

# Effects of Rapeseed and Vetch as Green Manure Crops and Fallow on Nematodes and Soil-borne Pathogens<sup>1</sup>

A. W. JOHNSON,<sup>2</sup> A. M. GOLDEN,<sup>3</sup> D. L. AULD,<sup>4</sup> AND D. R. SUMNER<sup>5</sup>

**Abstract:** In a rapeseed-squash cropping system, *Meloidogyne incognita* race 1 and *M. javanica* did not enter, feed, or reproduce in roots of seven rapeseed cultivars. Both nematode species reproduced at low levels on roots of the third crop of rapeseed. Reproduction of *M. incognita* and *M. javanica* was high on squash following rapeseed, hairy vetch, and fallow. The application of fenamiphos suppressed ( $P = 0.05$ ) root-gall indices on squash following rapeseed, hairy vetch, and fallow; and on Dwarf Essex and Cascade rapeseed, but not Bridger and Humus rapeseed in 1987. The incorporation of 30–61 mt/ha green biomass of rapeseed into the soil 6 months after planting did not affect the population densities of *Criconebella ornata*, *M. incognita*, *M. javanica*, *Pythium* spp., *Rhizoctonia solani* AG-4; nor did it consistently increase yield of squash. Hairy vetch supported larger numbers of *M. incognita* and *M. javanica* than rapeseed cultivars or fallow. *Meloidogyne incognita* and *M. javanica* survived in fallow plots in the absence of a host from October to May each year at a level sufficient to warrant the use of a nematicide to manage nematodes on the following susceptible crop.

**Key words:** *Brassica napus*, *Criconebella ornata*, *Cucurbita pepo*, fungus, *Meloidogyne incognita*, *M. javanica*, nematode, *Pythium* spp., rapeseed, *Rhizoctonia solani*, ring nematode, root-knot nematode, squash.

Rapeseed (*Brassica napus* L.) is a cool season annual crop that can be planted in the fall and harvested during spring or early summer in regions where winters are mild (min. mean soil temperature 10-cm deep during winter months = 4.7 C). Rapeseed has been grown for industrial oil for many years in Europe (1,7). Since the introduction of rapeseed into Canada in the 1940s, it has become a billion dollar industry in Canada (16). Until recent years, there was limited production of rapeseed in the United States with less than 40,000 hectares grown for grazing and oil production. Rapeseed meal has been used extensively in Canada and Europe as a high-protein feed supplement for livestock and poultry. Until recently, however, the value and

marketability of this major oilseed processing byproduct has been limited by the presence of high concentrations of glucosinolates in the seeds.

Glucosinolates are sulfur-containing compounds in all parts of the plant that are characteristic of the Cruciferae family (4,7,23). Glucosinolates, when hydrolyzed by the myrosinase enzyme present in the *Brassica* seeds and vegetative tissues, yield oxazolidinethiones, nitriles, thiocyanates, and various forms of fungicidal and bactericidal isothiocyanates (5,20).

Lewis and Papavizas (18) demonstrated that vapors from decomposition of cabbage (*Brassica oleracea* var. *capitata*) tissue, an amendment that suppressed pea root rot and adversely affected morphology, development of oospores, and mycelial growth of *Aphanomyces euteiches*. The sulfur-containing volatiles reported to be present in cabbage, or obtained from its decomposition, include mercaptans, sulfides of various types, and isothiocyanates. Isothiocyanates include methyl isothiocyanate, a breakdown product of metham sodium (19) and an active ingredient in DD-MENCS (20% methyl isothiocyanate + 80% chlorinated C<sub>3</sub> hydrocarbons), which are effective biocides (9,17).

Little information is available on nematodes that attack rapeseed roots. *Meloido-*

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<sup>2</sup> Supervisory Research Nematologist, USDA ARS, Coastal Plain Station, Tifton, GA 31793.

<sup>3</sup> Research Nematologist/Collaborator, Nematology Laboratory, Plant Sciences Institute, USDA ARS, Beltsville, MD 20705.

<sup>4</sup> Professor and Chairman, Department of Agronomy, Horticulture, and Entomology, Texas Tech University, Lubbock, TX 79409-2122. Formerly Professor, Plant Breeding and Genetics, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID 83843.

<sup>5</sup> Professor, Plant Pathology Department, University of Georgia, Tifton, GA 31793.

