CROP ROTATION SYSTEMS FOR THE MANAGEMENT OF *MELOIDOGYNE ARENARIA* IN PEANUT

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ABSTRACT

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An eight-year study with peanut (*Arachis hypogaea*), soybean (*Glycine max*), and corn (*Zea mays*) was established to determine the effect of selected rotation systems with these crops on population dynamics of *Meloidogyne arenaria*. The study was conducted in a field initially lightly infested with the nematode. The size of the population of the nematode, determined each year near peanut harvest time, increased with each succeeding year in plots with continuous peanut. The pattern of increase was best described by the logistic equation $J = 600/(1 + e^{3.088-0.3289 T})$, where L represented the number of juveniles per 100 cm³ soil and T the number of years in peanut. A rotation system of one year of peanut (P) followed by 2 years of corn (C) was most effective in maintaining low (<100/100 cm³ soil) juvenile populations of the nematode. A rotation of peanut followed by a year each of 'Bragg' soybean (S) and corn was almost as effective as the P-C-C system. The P-S-C rotation resulted in populations >100 juveniles/100 cm³ soil in the 7th year but maintained juvenile numbers < 50/100 cm³ soil in all previous years. Systems in which peanut was alternated with corn (P-C), or soybean (P-S), or in which corn was followed by two successive years of peanut (C-P-P) resulted in juvenile populations in the peanut years that were as large as those of plots in continuous peanut. The inclusion of a winter cover crop of rye (*Secale cereale*) in each rotation system had no effect on final populations of *M. arenaria* in the following summer crops; however, the cover crop resulted in significant increases in yield of soybeans and corn.

Additional key words: pest management, biological control, integrated pest management, nematode ecology.

RESUMEN

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Se estableció un experimento por 8 años para estudiar los efectos de rotaciones con maní (*Arachis hypogaea*), maíz (*Zea mays*) y soya (*Glycine max*) sobre la dinámica poblacional de *Meloidogyne arenaria*. El estudio se efectuó en un campo de maní que inicialmente contenía una población baja del nematodo. El tamaño de las poblaciones finales de larvas

del nematodo determinadas cada año cerca del tiempo de la cosecha del maní, aumentó con el paso de los años en las parcelas en monocultivo de maní. El aumento de la poblaciones finales del nematodo en esas parcelas siguió el modelo descrito por la ecuación logística: $L = 600/(1 + e^{3.088-0.3289T})$ donde L representa el numero de larvas en 100 cm³ de suelo y T el número de años transcurridos en cultivo de maní. El sistema de rotación de un año de maní (A) seguido por dos años consecutivos de maíz (Z) fue el más efectivo para mantener las poblaciones del nematodo a niveles bajos (<100 larvas/100 cm³ suelo). En otro sistema en el que al maní le siguió la soya (G) en el año siguiente y a ésta el maíz en el tercer año fue casi tan efectivo como el sistema A-Z-Z para mantener bajas poblaciones larvales. El sistema A-S-Z resultó en poblaciones de >100/cm³ de suelo sólo después de siete años siendo las poblaciones de <50/100 cm³ suelo en todos los años previos. Los sistemas en los que el maní se alternó con el maíz (A-Z) o con la soya (A-G), o en el que le maíz fue seguido por dos años consecutivos de maní (Z-A-A) dieron poblaciones finales de larvas equivalentes en tamaño a las correspondientes a las de las parcelas en monocultivo de maní. La inclusión de una cosecha de centeno (*Secale cereale*) en el invierno en cada uno de los sistemas de rotación estudiados no tuvo efecto alguno sobre las poblaciones finales de larvas de *M. arenaria* seguido los cultivos de verano, aunque el centeno resultó en aumentos significativos en los rendimientos de soya y maní.
Palabras claves adicionales: manejo de plagas, combate biológico, combate integrado, ecología de nematodos.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is subject to attack by a variety of plant parasitic nematodes (7,8). Principal among these are the root-knot nematodes *Meloidogyne hapla* Chitwood and *M. arenaria* (Neal) Chitwood. In Alabama, *M. arenaria* is the most important species, infesting approximately 47% of the peanut acreage (3). *Meloidogyne arenaria* causes severe losses and there is an inverse relation between harvest-time juvenile populations of the nematode in soil and peanut yields (15). Conventionally, management of *M. arenaria* in Alabama peanut fields has been based on the use of nematicides. This approach has been followed because of the lack of commercially available cultivars tolerant (or resistant) to the nematode (6). The use of the halogenated hydrocarbon fumigants (DBCP and EDB) provided a very efficacious and profitable means of suppressing *M. arenaria* in peanut (9,10). The recent removal of these chemicals from use by producers in the U.S.A. resulted in increased use of systemic nematicides (e.g., aldicarb, phenamiphos) which although effective (10,12) are considerably more expensive than the fumigants. Thus, there is a need for development of systems for the management of *M. arenaria* in the U.S.A. that do not require nematicides or that permit reductions in their use. The value of rotations with corn (*Zea mays* L.) or sorghum (*Sorghum vulgare* Pers.) for the management of *M. arenaria* in fields with heavy infestations of the nematode is questionable (13). Little information is available, however,

