CORRELATION OF *BELONOLAIMUS LONGICAUDATUS*, *HOPLOLAIMUS GALEATUS*, AND SOIL TEXTURE WITH YIELD OF ALYCECLOVER (*ALYSICARPUS* SPP.)†

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ABSTRACT

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The growth of selected genotypes of *Alysicarpus ovalifolius* and *A. vaginalis* was monitored for 2 years in a field infested with *Belonolaimus longicaudatus* and *Hoplolaimus galeatus*. Nematode populations, plant nutrients in the soil, and soil texture were measured periodically at various points within the field and compared with plant growth. *Belonolaimus longicaudatus* density was positively correlated and *H. galeatus* density was negatively correlated with soil sand content. Yield was negatively correlated with *B. longicaudatus* density and with percentage sand, but was positively correlated with *H. galeatus* density. Multiple regression analyses indicated that yield was more closely correlated with sand content than with the population density of either nematode species.

Key words: alyceclover, *Alysicarpus ovalifolius*,, *Alysicarpus vaginalis*, *Belonolaimus longicaudatus*, *Criconemella* spp., *Hoplolaimus galeatus*, leguminous forage crops, soil texture, tropical legume crops.

RESUMEN

Mashela, P., R. McSorley, L. W. Duncan y R. A. Dunn. 1991. Correlación de *Belonolaimus longicaudatus*, *Hoplolaimus galeatus*, y textura de suelo con el rendimiento de alisicarpo (*Alysicarpus* spp.). Nematrópica 21:177–184.

El desarrollo de genotipos seleccionados de *Alysicarpus ovalifolius* y *A. vaginalis* fue monitoreado por 2 años en un campo infestado de *Belonolaimus longicaudatus* y *Hoplolaimus galeatus*. Se midió en forma periódica las poblaciones de nematodos, nutrientes en el suelo y textura del suelo en varios puntos del campo y se comparó con el desarrollo de la planta. La densidad de *B. longicaudatus* se correlacionó de manera positiva con la textura del suelo, mientras que la densidad de *H. galeatus* lo hizo de manera negativa. El rendimiento se correlacionó negativamente con la densidad de *B. longicaudatus* y con el porcentage de arena, pero positivamente con la densidad de *H. galeatus*. El análisis de regresión múltiple indicó que el rendimiento se correlacionó mas estrechamente con el contenido de arena que con la densidad poblacional de ambas especies de nematodos.

Palabras clave: alisicarpo, *Alysicarpus ovalifolius*, *Alysicarpus vaginalis*, *Belonolaimus longicaudatus*, *Criconemella* spp., cultivo tropical leguminoso, *Hoplolaimus galeatus*, leguminosa forragera, textura de suelo.

INTRODUCTION

Alyceclover (*Alysicarpus* spp.) is a determinate, leguminous forage crop that is better adapted to tropical and subtropical climates (7) than are the *Trifolium* spp. (17) commonly used as forage legumes in temperate regions. Alyceclover has relatively few known pests (11) and provides excellent grazing, high quality hay, and feed (3,21). Its bushy growth habit affords excellent features for use as a cover crop, and it also may be used as a seed crop (18). Its potential as a summer forage legume is being

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evaluated in the southeastern region of the United States, particularly in Florida.

Meloidogyne spp. can seriously limit production of alyceclover (11,18,19). A selection program of *Alysicarpus* spp. for feeding quality, maturity, seedling vigor, and resistance to *Meloidogyne* spp. was initiated in 1982 at the University of Florida in Gainesville. The germplasm introduced into the United States from the Philippines in 1908 (13) was designated "common alyceclover" and served as a standard for rating more recently introduced germplasm from Africa, Australia, India, Brazil, and Sri Lanka (18). The recently introduced genotypes were each assigned the acronym FL (Florida), followed by an Arabic numeral. A series of studies indicating that *A. vaginalis* (L.) DC genotype FL-5 is of higher feeding quality, and matures one month earlier than common alyceclover, resulted in the release of FL-5 for commercial production in 1985 (4). However, FL-5 is susceptible to *Meloidogyne* spp. and lacks seedling vigor. The genotype FL-3 of *A. ovalifolius* (Schumach) J. Leon is resistant to *Meloidogyne* spp. and has vigorous seedlings (18) but low feeding quality due to thick stems (20). FL-3 was released in 1989, after it had been established that, when grown on soil infested with *Meloidogyne* spp., it produced higher feeding quality forage than did infected common alyceclover (2).

