Managing Nematodes, Fungal Diseases, and Thrips on Peanut with Pesticides and Crop Rotations of Bahiagrass, Corn, and Cotton[1]

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ABSTRACT

The influences of bahiagrass, corn, and cotton in rotation with peanut and treatments with aldicarb, flutolanil, and aldicarb plus flutolanil on nematodes, thrips, diseases caused by soilborne fungal pathogens, and yield of peanut were studied for 3 yr. Peanut yields following either 1 or 2 yr of bahiagrass, corn, or cotton were higher than those of continuous peanut. Peanut yield was greatest in the aldicarb plus flutolanil treated plots (5270 kg/ha), intermediate where aldicarb (4060 kg/ha), or flutolanil (4597 kg/ha) was used without aldicarb, and least in untreated (3690 kg/ha) plots. Yield increases in response to cropping sequences and pesticide treatments resulted primarily from suppression of crop damage by *Meloidogyne arenaria*, *Sclerotium rolfsii*, *Rhizoctonia solani*, and *Frankliniella* spp. The data document the pest management benefits and yield response associated with using two widely grown agronomic crops (corn and cotton), an improved bahiagrass cultivar, and pesticide treatments in peanut production.

Key Words: *Arachis hypogaea*, fungicide (flutolanil), *Gossypium hirsutum*, nematicide (aldicarb), *Paspalum notatum*, *Rhizoctonia solani*, ring nematode (*Criconemella ornata*), root-knot nematode (*Meloidogyne arenaria*), *Sclerotium rolfsii*, thrips (*Frankliniella* spp.), *Zea mays*.

Peanut (*Arachis hypogaea* L.) is grown in Georgia as a cash crop for fresh market and processing. Nematodes, insects, and diseases accounted for 34 to 50% yield loss in the 216,500 ha of peanut produced in Georgia in 1997 (Riley *et al.*, 1997; Bertrand, 1998). The most serious nematode pathogen of peanut is *Meloidogyne arenaria* (Neal) Chitwood race 1. Soilborne fungal pathogens, particularly *Sclerotium rolfsii* Sacc., causal agent of southern stem rot, and *Rhizoctonia solani* Kühn anastomosis group 4 (AG-4), causal agent of limb rot, also are damaging to peanut. These two soilborne fungal pathogens accounted for peanut yield losses in Georgia of approximately $39 million in 1997 (Bertrand, 1998). Thrips (*Frankliniella* spp.) caused approximately $6 million in peanut yield losses in Georgia in 1996 (Riley *et al.*, 1997). Continuous cropping of peanut is considered a poor production practice because of the resultant increase of soilborne pests and the expected loss in yield and quality (Johnson *et al.*, 1998). The integration of crop rotation, nematicides, and fungicides is often the most economical means of managing nematodes and soilborne fungal pests on peanut.

Corn (*Zea mays* L.) is a useful rotation crop for peanut in the Southeastern United States. Corn often is considered unprofitable, but is more effective in suppressing populations of *M. arenaria* than continuous peanut or other hosts of the nematode (Windham and Williams, 1994). Corn is a nonhost for two important soilborne pathogens of peanut, *S. rolfsii* and *R. solani* AG-4 (Sumner *et al.*, 1979). *Rhizoctonia solani* AG-4 is indigenous in soils of the Georgia coastal plain and can survive saprophytically in soil or debris during corn culture (Sumner *et al.*, 1986a,b). The fungus does not cause disease in young corn, but roots and stalks of corn are colonized as the plants mature. The fungus is isolated commonly from decaying stalks and roots of corn in

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Georgia and may survive for 2 yr in peanut shells in soil (Sumner and Hook, 1985; Baird *et al.*, 1993). These traits suggested that growers could sustain substantial losses to *R. solani* in rotations of peanut following corn.

Corn is marginally effective in suppressing root-knot nematode populations. Variability in root-knot nematode resistance exists within corn cultivars, hybrids, genotypes, and inbred lines (Windham and Williams, 1994), but resistance to *M. incognita* (Kofoid & White) Chitwood was not found in commercial hybrids (Windham and Williams, 1987). However, several commercial hybrids were identified with resistance to *M. arenaria* and *M. javanica* (Treub) Chitwood (Windham and Williams, 1988). Progress in developing corn germplasm with resistance to root-knot nematodes has been made in recent years (Windham, 1998).

