RESEARCH PAPERS - TRABAJOS DE INVESTIGACION

SOYBEAN YIELD LOSSES CAUSED BY *MELOIDOGYNE ARENARIA* AND *HETERODERA GLYCINES* IN A FIELD INFESTED WITH THE TWO PARASITES.

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ABSTRACT

Rodríguez-Kábana, R. and J.C. Williams. 1981. Determination of soybean yield losses caused by *Meloidogyne arenaria* and *Heterodera glycines* in a field infested with the two parasites. Nematropica 11: 93-104.

Linear multiple regression analyses were performed on data from six soybean [*Glycine max* (L) Merr.] field experiments to determine the relation between yield and soil larval populations of race 3 *Heterodera glycines* Ichinohe and of *Meloidogyne arenaria* (Neal) Chitwood. The experiments were nematicide efficacy tests conducted in 1980 in South Alabama with Bragg soybeans in a field infested with both parasites. The tests comprised treatments with fumigants (DD, EDB), systemic nematicides (aldicarb, carbofuran, oxamyl, phenamiphos) and other treatments in which combinations of anhydrous ammonia and a nitrification inhibitor (ethazole) were used to reduce nematode populations. Each experiment consisted of 14 treatments replicated eight times. A total of 672 sets of observations (yield: *H. glycines: M. arenaria*) were thus available for the study. Results indicated that larval numbers of *M. arenaria* and *H. glycines* were significantly and negatively related to yield but the the effect of *H. glycines* on yield was less pronounced than that of *M. arenaria.* The average yield loss per larva of *M. arenaria* per 100 cm^3 soil was 4.29 kg/ha, when larval numbers were determined near harvest time.

Additional key words: population dynamics, modelling, nematode control, pest management, threshold levels, root-knot nematodes, cyst nematodes.

RESUMEN

Rodríguez-Kábana, R. y J.C. Williams. 1981. Determinación de las pérdidas en rendimientos de la soya causadas por *Meloidogyne arenaria* y *Heterodera glycines* en un campo infestado con ambos parásitos. Nematropica 11: 93-104.

Se efectuaron análisis de regresión linear múltiple con datos obtenidos en 1980 de seis experimentos de campo con soya [*Glycine max* (L) Merr.] para determinar la relación entre rendimientos de soya (cultivar Bragg) y las poblaciones de larvas de *Meloidogyne arenaria* (Neal) Chitwood y de la raza 3 de *Heterodera glycines* Ichinohe. Los experimentos consistieron de pruebas sobre la eficacia de nematicidas usados en la parte meridional de Alabama en un campo infestado con los dos parásitos. Las pruebas se hicieron con tratamientos de fumigante (DD, dibromuro de etileno), nematicidas sistémicos (aldicarb, carbofurán, oxamil, fenamifos) y también con otros tratamientos en los que se utilizó amoniaco anhidro con un inhibidor de la nitrificación (ethazole) con el fin de reducir las poblaciones de los nematodos. Cada una de las seis pruebas constaba de 14 tratamientos con ocho replicaciones con un total de 672 grupos de observaciones (rendimiento: *H. glycines: M. arenaria*) para el estudio. Los resultados de los análises estadisticos señalaron que los números de larvas de *M. arenaria* y de *H. glycines* estaba correlacionado de manera linear y negativa con los rendimientos de soya pero que el efecto de las larvas de *H. glycines* sobre el rendimiento no fué tan agudo como el de *M. arenaria.* El promedio de pérdida en rendimiento por cada larva de *M. arenaria* en 100 cm^3 de suelo fue de 4.39 kg/ha.
Palabras claves adicionales: dinámica poblacional, simulación, fitomejoramiento, combate de nematodos, nematodo nodulador, nematodo del quiste.

INTRODUCTION

Species of root-knot nematodes (*Meloidogyne* Goeldi) and the cyst nematode (*Heterodera glycines* Ichinohe) are the most economically important parasites of soybeans (*Glycine max* (L) Merr.) in the southeastern United States. Control of these parasites has been primarily through the use of resistant cultivars and effective nematicides (3,4,5,9). Commercial cultivars typically have resistance to one or two species of the nematodes; presently there are no cultivars available with combined resistance to all *Meloidogyne* spp. and races of *Heterodera glycines* (3,7). Production fields in Alabama frequently are infested with mixtures of these parasites and control relying solely on resistant cultivars is not possible (10,11). A prerequisite to the development of strategies for control of nematodes in fields with species mixtures is the determination of the relative contribution of each component species of the mixture to soybean yield losses. Accurate indication of the main yield-limiting species present in a field is necessary to permit the correct choice of resistant cultivar and to assess the value of other control measures directed against the species. The present study was conducted to develop soybean yield loss estimates using data from a field with a mixture of two important nematode parasites of soybeans in Alabama.