*gyne chitwoodi* races 1 and 2 and *M. hapla* reproduced on 12 cultivars of *B. napus* and two cultivars of *B. campestris* (19). All three nematodes reproduced more on *B. campestris* than on *B. napus*. Amending *M. chitwoodi*-infested soil in plastic bags with chopped shoots of Jupiter rapeseed reduced the nematode population more than amendment with wheat shoots (19). Incorporating Jupiter shoots into soil heavily infested with *M. chitwoodi* in microplots reduced the nematode population more than fallow or corn shoot treatments. The greatest reduction in nematode population density was attained by cropping rapeseed for 2 months and then incorporating it into the soil as a green manure.

The need for additional winter cash crops, alternative winter-cover crops, and a new edible oil has provided incentives to determine if rapeseed might be useful in the southeastern United States. The root-knot nematodes *M. incognita* (Kofoid & White) Chitwood, *M. arenaria*, and *M. javanica* (Treb) Chitwood are of major concern for growing rapeseed in the southeastern United States. A study was conducted with rapeseed following peanut in soil infested with ca. 715 *M. arenaria* second-stage juveniles/150 cm<sup>3</sup> soil at the time of planting (29). The application of a nematicide, fenamiphos, reduced the nematode damage of all cultivars of rapeseed and increased plant stand, plant height, and seed yield.

Recently, different cultivars and experimental lines of rapeseed have been evaluated to identify those well adapted to the southeastern United States (22). Research on planting dates, time and method of harvest, double cropping potential, and other production practices of rapeseed has been conducted in Georgia (21,22,27-31). Attempts have been made to double crop rapeseed with peanut and soybean, but the data indicated that a rapeseed-peanut cropping system may not be fully adaptable in this region if harvest of the rapeseed is delayed (29). In 1987-1988, soybean was planted following rapeseed harvest. Soybean yield was comparable with

average yields from the area. If rapeseed could be double cropped, it could provide a soil cover and help reduce soil erosion during the winter months.

Control of nematodes on horticultural and agronomic crops in the southern United States is heavily dependent on the use of nematicides. The continued availability of nematicides is of major concern to growers. Thus, the search for alternative measures to manage nematodes on crops has become increasingly important. The objective of this research was to compare the effects of different rapeseed cultivars and hairy vetch (*Vicia villosa* Roth.), grown as green-manure crops from October to April, with fallow, and the application of fenamiphos on nematodes and soil-borne fungal pathogens on summer squash following these crops.

#### MATERIALS AND METHODS

The experiment was established on Tifton loamy sand (fine loamy, siliceous, Thermic Plinthic Paleudult; sand 85%, silt 10%, clay 5%; pH 6.5-7.0, 0.5% OM). The soil was naturally infested with the root-knot nematodes *Meloidogyne incognita* race 1 (62-68%) and *M. javanica* (32-38%); the ring nematode, *Criconemella ornata* (Raski) Luc & Raski; and plant-pathogenic fungi, primarily *Rhizoctonia solani* Kühn and *Pythium* spp.

A split-plot experiment with a randomized complete-block design was used. Whole plots were winter cover crops and fallow, and subplots were nematicide treatment versus untreated. Each subplot contained three beds 1.8 m wide and 12 m long. Whole plots and subplots were replicated four times.

The field plots were disk-harrowed 10-15 cm deep and moldboard plowed 25-30 cm deep to bury crop residue in October or November each year (1984-1986). Plots were established and fenamiphos 15G was broadcast at 6.7 kg a.i./ha to one-half of all plots and incorporated immediately into the top 15-cm soil layer with a power-driven tractor-mounted rototiller. Fenami-

phos was applied each year immediately prior to planting rapeseed and hairy vetch. One-half of the plots remained untreated and served as controls.