In 1987, during field seed increase programs for alyceclover genotypes FL-1, FL-2, and FL-3, patches of stunted and dead plants were observed. Transition areas between the affected and unaffected plants contained plants that exhibited a range of stunting. Root systems had no root-knot nematode galls, but there were substantial populations of *Belonolaimus longicaudatus* Rau and *Hoplolaimus galeatus* (Cobb) Filipjev & Schuurmans Stekhoven in some parts of the field and noticeable variation in soil texture throughout the field. Since *B. longicaudatus* is a major pest of certain crops in the southeastern United States, particularly in sandy soils, and since *H. galeatus* (6) is widespread in this region, a 2-year field study was conducted to examine relationships between the growth of alyceclover and soil texture and various naturally occurring population densities of each nematode species. Results of greenhouse studies to independently measure the effect of each factor on growth of alyceclover are reported elsewhere (12).

MATERIALS AND METHODS

First season, 1987: On 16 April 1989, a 76.5 × 22.4 m field with 0% slope at the University of Florida in Gainesville was prepared by plowing, discing, and incorporating a fertilizer mixture (3% N: 10% P: 20% K) and two herbicides, benefin and vernolate, at rates of 448, 1.26, ad 3.75 kg a.i./ha, respectively. On 22 May, a second fertilizer mixture (0% N: 10% P: 20% K) was applied (448 kg/ha) and incorporated into the soil. On 28 August, fertilizer (0% N: 10% P: 20% K) was broadcast (300 kg/ha) as a midseason supplement.

The field was divided into three 76.5-m × 4.8-m strips spaced 0.6 m apart, parallel to the direction of planting rows. Each strip contained seven planting rows spaced 0.27 m apart. On 23 May, all rows in each strip were planted to hand-scarified seed of one of the three genotypes, FL-1, FL-2, or FL-3. The land was sprinkler-irrigated immediately after planting and when necessary thereafter. Weeds were controlled by hoeing throughout the growing season. By mid-October, dead and stunted plants were readily evident.

On 26 October 1987, sixteen 1-m × 1-m plots, spaced 3.7 m apart, were demarcated along the middle row of each strip. Two plants in each plot were collected at random and plant heights and fresh weights of roots and foliage were determined. Five soil cores were collected from each plot at random to a depth of 20 cm using a cone-type subsampling tool (apex diam, 2.3 cm) (8). Soil cores were composited and nematodes were extracted from 100-cm^3 subsamples by a sugar flotation-centrifugation technique (10). Nematodes were identified and counted at 45× magnification under a dissecting microscope.

Soil texture was determined mechanically by the hydrometer method (5). The soil was analyzed for plant nutrients, pH, and organic matter by the University of Florida Soil Testing Laboratory, Gainesville, using standard analytical methods (15). After harvest, plant residues were plowed under and the land fallowed until the resumption of the experiment the following year.

Second season, 1988: The site was prepared as described for the previous season and planted on 24 May. Each of two 4.8-m-wide strips of land used in 1987 were subdivided into 1.8-m strips, spaced 0.3 m apart, and each 1.8-m strip was planted to FL-2, FL-3, or FL-4. Twenty-three 1.8-m × 1.8-m plots, spaced 2.7 m apart, were marked along each strip. Border rows between the strips were planted to common alyceclover.

Planting, cultural practices, and sampling procedures were the same as in the previous season. Samples for nematode assays were collected at planting, at midseason, and at harvest. Plants were collected and measured as in the previous year at midseason and at harvest. Soil texture was determined from midseason samples; nutrient elements were not evaluated.

Relationships between yield, nematode densities, soil sand content, and plant nutrients were evaluated by performing multiple regression analyses and by calculating Pearson's product-moment correlation coefficients (9). Reproduction of nematodes on alyceclover was evaluated by computing the multiplication factors at midseason (Pm/Pi) and at the end of the season (Pf/Pi) for plots with Pi > 0 nematodes/soil sample.