Cotton (*Gossypium hirsutum* L.) is a host of *M. incognita* races 3 and 4 but not *M. arenaria*, whereas peanut is a host of *M. arenaria* race 1 but not *M. incognita* (Taylor and Sasser, 1978). For these reasons, cotton and peanut have been suggested for use in rotation to reduce population densities of *M. incognita* on cotton and *M. arenaria* on peanut (Rodríguez-Kábana *et al.*, 1994; Johnson *et al.*, 1998). Disease loss estimates by the Cotton Disease Council place plant-parasitic nematodes second in importance following seedling diseases (Blasingame, 1992). Disease complexes involving *M. incognita* and certain soilborne fungal pathogens are common in cotton. Interactions between *M. incognita* and several seedling disease pathogens including *R. solani* are common in cotton (Brodie and Cooper, 1964; Starr, 1998).

Bahiagrass (*Paspalum notatum* Flüggé) is a perennial that is widely grown in the Southeastern United States. Rotations with bahiagrass are effective in reducing damage on peanut by *S. rolfsii* and *R. solani* (Johnson *et al.*, 1999) and *M. arenaria* (Rodríguez-Kábana *et al.*, 1994). Tifton 9 is an improved bahiagrass cultivar (Burton, 1989), but little is known about the effects of this cultivar on population densities of nematodes and fungi in a rotation with peanut (Brenneman *et al.*, 1995; Johnson *et al.*, 1999).

This study was part of a field experiment designed to determine the effects of a 0, 1, and 2-yr crop rotation of Tifton 9 bahiagrass sod, corn, and cotton, along with selected pesticides on peanut health and yield. Emphasis was placed on determining the effect of nematodes, soilborne fungal pathogens, and thrips on yield losses. Pesticides were used to ascertain the individual and combined effects of a crop damage by nematodes, fungal pathogens, and thrips. A continuous peanut sequence was included to compare the suppressive effects of bahiagrass, corn, and cotton.

Materials and Methods

The study was conducted 1991 through 1993 on the Gibbs Farm at the Coastal Plain Exp. Stn., Tifton, GA. The experimental area was planted on 9 April 1990 to cultivar Clemson Spineless okra (*Hibiscus esculentus* L.) and to hairy vetch (*Vicia villosa* Roth) on 15 Oct. 1990 to enhance nematode species endemic to the site. The soil was a Tifton loamy sand (fine-loamy, siliceous, thermic Plinthic Kandiudult; < 1% organic matter; pH 6.1 to 6.3) naturally infested with *M. arenaria* race 1, *M. incognita* race 3, *Criconemella ornata* (Raski) Loof & DeGrisse, *Paratrichodorus minor* (Colbran) Siddiqi, *S. rolfsii*, and *R. solani* AG-4. The soil was turned 20 to 25 cm deep with a moldboard plow 1 wk before planting peanut (P), corn (C), cotton (Ct), and bahiagrass (B). Seed beds were shaped 1.8 m wide and 10 to 15 cm high.

The experimental design was a split-plot with four replicates in a randomized complete block design. Whole-plot treatments were crop rotations as follows: P-B-B, B-P-B, B-B-P, P-C-C, C-P-C, C-C-P, P-Ct-Ct, Ct-P-Ct, Ct-Ct-P, and P-P-P. Cropping sequences were initiated so that peanut, bahiagrass, corn, and cotton were produced each year to separate rotation effects from year effects. Only data for peanut following 0, 1, and 2 crops of bahiagrass, corn, cotton, and monocrop peanut are included in this paper. Whole plots (11 m wide by 7.6 m long) consisted of six beds (four treated and two untreated borders). Fallow alleys (9.1 m) separated blocks of plots. Subplots were pesticide treatments—(a) aldicarb [2-methyl-2-(methylthio) propionaldehyde 0-(methylcarbamoyl) oxine] was applied at 3.4 kg a.i./ha in a 30 and 15 cm band ahead of the planter for peanut and cotton, respectively; (b) flutolanil {N-[3-(1-methylethoxy) phenyl]-2-(trifluoromethyl) benzamide} was applied to peanut in 124 L of water/ha in split applications of 0.85 kg a.i./ha each with the first application in a 30 cm band 60 d after planting and the second broadcast 90 d after planting; (c) aldicarb plus flutolanil; and (d) untreated control. Foliar diseases of peanut were controlled with the use of chlorothalonil (Bravo 720, ISK Biosciences, Mentor, OH) applied at 0.88 kg/ha in 233 L of water/ha on a regular 14-d schedule beginning 30 to 35 d after planting and continuing until 2 wk before digging. Mepiquat chloride (N,N-dimethylpiperidinium chloride) was applied at 0.03 kg a.i./ha in a spray volume of 3 L/ha at first bloom of cotton. Ethoprop (0-ethyl S,S-dipropyl phosphorodithioate) was applied at 2.5 kg a.i./ha in a 30-cm band ahead of the planter and terbufos (S-{[(1,1-dimethylethyl) thio] methyl} 0,0-diethyl phosphorodithioate) was applied at 1.1 kg a.i./ha in the seed furrow for corn. Bahiagrass received no treatment to control nematodes or soilborne fungi.