Based on soil tests, all plots were fertilized and limed to maintain the pH near 6.9 for rapeseed. The fertilizer and lime applications (kg/ha) were as follows: 13 November 1984, 560 kg 5-10-15 (nitrogen 5%, phosphoric acid 10%, soluble potash 15%, calcium 9%, and sulfur 7%); 23 October 1985, 6,720 kg dolomitic limestone, 336 kg ammonium nitrate (33% N), 112 kg sulphomag (22% sulfur, 22% K<sub>2</sub>O, and 11% magnesium), and 146 kg murate of potash (60% K<sub>2</sub>O); and 29 October 1986, 4,480 kg dolomitic limestone, and 560 kg 5-10-15. The fertilizer and limestone were spread on the soil surface, incorporated 5-10 cm deep, and the soil surface was leveled with a tractor-powered rototiller equipped with an attachment to smooth the seed bed. In 1984, no herbicide was applied to plots before seeding rapeseed. All plots were hand weeded as needed. Each year thereafter, trifluralin (0.56 kg a.i./ha) + triallate (1.12 kg a.i./ha) were sprayed broadcast on the soil surface and incorporated into the top 2.5 cm soil layer with a tractor-mounted rototiller.

Rapeseed (9.0 kg/ha) and hairy vetch (45 kg/ha) seeds were planted with a grain drill in rows 15 cm apart October or November each year. The rapeseed cultivars Dwarf Essex, Elena, Indore, and Jupiter were planted 5 cm deep in 1984. Seeds of Dwarf Essex, Cascade, Bridger, and Humus were planted 1.5 cm deep in 1985 and 1986. Cultivars of rapeseed were selected based on the concentrations ( $\mu$ moles/g) of glucosinolates in the defatted seed meal: Indore, Elena, and Cascade 15-20  $\mu$ moles, Bridger 35-40  $\mu$ moles, Dwarf Essex and Jupiter 50-95  $\mu$ moles, and Humus 60-120  $\mu$ moles. All fallow plots were rototilled 5-8 cm deep with a tractor-powered rototiller to destroy weeds as needed during the rapeseed growing season (October-April).

The top green foliage weight of rapeseed plants was recorded 1 April 1986 and 4 May 1987 from 1 m<sup>2</sup> in the center of

each plot. Green manure yields were calculated and reported as metric tons per hectare. Plants were dug and roots were cut from the stalks, washed in tap water, rated for galls, weighed, and stained with 0.05% acid fuchsin in lactophenol and cleared in lactophenol (2). The stage of development and number of *Meloidogyne* spp. per root system were recorded. The foliage was weighed and a subsample from each plot was weighed, placed in paper bags, and placed on greenhouse benches to dry.

All green plant material was mowed with a flail chopper each year. A sample of the chopped plant material was collected in 1987 and placed in a freezer (-20 C) until analyzed for glucosinolates. Glucosinolate content was determined by the method of the Canadian Grain Commission-Grain Research Laboratory (3). All plots were disk-harrowed 10-15 cm deep and moldboard plowed 25-30 cm deep to bury crop residue 22 May 1985, 1 April 1986, and 4 May 1987. Three weeks later, plots were reestablished. The nematicide treatments, each crop, and fallow were maintained on the same plot for the duration of the experiment. Fenamiphos was applied to designated plots as described for the rapeseed planting. The herbicides bensulide (4.5 kg a.i./ha) and naptalam (2.2 kg a.i./ha) in 187 liters water/ha were sprayed on the soil surface and incorporated with the fertilizer (560 kg/ha 5-10-15) into the top 5-cm soil layer with a tractor-powered rototiller 12 June 1985, 29 April 1986, and 25 May 1987. Squash (*Cucurbita pepo* (L.) Alef. cv. Dixie Hybrid) seeds were planted in all plots 30 cm apart in rows 0.9 m apart immediately after herbicide applications. Each year all plots were cultivated and squash plants were sidedressed with 560 kg/ha 5-10-15 fertilizer 3 weeks after planting and 336 kg/ha ammonium nitrate (33% N) 30-35 days after planting. Fruit of squash was harvested by hand from plants in the center bed 10-12 times at 2- and 3-day intervals from 15 July until 7 August, separated into marketable and cull, counted, and weighed.

Roots of 20 squash plants, 10 from each of the two outside beds, were dug from each plot ca. 40 and 85 days after planting and rated for percentage of roots galled by *Meloidogyne* spp. on the following scale: 1 = no galling, 2 = 1–25, 3 = 26–50, 4 = 51–75, and 5 = 76–100.