on the types of rotation systems that may maintain low populations of
M. arenaria in fields where the nematode occurs at low levels of infesta-
tion. Evidence from studies in Alabama (1) and Georgia (4,5) suggests
that it may be possible to maintain low populations of the root-knot
nematodes through the proper choice of cropping sequences. This
paper presents results of a study on the effects of selected cropping
systems on populations of *M. arenaria*.

MATERIALS AND METHODS

A long-term rotation study was established in 1977 in an essentially
level field at the Wiregrass substation near Headland, Alabama. The
field had previously been in a cropping system consisting of one year of
peanut followed by two consecutive years of corn, and was left fallow
every winter. The soil was a sandy loam with less than 1.0% (w/w) or-
ganic matter, pH = 6.1, and infested with a low level of *M. arenaria*
(<50 juveniles/100 cm³ soil determined at peanut harvest time). Crop-
ping systems in the study were: 1) continuous peanut [P]; 2) continuous
soybean, *Glycine max* (L.) Merr. [S]; 3) continuous corn [C]; 4) peanut
followed by corn [P-C]; 5) peanut followed by soybean [P-S]; 6) one year
of peanut followed by two consecutive years of corn [P-C-C]; 7) one year
of corn followed by two consecutive years of peanut [C-P-P]; and, 8) one
year each of peanut, soybean, and corn [P-S-C]. Each cropping system
was represented by 24 replications (plots). Twelve of these were left
fallow each winter and 12 were planted to rye (*Secale cereale* L.) as a
cover crop. The cultivars used in the study were: 'Florunner' peanut,
'Bragg' soybean, 'Pioneer 3147' (or 'Ring Around 1502') corn, and 'Ab-
ruzzi' rye. Plots were 8-row (each 0.9 m wide) × 15 m. Treatments in
the experiments were arranged in a split-plot design with cropping se-
quence as the subplot and the type of winter cover as the main plot.

Cultural practices and control of insects, weeds, and foliar diseases
were as recommended for the area (2). Each year the rye crop was
turned under 3-4 weeks prior to the corn planting to permit decompos-
ition of the rye.

Soil samples for nematode analysis were collected every year near
peanut harvest time (early September) to coincide with the period of
maximal population development of *M. arenaria* in that crop (3). The
samples consisted of 20-25 cores obtained from the root zone to a depth
of 20-25 cm using a standard 2.5-cm-diam probe and collected at 0.25-m
spacing along the center two rows of each plot. The cores from each
plot were composited and a 100 cm³ subsample was used to determine
nematode populations with the "salad bowl" incubation technique (11).
Yield was obtained by harvesting the center two rows of each plot at
maturity of the crops.

Data from the study were analyzed following standard procedures for analysis of variance of split-plot experiments (16); correlation analyses were also performed according to standard procedures (16). Fisher's least significant difference was calculated as described by Steel and Torrie (16). Unless otherwise stated, differences referred to in the text were significant at the 5% or lower level of probability.