MATERIALS AND METHODS

Data for the study were obtained from a series of experiments on nematicide efficacy conducted in 1980 in a soybean field near Summerdale, Alabama. The field had been in soybeans for the previous three years and was infested with a mixture of *Meloidogyne arenaria* (Neal) Chitwood and race three of the cyst nematode, *Heterodera glycines* Ichinohe. The soil was a loamy sand with a pH of about 6.1. Nematicides in the experiments were various rates of fumigants (DD, EDB), systemic nematicides (aldicarb, carbofuran, oxamyl, phenamiphos), and other treatments in which combinations of anhydrous ammonia and a nitrification inhibitor (ethazole) were used to establish gradients in populations of the two nematodes. There were a total of six experiments each consisting of 14 treatments with eight replications (plots) arranged in a randomized complete block design. Each plot consisted of two-rows, each 91 cm wide and six meters long. All experiments were with the cultivar Bragg. Cultural practices, control of weeds, insects, and foliar diseases were as recommended for the area (1). Yields were obtained at maturity by harvesting the entire plot area.

Soil samples for nematode analyses were collected from all plots both 14 days after planting and two weeks prior to harvesting. At each sampling, 2.5-cm-diameter soil cores were obtained from the root zone to a depth of 15-20 cm along the centers of each of the two rows in each plot for a total of 16-20 cores per plot. The cores within a plot were composited and a 100 cm^3 subsample was used for analysis. Nematode numbers were determined following a modified pie-pan technique described elsewhere (8).

Multiple regression equations were obtained following standard techniques for linear regression analyses (12). In establishing the regression equations between yields and larvae of the nematodes only the means from each treatment in every experiment were used.

RESULTS

Numbers of larvae of *M. arenaria* 14 days after planting were low and not related to soybean yields; however, numbers in samples taken prior to harvest ranged from 0-115/100 cm^3 soil (Table 1). Numbers of larvae of *H. glycines* were significantly higher in early season samples than in samples collected near harvest time (Tables 1,4).

Linear regression coefficients relating yield (Y) as the dependent variable to the number of larvae of *M. arenaria* near harvest (X_r) and early season larval numbers of *H. glycines* (X_{c1}) are presented in Table 1. The regression coefficients for cyst nematode larvae (b_{c1}) varied from -14.48 to -0.193 and the range in values for the corresponding *M. arenaria* coefficients (b_r) was from -14.796 to -3.086. The linear model described the relation of Y on the two independent variables well for all experiments except No. IV and VI ($P < 0.05$) and accounted for a large part of the variability in soybean yields ($R^2 > 0.41$). The generalized equation for all six experiments was Y = 1107 - 2.33

Table 1. Linear multiple regression analyses of Bragg soybean yields as dependent variable (Y) on numbers of larvae of *Meloidogyne arenaria* and early-season larval populations of *Heterodera glycines* (race 3) with data from six field experiments conducted in 1980 on a farm near Summerdale, Alabama

Experiment No.[w]	Y-intercept	Regression Coefficients[z]		Coefficient of determination	Probability
		b_{cl}	b_r	(R^2)	$(P > F)$
I	1214	- 0.19	- 3.48	0.46	0.03
II	1225	- 4.44	- 4.44	0.58	0.009
III	1293	- 7.69	-14.79	0.73	0.0007
IV	902	- 2.70	- 3.08	0.21	0.26
V	1099	-14.48	- 4.04	0.56	0.011
VI	1146	- 2.19	- 7.11	0.38	0.06

[w] Total number of sets per experiment = 14; each set of values represented the means of eight field observations for yield and larval numbers.

[z] b_{cl} = regression coefficient for early-season *H. glycines* larval populations; b_r = the coefficient for *M. arenaria* larvae.

Table 1 continued. Linear multiple regression analyses of Bragg soybean yields as dependent variable (Y) on numbers of larvae of *Meloidogyne arenaria* and early-season larval populations of *Heterodera glycines* (race 3) with data from six field experiments conducted in 1980 on a farm near Summerdale, Alabama

Experiment	Range			Mean		
	Yield	Larvae per 100 cm^3 soil			Larvae per 100 cm^3 soil	
No. [w]	(kg/ha)	*M. arenaria*	*H. glycines*	(kg/ha)	*M. arenaria*	*H. glycines*
I	859-1500	4-115	6-93	1005	49	57
II	676-1409	0-113	14-84	967	35	26
III	651-1383	0-29	4-47	989	22	9
IV	488-1332	13-84	10-39	697	24	45
V	498-1277	15-123	1-14	706	7	72
VI	556-1329	2-75	3-45	883	17	32

[w] Total number of sets per experiment = 14; each set of values represented the means of eight field observations for yield and larval numbers.

[z] b_{c1} = regression coefficient for early-season *H. glycines* larval populations; b_r = the coefficient for *M. arenaria* larvae.