Soil was assayed for plant-parasitic nematodes at monthly intervals each year, except September 1985 and August and September 1986. Twenty soil cores 2.5-cm-d  $\times$  25 cm deep were collected from rows in each plot and mixed thoroughly. A 150-cm<sup>3</sup> subsample was processed by centrifugal flotation (8) for nematode assay. Soil samples collected for nematode assays 5 May, 20 June, and 22 October 1985, 25 November 1986, and 25 June 1987 were subsequently assayed for *Pythium* spp. by soil dilutions on pimaricin-ampicillin-rifampicin-pentachloronitrobenzene (PARP) agar (15) and for *Rhizoctonia solani* and other basidiomycetes with a multiple-pellet soil sampler (6) on tannic acid-benomyl agar (TABA) (25). Ten colonies of *Pythium* spp. were selected at random from PARP agar and identified at each sampling. Colonies of *R. solani* and other basidiomycetes from TABA were identified for every plot at each sampling. The field plots remained undisturbed after the final harvest of squash until October or November when the squash crop residue was mowed, plots were disked and plowed, fertilizer was applied for rapeseed and hairy vetch, and the cropping systems were repeated.

All data were subjected to analysis of variance for split-plot designs (24). Either the Waller-Duncan multiple-range test or Fisher's protected least significant difference test was used for mean separations. Only significant ( $P = 0.05$ ) data are discussed unless stated otherwise.

## RESULTS

A poor stand of rapeseed was obtained in 1984 due to deep (5 cm) placement of seeds, which resulted in a weed problem, primarily corn spurry (*Spergula arvensis*).

Roots of corn spurry were galled, and *M. incognita* and *M. javanica* were identified from the galls. Excellent stands of rapeseed were obtained in 1985 and 1986 when seeds were placed 1.5 cm deep and plots were irrigated.

Numbers of *Meloidogyne* spp. second-stage juveniles (J2) ranged from 9 to 138/150-cm<sup>3</sup> soil in samples taken prior to establishment of the plots in 1984 and did not differ ( $P = 0.05$ ) among plots (data not presented). Numbers of J2 ranged from 0 to 35/150 cm<sup>3</sup> soil in plots of rapeseed in 1985 and were not affected by fenamiphos treatment, fallow, or rapeseed cultivars (data not presented). Numbers of J2 increased to 135/150 cm<sup>3</sup> soil in untreated plots of vetch 10 May 1985. At that time, numbers of J2 in untreated vetch plots were greater than those in fenamiphos-treated vetch plots (0/150 cm<sup>3</sup> soil), untreated fallow (2/150 cm<sup>3</sup> soil), or untreated rapeseed plots (8–30/150 cm<sup>3</sup> soil). Numbers of *C. ornata* ranged from 0 to 353/150 cm<sup>3</sup> soil in plots throughout the study and were not affected by winter cover crops or nematicide treatments (data not presented).

Numbers of J2 increased on squash in 1985 following rapeseed, vetch, and fallow (Table 1). Numbers of J2 were generally higher in untreated than in fenamiphos-treated plots, but were not different except following vetch. When averaged across nematicide treatments, there were more J2 in plots of vetch than in other plots on the 9 July and 7 August sampling dates. When averaged across winter cover crops, numbers of J2 were lower in fenamiphos-treated plots than untreated plots on 20 June and 7 August sampling dates.

Large numbers of J2 occurred in all plots following squash by 22 October 1985 (Table 2). The number of J2 was lower in fenamiphos-treated Cascade and vetch than those in untreated plots with the same cover crop. The number of J2 declined below detectable levels in most plots by 31 March 1986. Treatment means across winter cover crops indicated that numbers of J2 were lower in fenamiphos-treated plots

TABLE 1. Numbers of *Meloidogyne* spp. J2 per 150 cm<sup>3</sup> soil in squash planted 12 June 1985 following rapeseed, vetch, fallow, and fenamiphos.

Winter cover crop	20 June		9 July		7 August	
	F†	CK	F	CK	F	CK
Rapeseed						
Dwarf Essex	5a	10a	0b	8b	0a	10b
Elena	0a	13a	0b	3b	5a	50b
Indore	5a	18a	0b	0b	5a	30b
Jupiter	8a	5a	0b	0b	0a	40b
Vetch	3a	19a	10a	113a	0a	470a
Fallow	5a	5a	0b	3b	0a	90b
Treatment means	4y	12z	2z	21z	2y	115z

Data are means of four replications. Means with the same letter in columns or with contingent lines and treatment means in rows for a given sampling date are not different ( $P = 0.05$ ) according to LSD means analysis, and Waller Duncan multiple-range test.

