EFFECT OF TILLAGE SYSTEM, SOIL TYPE, CROP STAND, AND CROP SEQUENCE ON RENIFORM NEMATODES AFTER HARVEST

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ABSTRACT

Cabanillas, H. E., J. M. Bradford, and J. R. Smart. 1999. Effects of tillage, soil type, crop stand, and crop sequence on reniform nematodes after harvest. Nematropica 29:137-146.

Conservation tillage is rapidly being accepted by farmers in the United States because of its advantages over conventional systems. However, there is limited information about its impact on soil organisms, especially nematodes, which play an important role in crop production. Field studies were conducted to determine the effects of tillage system on nematodes after harvest in relation to soil type, crop stand, and crop sequence at two sites in the Lower Rio Grande Valley of Texas (LRGV). In a dryland site in Willacy Co., neither conventional tillage nor conservation minimum tillage systems affected the numbers of free-living (36 vs 27 nematodes/100cm^3 soil) and reniform nematodes, *Rotylenchulus reniformis* (2 vs 9 nematodes/100cm^3 soil). Although the number of free-living nematodes (25-42 nematodes/100cm^3 soil) was greater than that of *R. reniformis* (0-7 nematodes/100cc soil), they were not significantly different among soil types. In contrast, at the irrigated Hidalgo Co. site, higher numbers of *R. reniformis* were found in non-tillage and ridge tillage (118 and 102 nematodes/100cm^3 soil) than the conventional (39 nematodes/100cm^3 soil) systems. Crop sequence impacted nematode population; the highest number of *R. reniformis* was found in plots where the previous crop was cotton followed by corn (121 nematodes/100cm^3 soil) and the lowest nematode population was in plots with a corn (spring)-fallow (fall) sequence every year (64 nematodes/100cm^3 soil). Neither soil type nor crop stand affected the population of *R. reniformis* and free-living nematodes after harvest. Predominance of the reniform nematode, though in low numbers, indicates a potential threat for future susceptible crops such as cotton. Apparently, nematode population within a particular tillage system can be managed through crop sequence that includes a non-susceptible crop. Our study provides new information of value in implementing new farming practices and pest management programs in the LRGV of Texas.

Key words: conservation tillage, crop rotation, cultural control, no-till, *Rotylenchulus reniformis*, soil type, tillage.

RESUMEN

Cabanillas, H. E., J. M. Bradford y J. R. Smart. 1999. Efectos del sistema de labranza, tipo de suelo, condición del cultivo y la secuencia de cultivos en los nematodos reniformes, después de la cosecha. Nematrópica 29:137-146.

La conservación por labranza, está siendo rapidamente aceptada por los agricultores en los Estados Unidos, debido a sus ventajas sobre los metodos convencionales. Sin embargo, la información sobre su impacto en los organismos del suelo, especialmente nematodos, los que tienen un importante papel en la producción, es limitada. Para determinar los efectos del sistema de labranza sobre los nematodos después de la cosecha, en relación al tipo de suelo, a la situación del cultivo, y a la secuencia de cultivo, se realizaron experimentos de campo, en dos sitios de la parte baja del Valle de Río Grande en Texas (LRGV). En un sitio de tierra seca en Willacy Co., ni la labranza convencional ni los sistemas de conservación con mínima labranza, afectaron el número de los nematodos de vida libre (36 y 27 nematodos/100 cm^3 de suelo) y reniformes, *Rotylenchulus reniformis* (2 y 9 nematodos/100 cm^3 de suelo). Aunque el número de nematodos de vida libre (25-42 nematodos/100 cm^3 de suelo) fue mayor que el de *R. reniformis* (0-7 nematodos/100 cm^3 de suelo), no hubo diferencias significativas entre los tipos de suelo. En contraste, en el sitio irrigado de Hidalgo Co., se encontraron números mayores de *R. reniformis* en surcos sin y con labranza, (118 y 102 nematodos/100 cm^3 de suelo), comparado a los sistemas convencionales (39 nematodos/100 cm^3 de suelo). La secuencia de cultivo impactó la población de nematodos; el mayor número de *R. reniformis*, se encontró en parcelas donde el cultivo previo fue el algodón, seguido por maíz (121 nematodos/100 cm^3 de suelo), la menor población de nematodos estuvo en parcelas con una secuencia cada año de, maíz (primavera)-barbecho (otoño) (64 nematodos/100 cm^3 de suelo). Ningún tipo de suelo o situación del cultivo afectó la población de *R. reniformis*, ni a los nematodos de vida libre después de la cosecha. La predominancia del nematodo reniforme aunque en pequeños números, indica una amenaza potencial para futuros cultivos susceptibles, como el algodón. Aparentemente, la población de nematodos dentro de un sistema particular de labranza, puede ser manejada a través de una secuencia de cultivo que incluya un cultivo no susceptible. Nuestro estudio provee información novedosa de valor en la implementación de nuevas prácticas agrícolas y de programas para el manejo de plagas en el LRGV de Texas.