Table 2. Linear regression analyses of Bragg soybean yields as dependent variable (Y) on numbers of larvae of *Meloidogyne arenaria* disregarding the effect of *Heterodera glycines* (race 3) with data from six field experiments conducted in 1980 on a farm infested with both parasites near Summerdale, Alabama

Experiment No.[w]	Y-intercept	Regression[z] coefficient (b_r)	Coefficient of determination (R^2)	Probability $P > F$
I	1211	- 3.60	0.46	0.008
II	1103	- 5.22	0.46	0.007
III	1154	-17.78	0.56	0.002
IV	881	- 4.05	0.20	0.11
V	980	- 3.82	0.41	0.013
VI	1107	- 7.06	0.36	0.022

[w] Total number of sets per experiment = 14; each set of values represented the means of eight field observations for yield and larval numbers.

[z] b_r = regression coefficient for *M. arenaria* larvae.

Table 3. Linear regression analyses of Bragg soybean yields as dependent variable (Y) on early season numbers of larvae of *Heterodera glycines* (race 3) disregarding the effect of *Meloidogyne arenaria* with data from six field experiments conducted in 1980 on a farm infested with both parasites near Summerdale, Alabama

Experiment No.[w]	Y intercept	Regression[z] coefficient b_{c1}	Coefficient of determination (R^2)	Probability $P > F$
I	1121	- 2.36	0.18	0.121
II	1177	- 5.92	0.27	0.055
III	1227	-10.97	0.37	0.020
IV	857	- 6.58	0.15	0.17
V	793	-12.09	0.10	0.26
VI	913	- 1.79	0.01	0.72

w Total number of sets per experiment = 14; each set of values represented the means of eight field observations for yield and larval numbers.

z b_{c1} = regression coefficient for early season *H. glycines* larval populations.

Table 4. Multiple linear regression analyses of Bragg soybean yields as dependent variable (Y) on numbers of larvae of *Meloidogyne arenaria* and harvest-time larval populations of *Heterodera glycines* (race 3) with data from six field experiments conducted in 1980 on a farm near Summerdale, Alabama

Experiment No.[w]	Y intercept	Regression b_{c2}	Coefficients b_r	Coefficient of determination (R^2)	Probability $P > F$	*Heterodera glycines* Larvae per 100^3cm soil Range	Mean
I	1031	11.78	- 3.34	0.555	0.012	8-22	14
II	943	5.52	- 5.31	0.495	0.023	18-43	28
III	1035	7.27	-15.39	0.622	0.005	4-39	13
IV	938	-13.52	- 4.05	0.225	0.245	2-8	4
V	1380	-38.81	- 5.22	0.577	0.009	3-11	8
VI	1189	- 9.01	- 7.39	0.395	0.063	4-19	7

[w] Total number of sets per experiment = 14; each set of values represented the means of eight field observations for yield and larval numbers.

[z] b_{c2} = regression coefficient for harvest-time *H. glycines* larval populations; b_r = the coefficient for *M. arenaria* larvae.

Table 5. Linear regression analyses of Bragg soybean yields as dependent variable (Y) on harvest-time numbers of larvae of *Heterodera glycines* (race 3) disregarding the effect of *Meloidogyne arenaria* with data from six field experiments conducted in 1980 on a farm infested with both parasites near Summerdale, Alabama

Experiment No.[w]	Y intercept	Regression[z] coefficient b_{c2}	Coefficient of determination (R^2)	Probability $P > F$
I	788	15.516	0.170	0.1429
II	749	7.770	0.056	0.4025
III	801	14.120	0.262	0.0611
IV	755	-13.509	0.0215	0.6167
V	726	- 2.579	0.00097	0.9158
VI	908	- 3.221	0.0036	0.8384

[w] Total number of sets per experiment = 14; each set of values represented the means of eight field observations for yield and larval numbers.

[z] b_{c2} = regression coefficient for harvest-time *H. glycines* larval populations.

X_{c1} -4.29X_r and the regression was significant ($P < 0.0001$). The corresponding coefficient of determination for the equation was $R^2 = 0.550$.

Calculation of the linear regression equations relating yield to numbers of larvae of the root-knot nematode without consideration of the effect of *H. glycines* indicated that the regression coefficients varied from a value of -17.785 to a value of -3.602 (Table 2). All the simple regressions but one (experiment IV) were significant ($P < 0.05$); the generalized equation for yield and *M. arenaria* larvae for all yields was: $Y = 1069\text{-}4.84X_r$ with $R^2 = 0.526$ and was significant at $P < 0.0001$.

When regression coefficients were calculated considering yield and early season larval populations of the cyst nematode and disregarding the effect of *M. arenaria*, values for the coefficients varied from -12.098 to -1.797 (Table 3); only two of the regression coefficients were significant, viz., experiment III at $P < 0.05$ and experiment II at $P < 0.06$. The generalized equation was: $Y = 990\text{-}4.49X_{cl}$ with $R^2 = 0.381$ significant at $P < 0.001$.