† F = fenamiphos (6.7 kg a.i./ha) incorporated into the top 15-cm soil layer with a tractor-mounted rototiller before planting; CK = untreated control.

than in untreated plots on all sampling dates except 21 January and 31 March 1986.

Numbers of J2 increased on squash in 1986 following rapeseed, vetch, and fallow (Table 3). Data from treatment means across winter cover crops indicate that numbers of J2 were lower in fenamiphos-treated plots than in untreated plots on all sampling dates except 29 April. However, numbers of J2 were not affected by fenamiphos treatment within a given winter cover crop on most sampling dates.

Numbers of J2 declined on all winter cover crops after seeding rapeseed and vetch 29 October 1986 (data not pre-

sented). From 21 January to 25 May 1987, numbers of J2 ranged from 0 to 28/150 cm<sup>3</sup> soil in all plots and were not affected by fenamiphos or winter cover crops.

There were no nematodes observed in roots or galls on roots of the rapeseed cultivars in 1985 and 1986. No galls occurred on roots of Dwarf Essex, Cascade, or Bridger rapeseed in plots treated with fenamiphos in 1987 (Table 4). Adult female *Meloidogyne* spp. with eggs and galls occurred, however, on roots of all rapeseed cultivars in untreated plots in 1987. *Meloidogyne* species identified from galls in roots of the various cultivars of rapeseed were *M. incognita* 100%, Dwarf Essex; *M.*

 TABLE 2. Numbers of *Meloidogyne* spp. J2 per 150 cm<sup>3</sup> soil in rapeseed, vetch, and fallow following squash and fenamiphos 1985–1986.

Winter cover crop	1985						1986					
	22 Oct.		21 Nov.		18 Dec.		21 Jan.		20 Feb.		31 Mar.	
	F†	CK	F	CK	F	CK	F	CK	F	CK	F	CK
Rapeseed												
Dwarf Essex	83a	143b	5a	13ab	5a	28a	3a	9a	1a	3a	0a	3a
Cascade	103a	279a	5a	23a	4a	38a	0a	3a	3a	20a	0a	1a
Bridger	88a	50b	20a	16ab	0a	38a	3a	1a	0a	15a	0a	4a
Humus	93a	110b	0a	8b	8a	28a	3a	5a	0a	25a	0a	0a
Vetch	56a	158ab	10a	8b	5a	53a	5a	6a	4a	23a	0a	0a
Fallow	143a	160ab	0a	24a	0a	15a	3a	1a	0a	5a	0a	0a
Treatment means	94y	150z	7y	15z	4y	33z	3z	4z	1y	15z	0z	1z

Data are means of four replications. Means with the same letter in columns or with contingent lines and treatment means in rows for a given sampling date are not different ( $P = 0.05$ ) according to LSD means analysis and Waller Duncan multiple-range test.

† F = fenamiphos (6.7 kg a.i./ha) incorporated into the top 15-cm soil layer with a tractor-mounted rototiller before planting; CK = untreated control.

TABLE 3. Number of *Meloidogyne* spp. J2 per 150 cm<sup>3</sup> soil in squash planted 29 April 1986 following rapeseed, vetch, fallow, and fenamiphos.

Winter cover crop	29 April		29 May		2 July		27 Oct.	
	F†	CK	F	CK	F	CK	F	CK
Rapeseed								
Dwarf Essex	9a	4a	0a	9a	0a	25a	158a	523a
Cascade	6a	10a	0a	4a	0a	15a	44a	350a
Bridger	10a	10a	0a	6a	0a	9a	28a	103a
Humus	0a	3a	0a	4a	0a	13a	19a	155a
Vetch	10a	6a	0a	3a	0a	18a	204a	115a
Fallow	6a	1a	0a	1a	0a	13a	49a	353a
Treatment means	7z	6z	0y	4z	0y	15z	83y	266z

Data are means of four replications. Means with the same letter in columns or with contingent lines and treatment means in rows for a given sampling date are not different ( $P = 0.05$ ) according to LSD means analysis and Waller Duncan multiple-range test.