Palabras claves: conservacio por labranza, control cultural, labranza, *Rotylenchulus reniformis*, secuencia de cultivo, sin labranza, tipo de suelo.

INTRODUCTION

Soil cultivation practices affect soil fauna both quantitatively and qualitatively (House and Parmelee, 1985; Winter *et al.* 1990), and together with soil type and other edaphic factors greatly influence the distribution, community structure, and population dynamics of nematodes (Barker, 1985; Minton, 1986; Minton and Parker, 1987; Norton, 1978; Parmelee and Alston, 1986; Thomas, 1978). Plant-parasitic nematodes typically have patchy distributions within infested fields, which can be affected by the tillage system used (Been and Schomaker, 1998). Nematode species and communities are being considered as indicators of pollution (Poinar, 1983) and other aspects of soil quality (Bongers, 1990), and tillage has been shown to influence the structure of nematode communities (Freckman and Ettema, 1993; McSorley and Fredrick, 1996). Effects of tillage on nematode communities are likely to influence agriculture not only with respect to plant parasitic nematodes, but also beneficial nematodes including biological control agents of economically important insect pests (Cabanillas *et al.* 1994; Cabanillas and Raulston, 1994).

Conservation tillage is rapidly being accepted by farmers in the United States because of its advantages over conventional systems (Bull and Sandretto, 1996). Advantages include fuel and labor savings, lower machinery investments, less soil erosion by wind and water, long-term benefits to soil structure and fertility, improved productivity, and increased profitability. At the Lower Rio Grande Valley of Texas, conservation tillage trials were initiated in 1992 at dryland and irrigated sites. Lack of knowledge of benefits and risks of conservation tillage under a subtropical climate has slowed its adoption (Smart and Bradford, 1996). For example, Stinner and Crossley (1982) noted more plant-parasitic nematodes in grain sorghum grown under no-till than under conventional till. However, research data on the effects of tillage on plant-parasitic and other nematodes are limited. Information on the effect of tillage on the nematode community is essential to the implementation of new farming practices and pest management programs (Barker, 1985; Minton, 1986; Stinner and Crossley, 1982; Thomas, 1978).

The objectives of this study were to determine: (i) effect of continuous conventional tillage and no-tillage agroecosystems, soil type, and crop stand on the nematode community after sorghum harvest at a dryland site, and (ii) impact of crop sequence and three tillage systems (conventional, ridge, and no-tillage) on the reniform and free-living nematodes under irrigated conditions.

MATERIALS AND METHODS

Nematodes were sampled at a dryland site near Lyford, Willacy County, Texas, and an irrigated site near Weslaco, Hidalgo County, Texas.

Effect of tillage system, soil type, and crop stand on nematodes at Willacy County: At the Willacy Co. site, sampling for nematodes was conducted on 11 September 1997, after sorghum harvest in test plots located on an area of 30.8 ha at the Daniel Oakes farm near Lyford. Conventional (CT) and conservation minimum tillage (CMT) systems were randomly established on a heterogenous Willacy-Racombes complex following the 1994 fall harvest. The Willacy-Racombes complex consists of deep, nearly level and gently sloping, well drained loamy soils on ridges of middle stream terraces. The surface is convex. Slopes range from 0 to 3 percent. The research area included four soil types described as follows: WaA = Willacy (fine-loamy, mixed, hyperthermic Udic Argiustolls) fine sandy loam, 0 to 1 percent slopes; WaB = Willacy fine sandy loam, 1 to 3 percent slopes; Ra = Racombes (fine-loamy, mixed, hyperthermic Pachic Argiustolls) sandy clay loam; Ln = Lozano (fine-loamy, mixed, hyperthermic Aquic Haplustalfs) fine sandy loam (Turner, 1982).