Florunner peanut (100 to 112 kg/ha), Georgia King cotton (11 to 12 kg/ha), and Asgrow RX 945 corn (18 to 19 kg/ha) were seeded in rows 0.9 m apart each year. Seeds of Tifton 9 bahiagrass were broadcast at 22.4 kg/ha during late winter or early spring. Broadleaf weeds were controlled in bahiagrass with the amine salt of 2,4-D [(2,4-dichlorophenoxy) acetic acid] at 2.2 kg a.i./ha. Cultural practices and pest management on peanut, cotton, and corn were according to recommendations for the area (Delaplane, 1991). Irrigation from a traveling gun was applied to all crops as needed.

Nematodes were sampled by taking 10 soil cores (2.5 cm dia., 15 cm deep) from all plots at peanut harvest each year. Soil samples from each plot were mixed thoroughly, and a 150 cm^3 subsample was processed by a centrifugal flotation method (Jenkins, 1964).

Thrip (*Frankliniella* spp.) damage to peanut was rated based on the percentage of 40 leaflets per plot with injury in June of each year. The peanut plants were dug and inverted into windrows at the optimum maturity index (Williams and Drexler, 1981). Stem rot incidence (no. of disease loci per 15.2 m of row where a locus represents one or more infected plants in 30 cm of row) and limb rot severity (percentage of vines colonized by *R. solani* in 15.2 m of row) were rated immediately after digging. Roots and pods of 10 arbitrarily selected plants from each plot were examined and rated immediately after digging for percentage galled by *M. arenaria* on a 1 to 5 scale: 1 = no galling, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, and 5 = 76-100% (Barker *et al.*, 1986). When the moisture content declined to 12-16%, the pods were harvested with a combine, dried to *ca.* 8% moisture, and weighed. A 500-g pod sample was collected from each plot, cleaned to remove foreign material, shelled, and graded according to Federal-State Inspection Service methods (USDA, 1974). The percentages of total sound mature kernels (TSMK), immature kernels, and damaged kernels were calculated by weight.

Data collected each year were subjected to analysis of variance using a general linear model procedure (SAS Institute, 1985). Only significant (P = 0.05) differences are discussed unless stated otherwise.

Results

The environmental conditions varied each year during the period of study. Heavy rainfall (30 cm above normal) delayed planting in the spring of 1991. Rainfall was almost adequate from 15 June until 15 Aug., and only 10 cm irrigation was required from June through September. Near record low temperatures slowed pod development during the last 30 d of the growing season.

A mild winter in 1991 may have been conducive to a moderate increase of root and pod damage by *M. arenaria* in 1992. From planting until harvest in 1992 with 33 cm rainfall, there was a 10 cm mean daily deficit from normal that required 13 cm irrigation water.

During March 1993, a severe storm with sub-freezing temperatures, ice, snow, and high winds caused cold soil conditions at planting. Weather conditions were hot (near 38 C) and dry during May, June, and July with mean daily net evaporation of 0.53 cm. The high temperatures delayed flowering, pegging, and pod formation. The tips of many pegs were burned and aborted as they reached the extremely hot soil surface. Even with irrigation, it was difficult to maintain adequate moisture in the pod zone. From planting until harvest in 1993 with 24 cm rainfall, there was a 9 cm mean daily deficit from normal that required an additional 15 cm irrigation water. Rhizoctonia limb rot and southern stem rot were more prevalent than expected during the hot, dry conditions in 1993.