† F = fenamiphos (6.7 kg a.i./ha) incorporated into the top 15-cm soil layer with a tractor-mounted rototiller before planting; CK = untreated control.

*incognita* 68% + *M. javanica* 32%, Cascade; *M. incognita* 62% + *M. javanica* 38%, Bridger; and *M. incognita* 38% + *M. javanica* 62%, Humus.

The root-gall indices of squash following rapeseed averaged across nematicide treatments did not differ among the four rapeseed cultivars for any sampling date (Table 4). Root-gall indices were lower on squash following rapeseed cultivars or fallow than vetch in untreated plots 9 July 1985, but were not affected by winter cover crops in 1986. Root-gall indices were lower on squash following Bridger, Humus, or fallow than vetch in both fenamiphos-treated and untreated plots 25 June 1987. Root-

gall indices of squash in the fenamiphos treatment were consistently lower than those in untreated plots on all dates.

Populations of *Pythium* spp. were moderate (subplot means 8–18 colony forming units (CFU)/g oven-dry soil) 10 May 1985; low (0.5–4.6 CFU/g soil) 20 June; and low (nondetectable to 2.1 CFU/g soil) 22 October 1985. There were no differences among whole plots or between subplots. *Pythium aphanidermatum* Edson (Fitzp.) and *P. irregulare* Buis. each composed 10–20% of the colonies; the other colonies were not identified. On 25 November 1986, populations of *Pythium* spp. were high (298–483 CFU/g soil), and all of the colonies were

TABLE 4. Root-gall indices of squash and rapeseed as influenced by winter cover crops and fenamiphos.

Winter cover crop 1984	Squash 1985	Squash 1985		Squash 1986		Rapeseed 1987		Squash 1987	
		9 July		2 July		4 May		25 June	
		F†	CK	F	CK	F	CK	F	CK
Rapeseed									
Dwarf Essex	Dwarf Essex	1.00a	2.03b	1.08a	3.38a	1.00a	1.30a	1.05b	1.68ab
Elena	Cascade	1.00a	2.60b	1.23a	3.65a	1.00a	1.28a	1.18a	1.68ab
Indore	Bridger	1.15a	2.28b	1.08a	3.60a	1.00a	1.13a	1.00b	1.38bc
Jupiter	Humus	1.25a	1.68b	1.20a	3.38a	1.03a	1.18a	1.03b	1.53bc
Vetch	Vetch	1.03a	4.25a	1.43a	4.20a			1.28a	2.10a
Fallow	Fallow	1.00a	2.13b	1.18a	3.63a			1.03b	1.20c
Treatment means		1.07y	2.49z	1.20y	3.64z	1.01y	1.22z	1.09y	1.59z

Data are means of four replications. Root-gall index on 1–5 scale: 1 = no galling, 2 = 1–25, 3 = 26–50, 4 = 51–75, and 5 = 76–100% roots galled. Means followed by the same letter in columns or with contingent lines and treatment means in a row for a given sampling date are not different ( $P = 0.05$ ) according to LSD means analysis and Waller Duncan multiple-range test.

† F = fenamiphos 15G (6.7 kg a.i./ha) incorporated into the top 15-cm soil layer with a tractor-mounted rototiller before planting; CK = untreated control.

unidentified species. On 25 June 1987, populations of *Pythium* spp. were again high (1,061–1,424 CFU/g soil); 20% of the colonies were *P. ultimum* Trow, and the rest were unidentified. There were greater populations 25 November 1986 in whole plots of Humus than in hairy vetch and the other cultivars of rapeseed, but populations were similar in fallow. There were no differences among whole plots 25 June 1987. There were no differences between fenamiphos treated and untreated subplots at any sampling.

Populations of *R. solani* anastomosis group (AG) 4 (the soreshin pathogen) varied from nondetectable (<2 CFU/100 g soil) to moderate levels (10–23 CFU/100 g soil), but there were no differences among whole plots or between subplots at any planting date. Populations of other *R. solani* AGs were low or nondetectable. Densities of binucleate *Rhizoctonia* spp. CAG-2, CAG-3, CAG-4, or CAG-5 ranged from nondetectable to 8 CFU/100 g soil, and total populations of binucleate *Rhizoctonia* spp. did not exceed 8 CFU/100 g soil. Populations of *R. zaeae* Voorhees were low (<3 CFU/100 g soil). There were no differences in populations of binucleate *Rhizoctonia* spp. or *R. zaeae* among treatments at any sampling. *Laetisaria arvalis* Burdfall, a basidiomycete known to have potential for