Table 1. Yield measurements or correlation coefficients relating final yield components of three *Alysicarpus* genotypes and final nematode densities of *Belonolaimus longicaudatus* (BL) or *Hoplolaimus galeatus* (HG), 1987.

Alyceclover genotype	Yield component	Yield[z]	Correlation coefficient	
			BL	HG
FL-1	Root wt (g)	4.7	–0.436*	0.752**
	Top wt (g)	126.0	NS	NS
	Top ht (cm)	72.9	–0.476*	0.587**
FL-2	Root wt (g)	4.1	NS	NS
	Top wt (g)	104.0	NS	NS
	Top ht (cm)	72.3	NS	NS
FL-3	Root wt (g)	9.8	–0.459*	0.497*
	Top wt (g)	134.0	–0.513**	0.596**
	Top ht (cm)	74.6	–0.512**	0.488*

*Significant at $0.05 \leq P \leq 0.10$; **significant at $P \leq 0.05$; NS = not significant at $P \leq 0.10$ (n = 16).
[z]Averaged over 16 plots.

RESULTS

First season, 1987: Three plant-parasitic nematodes were common in the test plots: *Belonolaimus longicaudatus, Hoplolaimus galeatus* (Cobb) Filipjev & Schuurmans Stekhoven, and *Criconemella* spp. All yield component measurements of FL-1 and FL-3 except for foliar weight of FL-1 were inversely related ($P < 0.05$) to *B. longicaudatus* Pf and positively realted ($P < 0.05$) to *H. galeatus* Pf (Table 1). Multiple regression of yield data on Pf of *B. longicaudatus* and *H. galeatus* indicated *B. longicaudatus* was the better predictor of yield. Yields were not correlated with densities of *Criconemella* spp.

Sand content in the test plots ranged from 76 to 94%. Final yield components were generally negatively correlated with percentage sand, but only the correlations of percentage sand with FL-1 root weight ($r = -0.635$) and with FL-3 height ($r = -0.539$) were significant ($P < 0.05$). In each of these two cases, multiple regression of yield on final densities of *B. longicaudatus* indicated that percentage sand was more closely correlated with yield than was *B. longicaudatus* density.

Plots with $> 80\%$ sand, towards the center of the field, had the highest densities of *B. longicaudatus.* Soil nutrient concentrations in plots with $> 80\%$ sand were similar to those in plots with $< 80\%$ sand. Foliar height and weight of genotype FL-1 were correlated with Ca level ($r = 0.499$, $P < 0.10$), while foliar height and weight of FL-3 were correlated with Mg level ($r = 0.571$, $P < 0.05$). Multiple regression of yield on Ca, Mg, *B. longicaudatus,* and percentage sand indicated that *B. longicaudatus* and percentage sand were much better predictors of yield than were nutrients. Yield was not correlated with pH or organic matter.

Second season, 1988: At planting, *Criconemella* spp. had declined to negligi-

Table 2. Initial (Pi), midseason (Pm), and final (Pf) population densities of *Belonolaimus longicaudatus* and *Hoplolaimus galeatus,* and their reproductive factors (Pm/Pi, Pf/Pi) on three alyceclover genotypes, 1988.

		Population density/100 cm^3 soil[z]			Reproductive factors	
Genotype	Replication	Pi	Pm	Pf	Pm/Pi	Pf/Pi
		Belonolaimus longicaudatus				
FL-2	1	3 (0–11)	6 (0–11)	9 (0–21)	0.45	0.45
	2	9 (0–18)	8 (0–37)	5 (0–17)	2.08	0.58
FL-3	1	6 (0–16)	11 (0–29)	6 (0–15)	1.63	0.88
	2	11 (0–25)	16 (0–37)	6 (0–16)	1.36	0.43
FL-4	1	6 (0–29)	9 (0–26)	6 (0–20)	2.56	0.67
	2	8 (0–21)	18 (0–73)	5 (0–17)	1.92	0.67
		Hoplolaimus galeatus				
FL-2	1	4 (0–17)	8 (0–32)	7 (0–24)	1.43	1.43
	2	5 (0–14)	5 (0–21)	8 (0–23)	0.86	1.29
FL-3	1	6 (0–13)	12 (0–41)	5 (0–21)	1.76	0.63
	2	5 (0–18)	11 (0–43)	14 (0–36)	2.00	2.43
FL-4	1	6 (0–18)	14 (0–37)	14 (0–34)	1.89	2.00
	2	6 (0–18)	14 (0–37)	13 (0–34)	1.67	1.11