Significant (P = 0.05) cropping sequence by pesticide treatment interactions in 1993 prevented combining data for second-stage juveniles (J2) of *M. arenaria*, root-gall index, stem rot incidence, and yield. *Meloidogyne arenaria* race 1 was the most prevalent plant-parasitic nematode encountered. Fewer J2 of *M. arenaria* were present in aldicarb-treated plots than in flutolanil-treated, aldicarb plus flutolanil-treated, or untreated peanut plots in 1991 (Table 1). Numbers of J2 were lower in all pesticide-treated plots than in untreated plots of peanut in 1992. Population densities were lower in peanut plots following one crop of cotton than in peanut following 1 yr of bahiagrass, corn, or continuous peanut. Numbers of J2 in 1993 were lower in all treated plots of peanut following 2 yr of corn or cotton compared to 2 yr of bahiagrass or continuous peanut. In untreated plots, numbers of J2 were lowest in peanut following 2 yr of cotton, intermediate following 2 yr of corn or bahiagrass, and greatest in continuous peanut. After this study was

Table 1. Effects of cropping sequences and pesticide treatments on populations of J2 juveniles of *Meloidogyne arenaria* per 150 cm^3 soil at harvest of peanut during a 3-yr rotation experiment at Tifton, GA.[a]

		Pesticide treatment[b]				Mean	
Year	Cropping sequence[c]	Aldicarb	Flutolanil	Aldicarb + flutolanil	Untreated control	Cropping sequence	Year
		no. J2					
1991	P						
Treatment mean		48 B	386 A	270 A	273 A		244 z
1992	B-P					99 z	
	C-P					94 z	
	Ct-P					38 y	
	P-P					129 z	
Treatment mean		70 B	94 B	67 B	132 A		90 y
1993[d]	B-B-P	43 a	80 b	58 b	158 b	84 y	
	C-C-P	13 b	23 c	35 c	123 b	48 y	
	Ct-Ct-P	8 b	10 c	10 c	35 c	16 y	
	P-P-P	58 a	173 a	133 a	343 a	176 z	
Treatment mean		31 B	72 B	59 B	165 A		81 y

[a]Data are means of four replications. Means of pesticide treatments arranged horizontally and cropping sequences within the same year and years arranged vertically followed by the same letter are not different (Duncan's New Multiple Range Test; P = 0.05).

[b]Treatments were aldicarb at 3.4 kg a.i./ha, flutolanil at 1.7 kg a.i./ha, aldicarb + flutolanil, and untreated control. Aldicarb was applied in a 30-cm band at planting and incorporated 3 to 5 cm deep. Flutolanil was applied at 0.85 kg a.i./ha to peanut 60 d after planting in a 30-cm band and broadcast 30 d later in 124 L of water/ha.

[c]P = peanut, B = bahiagrass, C = corn, and Ct = cotton.

[d]Significant (P = 0.05) pesticide treatment × cropping sequence interaction in 1993.

completed, spores of *Pasteuria penetrans* Sayre and Starr, a bacterial parasite of root-knot nematodes, were observed on 0-92% of the J2 population in the four replicates of continuous peanut.

Root-gall indices were lower on peanut treated with aldicarb and aldicarb plus flutolanil than in other plots in 1991 (Table 2). In 1992, root-gall indices were lower in peanut plots treated with aldicarb plus flutolanil than in untreated plots, and lower in peanut following 1 yr of cotton than in continuous peanut. In 1993, root-gall indices were lower on peanut following 2 yr of bahiagrass, corn, or cotton than continuous peanut in all plots except peanut treated with aldicarb plus flutolanil following 2 yr of bahiagrass. Root-gall indices in untreated peanut generally declined following 1 or 2 yr of bahiagrass, corn, or cotton, but increased each year in continuous peanut.