biological control of *R. solani*, was found frequently at all samplings. Densities ranged from 1 to 51 CFU/100 g soil among whole plots but were not different at any samplings. In contrast, populations were greater in subplots treated with fenamiphos compared with untreated soil 22 October 1985 (34 vs. 10 CFU/100 g soil), 25 November 1986 (4.8 vs. 1.4 CFU/100 g soil), and 25 June 1987 (6.7 vs. 1.1 CFU/100 g soil).

Due to poor stands, foliage weight of rapeseed was not recorded in 1985. Foliage weight did not differ among the rapeseed cultivars in fenamiphos-treated or untreated plots in 1986 and 1987 (Table 5). Foliage mean weight across nematicide treatments was greater for Dwarf Essex than for Humus in 1986 and for all other cultivars in 1987.

The concentrations of butanyle, pentanyle, hydroxybutanyle, hydroxypentanyle, and total glucosinolates were higher in Dwarf Essex and Humus than in Cascade and Bridger (Table 6). The total concentration of glucosinolates in the green tissue was 6–10 times higher in Dwarf Essex and Humus than in Cascade or Bridger.

Yields of marketable squash during 1985–1987 were 0–26% greater in fenamiphos-treated plots than in untreated plots, but were not different except following Ju-

TABLE 5. Yield of marketable squash and foliage weight of rapeseed as influenced by winter cover crops and fenamiphos.

Winter cover crop		Squash 1985		Squash 1986		Squash 1987		Rapeseed 1986		Rapeseed 1987	
		(mt/ha)		(mt/ha)		(mt/ha)		(mt/ha)		(mt/ha)	
1984	1985–1987	F†	CK	F	CK	F	CK	F	CK	F	CK
<b>Rapeseed</b>											
Dwarf Essex	Dwarf Essex	15.5a	12.3a	20.1a	18.8ab	13.6a	12.7a	55.8a	53.6a	60.8a	49.7a
Elena	Cascade	16.4a	14.4a	17.8a	15.3c	13.8a	12.0a	49.9a	44.0a	33.7a	30.1a
Indore	Bridger	12.8a	12.1a	18.5a	16.8bc	13.5a	12.1a	59.5a	44.9a	41.7a	36.9a
Jupiter	Humus	14.1a	12.3a	18.6a	18.8ab	11.9a	12.5a	50.4a	40.9a	36.9a	34.9a
Vetch	Vetch	13.5a	12.8a	19.8a	18.5ab	14.5a	14.0a				
Fallow	Fallow	14.4a	12.7a	19.2a	19.8a	14.2a	11.6a				
Treatment means		14.4z	12.8z	19.0z	18.0z	13.6z	12.5z	53.9z	45.8y	43.3z	37.9z

Data are means of four replications. Means followed by the same letter in columns or with contingent lines and treatment means in a row for a given parameter are not different ( $P = 0.05$ ) according to LSD means analysis and Waller Duncan multiple-range test.

† F = fenamiphos 15G (6.7 kg a.i./ha) incorporated into the top 15-cm soil layer with a tractor-mounted rototiller before planting; CK = untreated control.

TABLE 6. Concentration ( $\mu$ moles/g) of five classes and total glucosinolates in dry foliage of four cultivars of rapeseed grown at Tifton, Georgia, 1987.

Cultivar	Butanyl	Pentanyl	Hydroxy-butanyl	Hydroxy-pentanyl	Hydroxy-benzyl	Total
Dwarf Essex	0.99a	2.92a	2.85a	0.65a	0.19a	7.60a
Cascade	0.10c	0.13c	0.23b	0.02c	0b	0.48c
Bridger	0.17c	0.16c	0.35b	0.01c	0.01b	0.69c
Humus	0.69b	1.36b	2.03a	0.28b	0.04b	4.40b
CV	56%	64%	64%	81%	137%	63%

Data are means of four replications over fenamiphos-treated (6.7 kg a.i./ha) and untreated plots. Means with the same letter within a column are not different ( $P \leq 0.05$ ) according to Fisher's protected least significant difference test.

piter in 1985 and Bridger in 1986 (Table 5). Yields averaged across winter cover crops, however, did not differ between nematicide treatments. Yield means across subplot treatments were not different in 1985 and 1987 but were lower following Cascade than following Dwarf Essex, vetch, and fallow in 1986.