[z] Data are means and ranges (in parentheses) of 23 plots; reproductive factors computed for plots with Pi > 0.

ble levels compared with the first season and were subsequently excluded from the study. *Belonolaimus longicaudatus* and *H. galeatus*, however, were common in the test plots with *B. longicaudatus* densities gradually increasing from the ends of the field toward the center, while *H. galeatus* densities increased in the opposite direction. By midseason, populations of both nematode species had increased. By the end of the season, the reproductive factors (Table 2) for *H. galeatus* under all genotypes but FL-3 in Field 1 were greater than one; those for *B. longicaudatus* under all genotypes in both fields were less than one.

Midseason and final yields were negatively correlated with Pi, Pm and Pf of *B. longicaudatus*, but positively correlated with *H. galeatus* densities (Table 3). Multiple regression models relating yield components to densities of both *B. longicaudatus* and *H. galeatus* were attempted, but *H. galeatus* was not a useful predictor. Plant sizes at midseason and harvest also were negatively correlated with percentage sand. The strongest correlations were between percentage sand and plant height, followed by root weight and foliar weight (Table 3). Multiple regression of yield against *B. longicaudatus* densities and percentage sand indicated that sand content was more closely correlated with yield than was *B. longicaudatus* density. In most cases, *B. longicaudatus* densities were positively related to percentage sand (*P*

Table 3. Correlation coefficients (n = 23) relating midseason (M) or final season (F) yield of three alyceclover genotypes and initial nematode densities for each of two nematodes, *Belonolaimus longicaudatus* (BL) and *Hoplolaimus galeatus* (HG), or percentage sand (PS), 1988.

				Correlation coefficient					
				Field 1			Field 2		
Genotype	Harvest time	Yield component	Yield^z	BL	HG	PS	BL	HG	PS
FL-2	M	root wt (g)	3.2	–0.60**	NS	NS	–0.52**	0.40**	–0.50**
		top wt (g)	58.5	–0.60**	0.56**	NS	–0.49**	0.54**	–0.55**
		top ht (cm)	20.4	–0.72**	NS	NS	–0.73	0.36*	–0.71**
	F	root wt (g)	5.2	NS	0.41**	NS	–0.71**	NS	–0.67**
		top wt (g)	102.4	NS	0.55**	NS	–0.54**	0.40**	–0.37*
		top ht (cm)	19.0	–0.46**	0.43**	NS	–0.73**	0.41**	–0.63**
FL-3	M	root wt (g)	3.3	NS	0.44**	NS	NS	NS	NS
		top wt (g)	70.2	NS	0.61**	NS	NS	NS	NS
		top ht (cm)	49.4	–0.56**	0.79*	–0.73**	NS	0.56**	–0.42*
	F	root wt (g)	6.4	–0.43*	0.40**	–0.54**	NS	0.47**	NS
		top wt (g)	92.9	NS	NS	NS	NS	0.38*	NS
		top ht (cm)	47.2	NS	0.44**	–0.44*	NS	0.48**	–0.59**
FL-4	M	root wt (g)	4.0	–0.40*	NS	–0.74**	NS	NS	–0.37*
		top wt (g)	71.9	–0.72**	NS	–0.70**	NS	NS	–0.37*
		top ht (cm)	34.8	NS	NS	NS	–0.72**	NS	–0.62**
	F	root wt (g)	7.1	NS	0.46**	–0.68**	–0.36*	NS	–0.59**
		top wt (g)	82.7	NS	0.36*	–0.62**	NS	NS	–0.50**
		top ht (cm)	36.9	–0.46**	NS	–0.88**	NS	NS	–0.36*

*Significant at $0.05 \leq P \leq 0.10$; **significant at $P \leq 0.05$; NS = not significant at $P \leq 0.10$.