Numbers of *C. ornata* per 150 cm^3 soil in plots of peanut at harvest were greater during the first year of the study (942) than in 1992 (138) or 1993 (130). Analysis of pooled data indicated that neither aldicarb nor aldicarb plus flutolanil suppressed population densities of *C. ornata* compared with untreated controls. Numbers of *C. ornata* were greater in peanut following 1 yr (242) and 2 yr (274) of cotton than in other cropping sequences (range 50-154). Population densities of *Paratrichodorus minor* were less than 20/150 cm^3 soil and were not affected by pesticide treatments or cropping sequences.

Thrips damage to peanut was moderate (14-31% damaged leaflets) during the first year of the study, but increased in all cropping sequences in 1992 (68-72%) and 1993 (53-59%). Percentages of peanut leaflets damaged by thrips were consistently greater in peanuts not treated with aldicarb, but were not affected by cropping sequences. Means across years indicated that 35, 64, 38, and 64% of peanut leaflets in plots treated with aldicarb, flutolanil, aldicarb plus flutolanil, and untreated plots, respectively, were damaged by thrips.

Incidence of southern stem rot of peanut in 1991 and 1992 was greater in aldicarb-treated plots and untreated plots than in plots treated with flutolanil or aldicarb plus flutolanil (Table 3). Numbers of stem rot loci were not affected by 1-yr rotations of bahiagrass, corn, or cotton. In aldicarb-treated and untreated plots, damage by stem rot in 1993 was lower in peanut following 2 yr of bahiagrass, corn, or cotton than in continuous peanut. In aldicarb plus flutolanil-treated plots, stem rot was most severe in continuous peanut, intermediate in peanut following 2 yr of corn or cotton, and lowest in peanut following 2 yr of bahiagrass.

Rhizoctonia limb rot severity in peanut was lower each year in plots treated with flutolanil and aldicarb plus flutolanil than in untreated and aldicarb-treated plots (Table 4). There was no difference in severity of limb rot among cropping sequences after 1 yr of rotation in 1992, but the severity was lower following 2 yr of bahiagrass than in continuous peanut in 1993.

Peanut yield in 1991 was greatest in aldicarb plus flutolanil-treated plots, intermediate in flutolanil-treated plots, and lowest in aldicarb-treated and untreated plots (Table 5). Peanut yield in 1992 was greatest in aldicarb plus flutolanil-treated plots, intermediate where aldicarb or flutolanil was used alone, and lowest in untreated

Table 2. Effects of cropping sequences and pesticide treatments on root-gall indices of peanut during a 3-yr rotation experiment at Tifton, GA.[a]

Year	Cropping sequence[d]	Root-gall index[b]: Pesticide treatment[c]: Aldicarb	Flutolanil	Aldicarb + flutolanil	Untreated control	Mean: Cropping sequence	Mean: Year
1991	P						
Treatment mean		1.1 B	1.6 A	1.0 B	1.6 A		1.3 z
1992	B-P					1.4 yz	
	C-P					1.5 yz	
	Ct-P					1.3 y	
	P-P					2.0 z	
Treatment mean		1.5 AB	1.6 AB	1.4 B	1.7 A		1.5 y
1993[e]	B-B-P	1.2 b	1.3 b	1.2 ab	1.3 b	1.3 z	
	C-C-P	1.1 b	1.1 c	1.1 b	1.2 b	1.1 z	
	Ct-Ct-P	1.1 b	1.2 bc	1.1 b	1.2 b	1.2 z	
	P-P-P	1.4 a	2.0 a	1.3 a	2.5 a	1.8 z	
Treatment mean		1.2 A	1.4 A	1.2 A	1.6 A		1.3 z

[a]Data are means of four replications. Means of pesticide treatments arranged horizontally and cropping sequences within the same year and years arranged vertically followed by the same letter are not different (Duncan's New Multiple Range Test; P = 0.05).

[b]1 to 5 scale: 1 = no galls, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100% of pods and roots galled at harvest.

[c]Treatments were aldicarb at 3.4 kg a.i./ha, flutolanil at 1.7 kg a.i./ha, aldicarb + flutolanil, and untreated control. Aldicarb was applied in a 30-cm band at planting and incorporated 3 to 5 cm deep. Flutolanil was applied at 0.85 kg a.i./ha to peanut 60 d after planting in a 30-cm band and broadcast 30 d later in 124 L of water/ha.