RESULTS AND DISCUSSION

Nematode populations. Juvenile populations of *M. arenaria* in soil were highest in plots with continuous peanut compared with plots with continuous soybean or continuous corn (Table 1). The populations in plots with continuous peanut increased exponentially with each succeeding year. The relation between numbers of juveniles in soil (J) in plots with peanut and the number of years after initiation of the study (T) conformed well (R^2 = 0.844) to the logistic equation model corresponding to:

$$J = \frac{600}{[1 + e^{3.088 - 0.3289T}]} \tag{I}$$

Other models also fit the data well. For example, the exponential equation $J = Ae^{BT}$, where A and B are constants, also fit the data well (R^2 = 0.815). However, in previous studies on development of root-knot nematodes in soybeans (14), the logistic equation model afforded good descriptions of population development for these nematodes. Consequently, we chose the logistic equation as more likely to represent population development for these nematodes across crops. Also, the logistic equation model implies that each field and crop combination has a certain "carrying capacity" or maximal population limit for the nematode. Equation (I) indicates that populations of the nematode would approach a maximum of 600 juveniles/100 cm^3 soil and that one-half the size of this maximum would be attained after approximately 9.4 years of peanut monoculture. These figures agree well with previous observations in Alabama peanut fields heavily infested with the nematode. In these fields, populations of the nematode in excess of 500 juveniles/100 cm^3 soil are common (3).

Plots with P-C and C-P-P after the first three years of the study produced higher numbers of juveniles in years with peanut than corn (Table 1). The size of the juvenile populations following peanut in these systems was predictable using equation (I), indicating that these rotations had no effect in suppressing population developments of *M. arenaria.*

The P-C-C system resulted in the lowest juvenile populations of all the multicrop systems in the study (Table 1). The size of the juvenile

Table 1. Effect of rotation systems with 'Florunner' peanut (P), 'Bragg' soybean (S), and corn (C) on juvenile populations of *Meloidogyne arenaria* determined near peanut-harvest time.

Cropping System[z]	No. juveniles/100cm³ soil by year							
	1977	1978	1979	1980[x]	1981	1982	1983	1984
Cont. Peanut	31[y]	81	46	—	129	115	158	289
Cont. Corn	0	0	1	—	2	0	17	0
Cont. Soybean	4	0	6	—	6	0	8	0
P-C	28	0	45	—	188	0	185	0
P-C-C	33	0	5	—	5	0	69	0
P-S-C	29	0	1	—	4	0	109	0
S-P	2	46	5	—	15	107	19	214
C-P-P	1	11	22	—	136	117	17	236
LSD (P = 0.05):	16	16	18	—	57	34	47	76

[x]Data for 1980 were not available; the peanut crop failed due to late season drought.
[y]Each figure represents the average of 24 replications.
[z]First crop in sequence was grown in 1977.

populations of plots with this system were never significantly higher than the population at the start of the study.

Significant increase in juvenile numbers in plots with P-S-C was observed only in the 7th year of the experiment (Table 1); however, the population then was lower than predicted with (I).

Plots with S-P resulted in such juvenile population levels in years with peanut (Table 1) that suggested that the soybean had no inhibitory effect on development of *M. arenaria* in the succeeding peanut crop when compared with development of the populations in plots with continuous peanut.

Results suggest that for a rotation of peanut with corn to be successful in maintaining low populations of *M. arenaria* in soil a period of corn cropping longer than one year is necessary. This requirement may result not only from the fact that corn is a poorer host than peanut for the nematode but also suggests that corn cropping could be conducive to development of a soil microflora antagonistic to *M. arenaria*. Extensive changes in the components of soil microflora can be expected to require long periods of time.