^{z}Averaged over 23 plots.

Table 4. Correlation coefficients relating initial (Pi), midseason (Pm), or final (Pf) population densities of either *Belonolaimus longicaudaus* (BL) or *Hoplolaimus galeatus* (HG) with percentage sand in two fields under three alyceclover genotypes, 1988.

		Correlation coefficient^z			
		Field 1		Field 2	
Population	Genotype	BL	HG	BL	HG
Pi	FL-2	NS	NS	0.656**	–0.377*
	FL-3	0.663**	–0.644**	0.514**	NS
	FL-4	0.736**	NS	0.689**	NS
Pm	FL-2	NS	NS	0.499**	–0.395*
	FL-3	0.533**	–0.792**	0.807**	–0.500**
	FL-4	0.585**	NS	0.630**	–0.487**
Pf	FL-2	0.450*	NS	0.603**	NS
	FL-3	NS	–0.651**	0.518**	–0.435*
	FL-4	0.429*	NS	0.599**	–0.716**

*Significant at $0.05 \leq P \leq 0.10$; **significant at $P \leq 0.05$; NS = not significant at $P \leq 0.10$.
^{z}Based on data from 23 plots.

< 0.05). *Hoplolaimus galeatus* densities were inversely related to percentage sand in about half of the cases measured (Table 4).

DISCUSSION

Reproductive factors measured at midseason indicated that *B. longicaudatus* and *H. galeatus* reproduced and developed on all alyceclover genotypes tested. However, *B. longicaudatus* populations declined after midseason under all three genotypes tested, suggesting the acquisition of resistance during plant maturity or the downward movement of *B. longicaudatus* below the 20-cm sampling depth (14). *Belonolaimus longicaudatus* feeds on root tips (6), which occur more deeply as the plant grows.

Generally, where sand content was high, *B. longicaudatus* densities were high, *H. galeatus* densities were low, and plant growth was reduced. *Belonolaimus longicaudatus* has a wide host range (6), and significant negative correlations between yield and *B. longicaudatus* density suggest that *B. longicaudatus* damages alyceclover.

Yield was negatively correlated with percentage sand. Since there was no positive correlation between yield and nutrient concentrations, the effect of sand on yield is not likely due to nutrient leaching. Positive correlations between *B. longicaudatus* densities and percentage sand are consistent with reported effects of sand content on *B. longicaudatus* (16). Alyceclover growth was inversely related to preplant population density of *B. longicaudatus* in greenhouse experiments where the tolerance limit was estimated to be < 3.0 nematodes/100 cm^3 soil (12). It would seem reasonable to conclude that reduced plant growth in sandier areas was due, in part, to the presence of pathogenic levels of *B. longicaudatus.*

The positive correlation between final population of *H. galeatus* and yield in 1987 likely resulted from increased reproduction in vigorous plants. The positive correlation between yield and initial density of *H. galeatus* in 1988, however, requires a different explanation. Alyceclover growth could have been stimulated by *H. galeatus* as Wallace (20) observed for some crops infected with low densities of *Meloidogyne* spp. A more likely explanation is that high initial populations of *H. galeatus* were coincidental with low sand content and innocuous levels of *B. longicaudatus*. Ahmad and Chen (1) noted that *H. galeatus* reproduction is greater in sandy clay loam than in loam or sandy soil, in agreement with the negative correlations between population density of *H. galeatus* and percentage sand measured in this study.

In conclusion, positive correlations of *H. galeatus* with yield, and negative correlations of yield with percentage sand or *B. longicaudatus* density, were observed for all of the alyceclover genotypes. The poor performance of alyceclover genotypes in sandier soil (> 80% sand) may be related to high sand content or to the prevalence of *B. longicaudatus* in sandy soils. In either case, these results indicate that alyceclover, a primary forage with some genotypes resistant to root-knot nematodes, may perform poorly on sandy soils infested with *B. longicaudatus*.

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