[d]P = peanut, B = bahiagrass, C = corn, and Ct = cotton.

[e]Significant (P = 0.05) pesticide treatment × cropping sequence interaction in 1993.

Table 3. Effects of cropping sequences and pesticide treatments on the incidence of southern stem rot of peanut caused by *Sclerotium rolfsii* during a 3-yr rotation experiment at Tifton, GA.[a]

		Stem rot loci[b]					
		Pesticide treatment[c]				Mean	
Year	Cropping sequence[d]	Aldicarb	Flutolanil	Aldicarb + flutolanil	Untreated control	Cropping sequence	Year
		% diseased loci/15.2 m row					
1991	P						
Treatment mean		27 A	8 B	7 B	26 A		17 z
1992	B-P					6 z	
	C-P					7 z	
	Ct-P					7 z	
	P-P					10 z	
Treatment mean		12 A	4 C	4 C	10 B		8 x
1993[e]	B-B-P	6 c	2 a	2 b	8 b	5 z	
	C-C-P	17 b	4 a	6 ab	15 b	10 z	
	Ct-Ct-P	20 b	7 a	9 ab	15 b	13 z	
	P-P-P	31 a	10 a	13 a	32 a	21 z	
Treatment mean		19 A	6 A	8 A	18 A		12 y

[a]Data are means of four replications. Means of pesticide treatments arranged horizontally and cropping sequences within the same year and years arranged vertically followed by the same letter are not different (Duncan's New Multiple Range Test; P = 0.05).

[b]No. of disease loci per 15.2 m of row, where a disease locus represents one or more infected plants in 30 cm of row at harvest.

[c]Treatments were aldicarb at 3.4 kg a.i./ha, flutolanil at 1.7 kg a.i./ha, aldicarb + flutolanil, and untreated control. Aldicarb was applied in a 30-cm band at planting and incorporated 3 to 5 cm deep. Flutolanil was applied at 0.85 kg a.i./ha to peanut 60 d after planting in a 30-cm band and broadcast 30 d later in 124 L of water/ha.

[d]P = peanut, B = bahiagrass, C = corn, and Ct = cotton.

[e]Significant (P = 0.05) pesticide treatment × cropping sequence interaction in 1993.

Table 4. Effects of cropping sequences and pesticide treatments on Rhizoctonia limb rot of peanut during a 3-yr rotation experiment at Tifton, GA.[a]

		Rhizoctonia limb rot[b]					
		Pesticide treatment[c]				Mean	
Year	Cropping sequence[d]	Aldicarb	Flutolanil	Aldicarb + flutolanil	Untreated control	Cropping sequence	Year
		% colonized stems					
1991	P						
Treatment mean		20 A	15 B	15 B	18 A		17 y
1992	B-P					21 z	
	C-P					27 z	
	Ct-P					20 z	
	P-P					29 z	
Treatment mean		28 A	20 B	22 B	26 A		24 z
1993	B-B-P					5 y	
	C-C-P					8 yz	
	Ct-Ct-P					8 yz	
	P-P-P					11 z	
Treatment mean		11 A	5 C	7 BC	8 B		8 x

[a]Data are means of four replications. Means of pesticide treatments arranged horizontally and cropping sequences within the same year and years arranged vertically followed by the same letter are not different (Duncan's New Multiple Range Test; P = 0.05). Data pooled over pesticide treatments and cropping sequences.

[b]Percentage of stems colonized by *Rhizoctonia solani* in 15.2 m of row at harvest.

[c]Treatments were aldicarb at 3.4 kg a.i./ha, flutolanil at 1.7 kg a.i./ha, aldicarb + flutolanil, and untreated control. Aldicarb was applied in a 30-cm band at planting and incorporated 3 to 5 cm deep. Flutolanil was applied at 0.85 kg a.i./ha to peanut 60 d after planting in a 30-cm band and broadcast 30 d later in 124 L of water/ha.

[d]P = peanut, B = bahiagrass, C = corn, and Ct = cotton.