The field was under continuous cropping with field corn 'Pioneer' in 1995, cotton 'DPL- 50' in 1996, and grain-sorghum 'Pioneer 8310' in 1997. Neither insecticides nor nematicides were applied during 1995-1997. The experimental design was a randomized complete block with two tillage treatments (CT and CMT) and two replications. Each replication consisted of a 7.7 ha plot planted with grain-sorghum in 782 m long and 0.81 m wide rows for the conventional system and 0.76 m wide for the conservation system. The grain sorghum was harvested on 29 June 1997. Following harvest in the conventional tillage (CT) system, the soil was moldboard plowed (11 August 1997) and disked. In the conservation minimum tillage (CMT) plots, a stalk puller was used to uproot the sorghum stalks in July, 1997 as in the two previous years.

Soil samples for nematodes were collected from each tillage plot by sampling in a zig-zag pattern to a depth of 20 cm with a standard oakfield probe (2.5 cm i.d.). Ten soil cores per soil type on each of two crop stands (good and poor) in each plot were taken and composited and mixed. A 50 cm^3 sample was removed for extraction of nematodes by the modified Baermann funnel method (Robinson and Heald, 1989). Extracted nematodes were identified and enumerated as free-living nematodes or the most predominant plant-parasitic nematode, the reniform nematode, *R. reniformis.* Soil remaining in each sample from each tillage system, soil type, and crop stand was used to detect entomopathogenic nematodes through a modified laboratory bioassay (Cabanillas and Raulston, 1994).

Data were analyzed as a 2 × 4 × 2 factorial experiment with two tillage systems (CT and CMT), four soil types (WaA, WaB, Ra, and Ln), and two crop stands (good and poor). We included all known sources of variation (those due to variables deliberately controlled in the experiment and also uncontrolled variables). Throughout the course of the experiment, we considered that not only factors controlled by the design (tillage) but also uncontrolled factors (soil type and crop stand) which can affect the results should be included in the data analysis. Since there were few insects infected with entomopathogenic nematodes, the statistical analysis was performed only on data for free-living and reniform nematodes. Data were subjected to factorial analysis of variance using PROC GLM of SAS (SAS Inst., 1990). Main effects and their interactions were tested. Means of numbers of nematodes were separated by Duncan's new multiple range test at the 0.05 probability level (SAS Inst., 1990).

Effect of tillage system and crop sequence on nematodes at Hidalgo County: At the Hidalgo Co. site, sampling for nematodes was conducted on 17 September 1997, after harvest, on test plots located at the U.S. Department of Agriculture, Subtropical Agricultural Research Center North Farm, near Weslaco. Conventional tillage (CT), ridge tillage (RT), and no-tillage (NT) systems were established in 1992 on a Hidalgo sandy clay loam soil type (56% sand, 25% clay, 19% silt; 1.23% organic matter; pH 8.0). The experimental design was a split-plot with tillage system as the main plot and crop sequence as the subplot. Three tillage systems (CT,RT, and NT) and three crop sequences with four replications were established. Each replication consisted of 162 rows 0.76 m wide; each subplot consisted of 18 rows 0.76 m wide. Every year, the subplots (crop sequence) changed but the main plots (tillage systems) remained in the same place. The three crop sequences for spring-fall in 1995, 1996, and 1997 were as follow: 1) cotton- corn every year, 2) corn-fallow every year, and 3) grain sorghum-fallow (1995), cotton-fallow (1996), corn-fallow (1997). In the CT, the soil was moldboard plowed, disked twice, and cultivated 2 or 3 times. Under RT, sweeps were used to maintain the ridges, herbicide was applied before planting, there were 2 or 3 cultivations, and a stalk puller uprooted the cotton, sorghum, and corn. In the NT, the soil remained with no cultivation, with herbicide application only, and a stalk puller was used on corn but not on cotton. Soil samples were collected separately from each crop sequence subplot in each tillage system and nematode extraction was according to the procedure used for the Willacy Co. site.

Treatments were arranged in a 3 × 3 factorial experiment with three tillage systems (CT, RT, and CMT) and three crop sequences. Data were collected and analyzed as indicated for the experiment at Willacy Co. site.