The interaction between the effects of cropping systems and those of cover crop on juvenile populations of *M. arenaria* were not significant. The rye cover crop had no effect on development of *M. arenaria* in plots
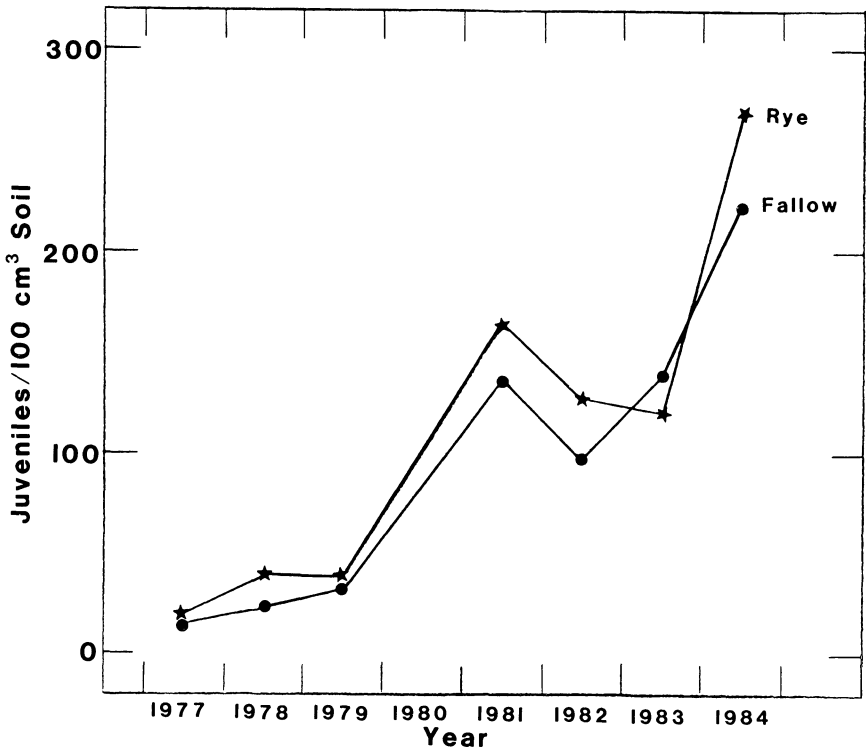
Fig. 1. Comparison of the effects of winter fallow and a winter cover crop of rye on the larval populations of *M. arenaria* following the succeeding summer crop.

with peanuts (Fig. 1). Juvenile populations of *M. arenaria* in plots with soybean or corn were low whether the crops followed rye or winter fallow. Soil samples were collected in September near peanut harvest time. Consequently, it is possible that juvenile populations in plots with corn, a poorer host for *M. arenaria* than peanut, were past their maximal level since corn in the area matures in late July-early August and larval populations of root-knot nematodes decline rapidly after maturity of the crop (1). Conversely, for soybean the sampling time may have been too early (14), although the isolate of *M. arenaria* in this field does not develop well in 'Bragg' soybean (unpublished data).

 Yields. Peanut yields from the various crop systems are presented in Table 2. Plots with P-C gave equivalent yields to those obtained with continuous peanut. In the one year (1983) when peanut yields for the P-C-C or the P-S-C systems could be obtained, yields for these systems were superior to those corresponding to the continuous peanut se-

Table 2. 'Florunner' peanut (P) yields in an 8-year study on the effects of selected cropping systems with corn (C) and 'Bragg' soybean (S) on population development of *Meloidogyne arenaria* in a field at the Wiregrass substation, near Headland, Alabama.

Cropping System[z]	Yield (kg/ha) by year							
	1977	1978	1979	1980[x]	1981	1982	1983	1984
Cont. Peanut	3588[y]	3055	2617	—	4217	3110	2297	2767
P-C	3491	—	2712	—	4388	—	2243	—
P-C-C	3344	—	—	—	—	—	3068	—
P-S-C	3350	—	—	—	—	—	2867	—
S-P	—	3270	—	—	—	3655	—	2959
C-P-P	—	3339	2753	—	4532	3115	—	2514
LSD (P = 0.05):	266	167	195	—	260	283	217	247

[x]Data for 1980 were not available; the peanut crop failed due to late season drought.
[y]Each figure represents the average of 24 replications.
[z]First crop in sequence was grown in 1977.

Table 3. 'Bragg' soybean (S) yields in an 8-year study on the effects of selected cropping systems with corn (C) and 'Florunner' peanuts (P) on population development of *Meloidogyne arenaria* in a field at the Wiregrass substation, near Headland, Alabama.

Cropping System[z]	Yield (kg/ha) by year						
	1977	1979	1980[x]	1981	1982	1983	1984
Cont. Soybean (S)	2831[y]	1771	—	2926	2170	2441	1459
P-S-C	—	—	—	2986	—	—	1749
S-P	2881	1920	—	2975	—	2552	—
LSD (P = 0.05):	N.S.	100	—	N.S.	N.S.	N.S.	160

[x]Data for 1980 were not available; the crop failed due to late season drought.
[y]Each figure represents the average of 24 replications.
[z]First crop in sequence was grown in 1977.

quence. Plots with the S-P rotation resulted in higher yields than those with P in 1978 and 1982 but not in 1984 when their yield was not different from that of the P plots. Peanut yields from C-P-P plots were higher than those of the P plots only in 1978 and 1981; yields in the

Table 4. Corn (C) yields in an 8-year study on the effects of selected cropping systems with 'Bragg' soybean (S) and 'Florunner' peanut (P) on population development of *Meloidogyne arenaria* in a field at the Wiregrass substation, near Headland, Alabama.