Linear regression coefficients relating yield and number of *M. arenaria* and late-season larval numbers of *H. glycines* are presented in Table 4. The regression coefficients for cyst nematode larvae (b_{c2}) varied from -38.81 to 11.78 and the corresponding range in values for the *M. arenaria* coefficient was -15.39 to -3.34. The average yield loss from one cyst nematode larva per 100 cm^3 of soil was -6.13 ± 17.16 kg/ha; the average yield loss caused by a single *M. arenaria* larva was -6.78 ± 4.05 kg/ha. The linear model chosen to describe the relation between yield and nematode numbers fitted well for all experiments except two (No. IV and VI). The generalized equation for all the experiments was $Y = 987 + 5.89X_{c2}$ -4.65X_r where X_{c2} represented late season larval populations of *H. glycines.* The linear regression and corresponding coefficient of determination for the equation ($R^2 = 0.542$) were significant ($P < 0.0001$).

Calculation of the regression coefficients for yield and late-season larval populations of *H. glycines* disregarding the effect of *M. arenaria* evidenced a range in values for the coefficients from -13.50 to + 15.516 (Table 5); none of the simple regression coefficients was significant ($P < 0.05$).

DISCUSSION

Although the soybean cyst nematode is relatively new to Alabama, it has spread in the last decade to virtually all counties (2). In many soybean fields of the state, the nematode occurs simultaneously with species of *Meloidogyne*. Our results indicate that severe yield losses are caused by the combination of *H. glycines* and *M. arenaria*. This is important in view of the current scarcity of commercial soybean cultivars with resistance to both species. Indeed, we have found (11) that an inverse relation exists between larval populations of the two species in response to the presence of cultivars with tolerance (resistance) to either of the two species. It is thus important to determine which of the two parasites contributes greatest to yield loss in any field with mixed populations of the two nematode species. Such determination is a prerequisite for development of recommendations for use of resistant (or tolerant) cultivars against one of the two species present in fields with mixed populations of the nematodes and to be able to assess the damage sustained from the other species to which the cultivar chosen is susceptible.

Results from this study indicate that end-of-season larval populations of *M. arenaria* influenced yield more than larval populations of *H. glycines* determined early in the season; late season larval populations of *H. glycines* were not related to yield. The average yield loss per larva (100 cm^3 of soil) of *M. arenaria* adjusted for the effect of *H. glycines* was 4.29 kg/ha. This agrees well with the expected loss in fields of Bragg soybeans where the nematode occurs singly (8). The cultivar Bragg is somewhat tolerant of *M. arenaria* and susceptible to race 3 of *H. glycines* (3,7); however, other studies have shown that *M. arenaria* causes significant damage to the cultivar resulting in substantial yield losses (5,11).

The field chosen for the experiments contained end-of-season larval populations of *M. arenaria* ranging from 0-123 larvae/100 cm^3 of soil. This range would encompass situations existing in lightly (less than 50 larvae/100 cm^3 soil) to intermediately infested (50-250 larvae/100 cm^3 soil) fields. The corresponding range for early-season larval populations of *H. glycines* was 1-93 which we consider encompasses light to moderate infestations of this nematode. Consequently, our calculations are based on data comparable to those expected from representative soybean fields in South Alabama. We consider, therefore, that the equations derived from this study should serve as good guides to estimate yield losses for the area in fields with combined infestations of the two parasites. However, data used for the study were from a single season, one field, and one cultivar. The equations obtained are thus limited in their application since the influences of season, soil type and cultivar on regression coefficients remain undetermined. We have shown that soybean cultivar can affect the value of regression coefficients between yield and larval numbers of *M. arenaria*, and that regression coefficients may also be subject to seasonal variations (8). Thus, it will be necessary to determine the magnitude of the effects of these variables on regression coefficients before the equations can be put to general use by advisory personnel. Although these equations were developed using nematode counts taken after planting, their predictive capabilities can be increased when these post-plant counts can be related to preplant nematode densities.

The data for the cyst nematode suggest that its larval populations in the soil did not develop well in comparison with *M. arenaria*; there were significantly lower numbers of *H. glycines* larvae at the end of the season than in the early-season samples. The prevailing high soil temperatures (28-35C at 10 cm depth) in the field during the season may explain the dominance of *M. arenaria* over *H. glycines*. The relation between *M. arenaria* and *H. glycines* may also be affected by the presence of fungal parasites of the cyst nematode. A number of fungi capable of destroying cysts and eggs of *H. glycines* have been found in southern Alabama (6) and are present in cysts from fields in areas of Florida bordering Alabama (Rodríguez-Kábana, unpublished, December, 1981).

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