RESULTS

Effect of tillage system, soil type, and crop stand on nematodes at Willacy County site: Results of statistical analysis (probability > F) for the effects of tillage system, soil type, and crop stand on the reniform and free-living nematodes at Willacy County are shown in Table 1. No significant interactions ($P > 0.05$) resulted from this analysis.

Tillage system did not affect the nematode population following sorghum harvest. Density of *R. reniformis* ($P = 0.09$) and free-living nematodes ($P = 0.30$) was similar in both conventional and conservation tillage treatments (Table 1). Among tillage treatments, average nematode density of free-living nematodes (31 nematodes/100 cm^3 soil) was greater than the reniform nematodes (6 nematodes/100 cm^3 soil). However, within tillage treatments, number of free-living (36 and 27 nematodes / 100 cm^3 soil for CT and CMT, respectively) and reniform nematodes (2 and 9 nematodes/100 cm^3 soil) were not significantly different ($P > 0.05$).

The nematode genera identified in this study are summarized by trophic category in Table 2. Results from the laboratory bioassay to detect entomopathogenic nema-

Table 1. Variance components and their *P*-values for *Rotylenchulus reniformis* and free-living nematodes as affected by tillage system, soil type, and crop stand after sorghum harvest at Willacy County, Texas.

		P-value	
Source of variation	df	*R. reniformis*	Free-living
Tillage system	1	0.0909	0.3095
Soil type	3	0.9248	0.5004
Crop stand	1	0.3574	0.8176

todes showed that one corn earworm was killed by a nematode from the genus *Steinernema.* This was found in a soil sample (Ra-soil type) of the CMT plot.

Soil type did not affect population densities of *R. reniformis* ($P = 0.92$) or nonstylet-bearing nematodes ($P = 0.50$) (Table 1). Although *R. reniformis* was the most prevalent plant-parasitic nematode (0-30 nematodes/100 cm^3 soil), other plant-parasitic nematodes were also present in very low numbers (2-10 nematodes/100 cm^3 soil) in certain soil types, but did not differ by tillage system. The following plant-parasitic nematodes were found in the conventional tillage: stubby-root nematode *Trichodorus* sp. (Ra-soil type), root-lesion nematode *Pratylenchus* sp. (Ra-soil type), lance nematode *Hoplolaimus* sp. (Ra-soil type), and stunt nematode *Tylenchorhynchus* sp. (Ln-soil type). The stylet-bearing nematodes in the conservation tillage included: *Trichodorus* sp. (WaA-soil type), *Pratylenchus* sp. (Ra and WaA soil- types), and *Tylenchorhynchus* sp. (Ra-soil type).

Similarly, crop stand was unrelated to numbers of *R. reniformis* ($P = 0.36$) or those of the free-living nematodes ($P = 0.82$; Table 1). Nematode densities estimated in the poor and good stands, respectively, were similar among the free-living nematodes (33 and 28 nematodes/100cm^3 soil) and among the reniform nematodes (4 and 8 nematodes/100 cm^3 soil) (Fig. 1).

Effect of tillage system and crop sequence on nematodes at Hidalgo County site: No significant interactions ($P > 0.05$) were detected for the effects of crop sequence and tillage systems on the reniform and free-living nematodes at Hidalgo County. Tillage system influenced the nematode population of both the reniform nematode ($P = 0.004$)

Table 2. Representative nematode genera and trophic classification of the nematode community after sorghum harvest at the Willacy County, Texas study site.

Plant parasite	Fungivore	Bacterivore	Omnivore-predator	Entomopathogenic
Helicotylenchus	*Aphelenchoides*	*Acrobeles*	*Dorylaimus*	*Steinernema*
Hoplolaimus	*Aphelenchus*	*Acrobeloides*	*Mononchus*	
Pratylenchus	*Neotylenchus*	*Cephalobus*	*Tripyla*	
Tylenchorhynchus	*Psilenchus*	*Diplogaster*		
Rotylenchulus	*Tylenchus*	*Rhabditis*		
Trichodorus				