Cropping System[z]	Yield (kg/ha) by year					
	1978[x]	1980	1981	1982	1983	1984
Cont. Corn (C)	1325[y]	2433	3152	2442	2967	2349
P-C	1627	3732	—	2767	—	3184
P-C-C	1777	—	3649	2441	—	3116
P-S-C	—	—	—	2670	—	—
C-P-P	—	4028	—	—	3919	—
LSD (P = 0.05):	295	876	490	233	353	445

[x]Data for 1977 and 1979 were not available; the crop failed because of drought.
[y]Each figure represents the average of 24 replications.
[z]First crop in sequence was grown in 1977.

other years were either not different or were inferior to those of the P plots.

Soybean yields (Table 3) could not be obtained for 1978. Yields in plots with the S-P system were higher than those for the S plots in 1979 but not in other years. The P-S-C sequence resulted in higher soybean yields than those of plots with S in 1984 but not in 1981, the other year for which yields for the P-S-C systems were available.

Corn yields (Table 4) for 1977 and 1979 were not available; in both these years early season droughts eliminated the crop. Corn yields for all systems were higher when peanuts were planted in the preceeding year than in plots with continuous corn.

The interactions between the effects of cropping systems and those of cover crop on yields of peanut, soybean, or corn were not significant. The rye cover crop had a positive effect on yields of soybean and corn but did not affect peanut yields (Fig. 2).

CONCLUSIONS

Results from this study indicate that it possible to maintain low populations of *M. arenaria* in peanut fields with the use of cropping systems. The most effective cropping systems were those that included two successive years of corn after peanut or a sequence of a year each of peanut, soybean, and corn. The use of a rye cover crop was beneficial in increasing yields of corn and soybean.
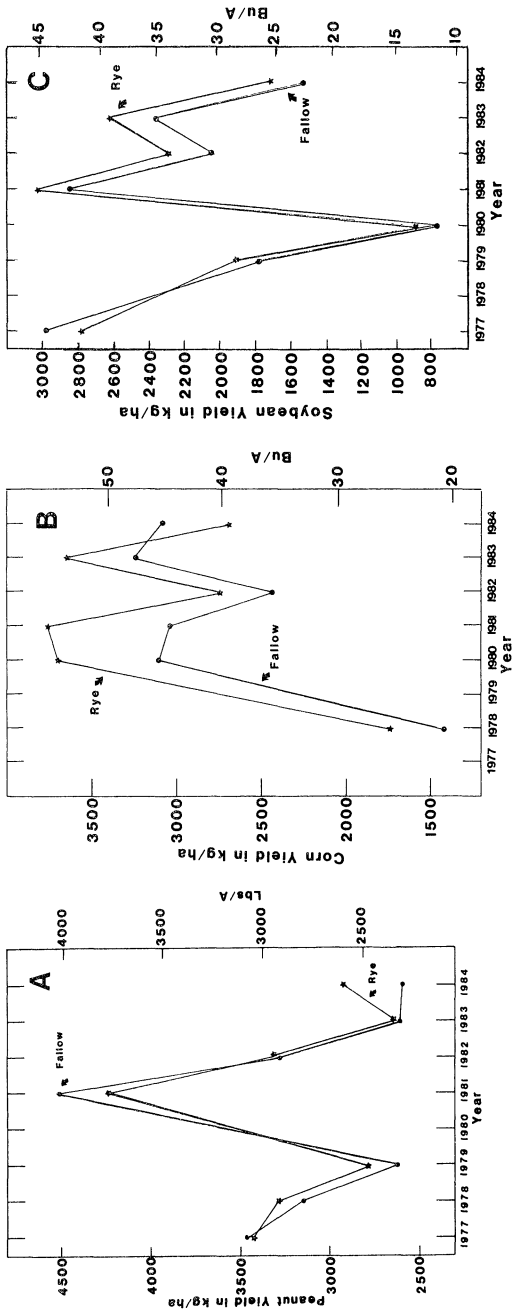
Fig. 2. Effect of a winter cover crop of rye on yields of peanut (A), corn (B), and soybean (C).

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