has poor diffusion characteristics and its activity tends to be limited to the zone of application (Rodriguez-Kabana *et al.* 1981), so that its activity may have been limited to upper soil layers.

Since root-knot nematode populations in amended plots 7 weeks after application did not differ significantly from untreated plots and NH_4^+-N levels at this stage had declined to relatively low levels in most plots, it is unlikely that NH_3 played a role in the nematicidal effect of poultry manure and sawdust. The lower nematode populations and damage ratings in these amended plots became more apparent as the experiment progressed, suggesting an alternative mechanism of action that continued throughout the term of the experiment. Perhaps the amendments increased the resistance of rhizomes to nematodes, or induced microbiological changes in soil that were detrimental to nematodes. Such effects would be particularly useful for a relatively long-term annual crop such as ginger, where nematicides alone tend to provide inadequate nematode control late in the season. It may be possible to use organic amendments to supplement the control obtained with nematicides and the excellent results obtained with nematicides plus poultry manure and urea provide cause for optimism that such a strategy might be successful.

Acknowledgements

Mr L. Palmer, Manager of the Australian Golden Ginger property near Kandanga provided able assistance and cooperation throughout the term of the experiment. Mr J. Rochecouste, Mrs S. Hamill and Mr A. Nikulin provided invaluable technical assistance, while Mr G. Barry and Mr J.C. Mulder carried out nutrient analyses and statistical analyses, respectively. Their help is gratefully acknowledged. The project was supported in part by a grant from the Buderim Ginger Growers Co-operative Association Ltd.

References

Bruce, R.C. and Rayment, G.E. (1982)—Analytical methods and interpretations used by Agricultural Chemistry Branch for soil and land use surveys. *Queensland Department of Primary Industries Bulletin* QB82004.

Dupleiss, M.C.F. and Kroontje, W. (1964)—The relationship between pH and ammonia equilibria in soil. *Proceedings of the Soil Science Society of America* **28**: 751–754.

Eno, C.F., Blue, W.G. and Good, J.M. (1955)—The effect of anhydrous ammonia on nematodes, fungi, bacteria and nitrification in some Florida soils. *Proceedings of the Soil Science Society of America* **19**: 55–58.

Huebner, R.A., Rodriguez-Kabana, R. and Patterson, R.M. (1983)—Hemicellulosic waste and urea for control of plant parasitic nematodes: effect on soil enzyme activities. *Nematropica* **13**: 37–54.

Johnson, L.F. and Shamiyeh, N.B. (1975)—Effect of soil amendments on hatching of *Meloidogyne incognita* eggs. *Phytopathology* **65**: 1178–1181.

Mian, I.H. and Rodriguez-Kabana, R. (1982a)—Soil amendments with oil cakes and chicken litter for control of *Meloidogyne arenaria. Nematropica* **12**: 205–220.

Mian, I.H. and Rodriguez-Kabana, R. (1982b)—Survey of the nematicidal properties of some organic materials available in Alabama as amendments to soil for control of *Meloidogyne arenaria. Nematropica* **12**: 235–246.

Muller, R. and Gooch, P.S. (1982)—Organic amendments in nematode control. An examination of the literature. *Nematropica* **12**: 319–326.

Rodriguez-Kabana, R. (1986)—Organic and inorganic nitrogen amendments to soil as nematode suppressants. *Journal of Nematology* **18**: 129–135.

Rodriguez-Kabana, R. and King, P.S. (1980)—Use of mixtures of urea and blackstrap molasses for control of root-knot nematodes in soil. *Nematropica* **10**: 38–44.

Rodriguez-Kabana, R., King, P.S. and Pope, M.H. (1981)—Combinations of anhydrous ammonia and ethylene dibromide for control of nematodes parasitic of soybeans. *Nematropica* **11**: 27–41.

Whiley, A.W. (1974)—Ginger growing in Queensland. *Queensland Agricultural Journal* **100**: 551–557.

Whitehead, A.G. and Hemming, J.R. (1965)—A comparison of some quantitative methods of extracting small vermiform nematodes from soil. *Annals of applied Biology* **55**: 25–38.

Manuscript received 6 February 1989, accepted 5 May 1989.