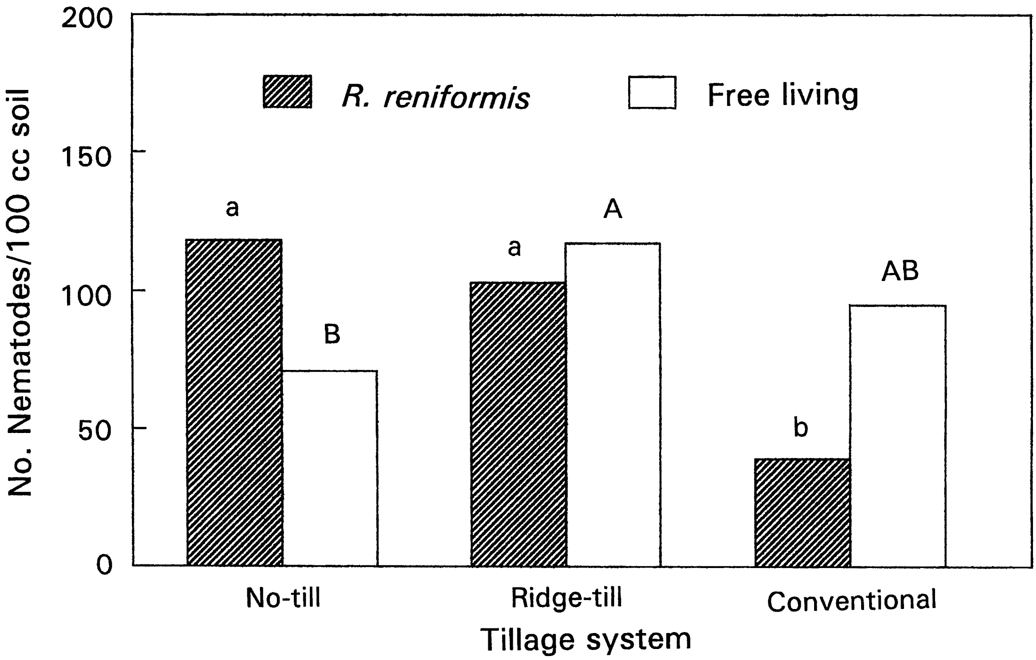

Fig. 1. Numbers of *R. reniformis* and free-living nematodes as affected by tillage system after harvest at Hidalgo County, Texas. Means followed by the same capital letter (free-living) or lower case letter (*R. reniformis*) are not significantly different according to the Duncan's new multiple range test at $P = 0.05$.

and the free-living nematodes ($P = 0.04$) following harvest (Table 3). More reniform nematodes were found in the NT and RT (118 and 103 nematodes/100 cm^3 soil) tillage systems than under CT (39 nematodes/100 cm^3 soil) tillage (Fig. 1). However, greater numbers of free living nematodes were found in both CT and RT (117 and 95 nematodes/100 cm^3 soil) tillage systems than under the NT (71 nematodes/100 cm^3 soil) system (Fig. 2).

Crop sequence influenced the population densities of *R. reniformis* ($P = 0.04$) but did not affect free-living nematodes ($P = 0.83$) following harvest (Table 3). Highest *R. reniformis* numbers were found in plots where the previous crop was cotton (spring) followed by corn (fall) every year (121 nematodes/100cm^3 soil; Fig. 2). Numbers of free-living nematodes (89-98 nematodes/100cm^3 soil) were similar in all crop sequences at this site. One corn earworm was killed by an entomopathogenic nematode from the genus *Steinernema* from a CT plot.

DISCUSSION

The presence of low numbers of the reniform nematode after sorghum harvest in both CT and CMT tillage systems, indicates a threat to future susceptible crops such as cotton (Heald and Robinson, 1990; Koenning *et al.,* 1996). Nematode populations and communities change over time, with the maximum numbers usually occurring at midseason or near harvest, followed by a decline on annual crops (Barker, 1985). Because our objective was to determine nematode population after harvest, nematode densities may not have been at their highest levels. However, mini-

Table 3. Variance components and their *P*-values for *Rotylenchulus reniformis* and free-living nematodes as affected by crop sequence and tillage system after harvest at Hidalgo County, Texas.

		P-value	
Source of variation	df	*R. reniformis*	Free-living
Tillage system (T)	2	0.0035	0.0429
Crop sequence (S)	2	0.0382	0.8287
T × S	4	0.4877	0.4289

mal or no tillage cropping practices allow nematodes to remain in greater numbers in the root zones of the old crop, resulting a more patchy spatial pattern. In contrast, tillage of land after crop harvest disperses the nematodes from the old roots as well as increases death rates of the nematodes. That is why soil samples should be collected after plowing which results in the nematodes being more randomly distributed (Jones and Kempton, 1978).