Table 5. Effects of cropping sequences and pesticide treatments on peanut yield during a 3-yr rotation experiment at Tifton, GA.[a]

		Pesticide treatment[b]				Mean	
Year	Cropping sequence[c]	Aldicarb	Flutolanil	Aldicarb + flutolanil	Untreated control	Cropping sequence	Year
		kg/ha				kg/ha	
1991	P						
Treatment mean		3600 C	4940 B	5510 A	3410 C		4370 y
1992	B-P					4800 z	
	C-P					4880 z	
	Ct-P					4860 z	
	P-P					4260 y	
Treatment mean		4560 B	4640 B	5420 A	4190 C		4700 z
1993[d]	B-B-P	4900 a	4540 ab	5300 a	3970 a	4680 z	
	C-C-P	4280 b	4570 a	4980 a	3890 a	4430 z	
	Ct-Ct-P	4000 b	4210 b	5120 a	3950 a	4320 z	
	P-P-P	2900 c	3510 c	4120 b	2070 b	3150 z	
Treatment mean		4020 A	4208 A	4880 A	3470 A		4140 x

[a]Data are means of four replications. Means of pesticide treatments arranged horizontally and cropping sequences within the same year and years arranged vertically followed by the same letter are not different (Duncan's New Multiple Range Test; P = 0.05).

[b]Treatments were aldicarb at 3.4 kg a.i./ha, flutolanil at 1.7 kg a.i./ha, aldicarb + flutolanil, and untreated control. Aldicarb was applied in a 30-cm band at planting and incorporated 3 to 5 cm deep. Flutolanil was applied at 0.85 kg a.i./ha to peanut 60 d after planting in a 30-cm band and broadcast 30 d later in 124 L of water/ha.

[c]P = peanut, B = bahiagrass, C = corn, and Ct = cotton.

[d]Significant (P = 0.05) pesticide treatment × cropping sequence interaction in 1993.

plots. Peanut yield was higher following 1 yr of bahiagrass, corn, or cotton than in continuous peanut. In 1993, yield of peanut depended on pesticide treatments and cropping sequences. In aldicarb-treated plots, peanut yield was greatest following 2 yr of bahiagrass, intermediate following 2 yr of corn or cotton, and lowest in continuous peanut. In flutolanil-treated plots, yield was greatest in peanut following 2 yr of corn, intermediate following 2 yr of bahiagrass or cotton, and lowest in continuous peanut. In aldicarb plus flutolanil and untreated plots, yield was greater in peanut following 2 yr of bahiagrass, corn, or cotton than continuous peanut. Yield of untreated continuous peanut declined 6% during the second year and 37% during the third year of the experiment.

The percentage of TSMK after grading peanuts from all plots ranged from 71 to 77% and immature kernels ranged from 4 to 8% (w/w), with neither affected significantly by pesticide treatments or cropping sequences.

Discussion

Separate studies have demonstrated the benefits of rotating peanut with bahiagrass or cotton for suppressing damage by *M. arenaria* and *S. rolfsii* compared with continuous peanut cropping systems. This study demonstrates the effectiveness of bahiagrass, cotton, and corn integrated with the use of pesticides to suppress damage by *M. arenaria*, *S. rolfsii*, *R. solani*, and thrips on peanut.

The first year of this experiment was used to determine the effects of pesticide treatments on nematodes, southern stem rot, limb rot, and thrips on peanut, and to establish a reference point that could be used to determine the effects of cropping sequences on these pests and peanut yield in subsequent years. The high J2 numbers for *M. arenaria*, particularly in flutolanil-treated and untreated plots in 1991, appeared to be carryover from previous cover crops of okra and hairy vetch. Numbers of J2 in the soil generally declined or remained stable in most plots, but increased in untreated continuous peanut over the period of the study. Aldicarb in combination with flutolanil did not consistently suppress numbers of J2 in soil. Culbreath *et al.* (1992) also reported variable effects of aldicarb on J2 population densities based on time of sampling.

Root-gall indices of peanut caused by *M. arenaria* generally were low during the experiment. The greatest increase in root-gall indices occurred in untreated continuous peanut which increased from 1.6 in 1991 to 2.5 in 1993. The reason for the low root-gall indices is not fully understood. However, *P. penetrans* has suppressed population densities of *M. arenaria* in peanut fields in Georgia and Florida (Minton *et al.*, 1991; Dickson and Chen, 1996), and may account for the low numbers of J2 in the soil and low root-gall indices in this study. The efficacy of aldicarb against *M. arenaria* and pod and root damage agrees with results of other studies (Minton *et al.*, 1991; Rodríguez-Kábana *et al.*, 1991). Our data demonstrated that root-gall indices were lower on peanut following one crop of cotton and two crops of bahiagrass, corn, or cotton than in continuous peanut. These results with bahiagrass and cotton agree with those reported by Rodríguez-Kábana *et al.* (1994). In addition, our results indicate that 2 yr of corn were as effective as 2 yr of bahiagrass or cotton in suppressing root-gall indices in peanut.