#### DISCUSSION

The reproduction of *Meloidogyne* spp. on a winter cover crop and the parasitism of the succeeding summer crop by the nematode may affect the value of the winter cover crop. The absence of feeding, development, and egg production on rapeseed roots in 1985 and 1986 indicated that rapeseed was a poor host for *M. incognita* and *M. javanica*. These results were different from those reported for *M. chitwoodi* races 1 and 2 and *M. hapla* on several cultivars of rapeseed (19). *Meloidogyne* species may respond differently to rapeseed cultivars grown under different environmental conditions. The few galls and mature females with eggs that occurred on roots of rapeseed in 1987, however, indicate that *M. incognita* and *M. javanica* could infect rapeseed under some conditions and could become a potential problem in intensive cropping systems with *Meloidogyne*-susceptible crops.

Although rapeseed cultivars were not consistent hosts for the reproduction of *C. ornata*, *M. incognita*, or *M. javanica*, population densities were maintained during the three winters at Tifton, Georgia. In the absence of reproduction on rapeseed cultivars, the number of *Meloidogyne* spp. J2 in

the soil were similar to those on vetch and fallow plots. *Meloidogyne* spp. populations survived in fallow plots in the absence of a host from October to May each year as reported from another study (10). The large number of *Meloidogyne* spp. J2, particularly in 1985, and the increased root-gall indices of squash following vetch indicate this legume is not a good winter cover crop to help control *Meloidogyne* spp. (10). Although not always indicated by numbers of J2 in the soil, hairy vetch also supports a large inoculum potential, including eggs of *Meloidogyne* spp. The eggs of some *Meloidogyne* spp. can survive for several months in moist soil (32,33). Our nematode assay method did not detect *Meloidogyne* spp. eggs. The cause of low numbers of J2 in all plots and low root-gall indices of squash in 1987 compared to other years is unknown. However, time of crop destruction relative to the nematode reproductive cycle may affect results (10).

The efficacy of fenamiphos on squash each year was expected because fenamiphos at similar rates reduced root-gall indices on many susceptible crops (9,11,12). The application of fenamiphos usually suppresses root-gall indices on *Meloidogyne*-susceptible crops, but the effects may not be reflected in increased yield of the crop. Squash plants grow and produce fruit 50–60 days after planting. Under optimum irrigation and fertilization, this crop may support many galls on roots before yield is reduced (11–13).

*Pythium* spp. and *R. solani* AG-4 were pathogenic on seedlings of oilseed rape in the Georgia coastal plain (26). However, in



these experiments we did not detect differences in populations of *Pythium* spp., *R. solani* AG-4, or beneficial basidiomycetes, in soil following rapeseed compared with fallow. The effects of rapeseed residues after seed harvest on populations of *Pythium* spp. and *R. solani* AG-4 in soil in the coastal plain has not been determined.

Based on numbers of *Meloidogyne* J2 in the soil, root-gall indices, fungal assays, and yield of squash, the incorporation of 30–61 mt/ha green biomass of rapeseed into the soil 6 months after planting did not affect population densities of *C. ornata*, *M. incognita*, *M. javanica*, *Pythium* spp., or *Rhizoctonia solani* AG-4, nor did it consistently increase the yield of squash. The glucosinolate concentration in the green tissue was a fraction of the level found in the mature seed (3) and apparently concentrations were too low for biocidal activity against soil-borne fungi and nematodes.

Concentrations of glucosinolates in green plants in our study were low compared to those reported by Jurges (14). He reported relatively high glucosinolate concentrations at the beginning of the vegetation period and reduction of concentrations in the progress of ontogeny. This may account for greater efficacy using 2-month-old rapeseed plants as green manure (19) than 6-month-old plants in our study.

Additional research is needed to determine if the glucosinolates found in the rapeseed can be used to suppress soil-borne pathogens.

Additional research also is needed on production, harvesting, and crop rotations before rapeseed can become a viable alternative winter cover crop in the southeastern United States. New and improved cultivars are being developed that produce edible oils and can be used as winter cover crops.

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