Criconemella ornata increased less on peanut following bahiagrass, corn, or continuous peanut than on peanut following cotton. Our results with corn and bahiagrass confirm those of other studies (Brenneman *et al.*, 1995), but those with peanut and cotton differ from others (Johnson *et al.*, 1974; Barker *et al.*, 1982). Reviews of nematodes attacking cotton have omitted *C. ornata* (Riggs and Niblack, 1993; Starr, 1998). Evidence of pathogenicity on cotton is lacking, but our data indicate that cotton may be a host for *C. ornata*.

The efficacy of aldicarb on suppressing thrips damage to peanut foliage agree with results reported by Johnson *et al.* (1998). Lynch *et al.* (1984) concluded that controlling the tobacco thrips alone on peanut with insecticides usually does not increase yield enough to offset the cost of control. Aldicarb is a systemic insecticide/nematicide and when used at nematicidal rates to control nematodes, thrips are controlled also. The nonsignificant effect of cropping sequence on thrips damage has been reported (Johnson *et al.*, 1998).

Incidence of southern stem rot varies each year based on environmental conditions, cropping sequences, and inoculum levels of *S. rolfsii* (Rodríguez-Kábana *et al.*, 1994). Our data support other results that indicate rotations longer than 1 yr are needed to suppress *S. rolfsii* damage in peanut (Brenneman *et al.*, 1995). Frequently, *S. rolfsii* and *M. arenaria* are concomitant in peanut fields. When populations of *M. arenaria* are suppressed by crop rotations or nematicide applications, the incidence of southern stem rot also may be reduced (Rodríguez-Kábana *et al.*, 1994). Culbreath *et al.* (1992) suggested that aldicarb may reduce predisposition of the peanut plant to *S. rolfsii* by *M. arenaria* and/or better enable it to resist attack by *S. rolfsii*. Those field studies suggested that infection of peanut by *M. arenaria* increases the incidence of southern stem rot. However, Starr *et al.* (1996) were unable to demonstrate an interaction between *M. arenaria* and *S. rolfsii* in microplot experiments. Similarly, we found no impact of aldicarb treatment on southern stem rot as previously reported by Minton *et al.* (1991). *In vitro* studies (A. S. Csinos, pers. commun.) indicate that aldicarb has no effect on growth of *S. rolfsii*.

The reduced incidence of Rhizoctonia limb rot in flutolanil treatments corroborates results reported by Brenneman *et al.* (1995). Damage by *R. solani* was reduced in peanut following a 2-yr bahiagrass sod which agrees with results of Jacobi *et al.* (1991), but not those obtained by Bell and Sumner (1993), in which damage was reduced following 1 yr of bahiagrass compared with continuous peanut. Overall, levels of limb rot were lower in 1993 than other years due to the hot, dry weather prevalent that year.

Yield increases in peanut resulting from aldicarb, flutolanil, and aldicarb plus flutolanil treatments in cropping sequences of peanut following 1 yr and 2 yr of bahiagrass and cotton confirm previous reports (Rodríguez-Kábana *et al.*, 1994; Brenneman *et al.*, 1995). Based on yield of peanut and other parameters, our data indicate that peanut benefits as much from 1 yr or 2 yr of corn as 1 yr or 2 yr of either bahiagrass or cotton. Increases in peanut yields obtained in response to pesticide treatments and cropping sequences resulted primarily from suppression of damage by *M. arenaria*, *S. rolfsii*, *R. solani*, and *Frankliniella* spp.

Our data indicate that the integrated use of aldicarb plus flutolanil with cropping sequences used in this study suppressed damage by common diseases of peanut in the region and increased yield compared to untreated continuous peanut culture. The results of this study provide information for growers to use these strategies for pest management to maximize peanut yield.

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