Cropping sequence affected the reniform nematode population in the soil. The sequence of cotton-corn every year increased *R. reniformis*. Cotton 'DPL 50' that was planted at the Willacy Co. site, is a better host for *R. reniformis* than corn or sorghum crops (Heald and Robinson, 1990). If the next crop were a susceptible one such as cotton, *R. reniformis* populations probably would continue to increase because of their higher overwinter survival and reproductive capacity than other plant-parasitic nematodes (Shaner *et al.*, 1992; Koenning *et al.*, 1996). However, if the next crop were a non susceptible crop used as monoculture, it could increase some of the other plant-parasitic nematodes to damaging levels (Claflin and Starr, 1986). In contrast to continuous cotton-corn sequence, fallow after a crop appears to be a major factor in decreasing *R. reniformis* in the soil. This deserves further investigation in establishing effective nematode management for conservation tillage systems. Clearly, standard management methods, such as crop rotation and resistant varieties, will play a major role in integrating effective nematode management into conservation tillage systems (Minton and Parker, 1987).

Soil type was not a determining factor for the prevalence of *R. reniformis* in either CT and CMT tillage systems in our research field. Researchers have shown that *R. reniformis* is more prevalent in fine-textured soils (Robinson *et al.*, 1987; Starr *et al.*, 1993). It is unknown whether patterns of nematode numbers in this field reflect the influence of soil type or other unmeasured variables.

Management practices often affect nematode populations and should be considered in the implementation of new farming practices and pest management programs (Barker, 1985; Minton, 1986; Stinner and Crossley, 1982; Thomas, 1978). The effect of tillage on nematode communities is not well known; most of the research effort has been concentrated on how tillage affects plant parasites (Fortnum and Karlen, 1985; Stinner and Crossley, 1982; Thomas, 1978). The role of nematodes in the process of decomposition is poorly understood. Although nematodes contribute little to direct mineralization of organic matter, accounting for probably less than 1% of total soil respiration, they

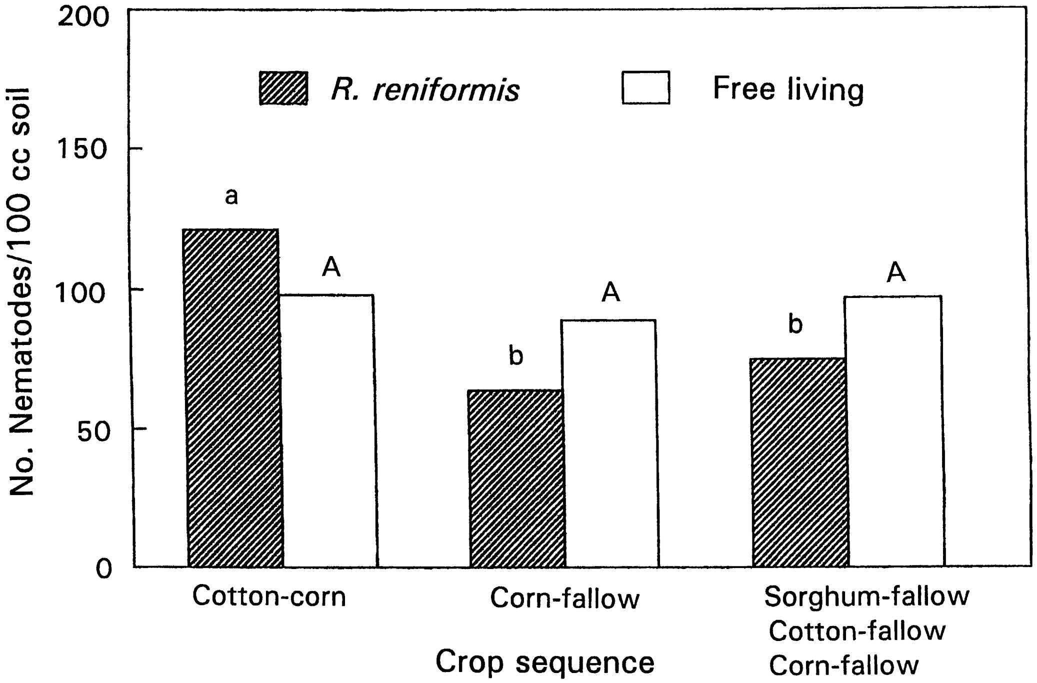

Fig. 2. Numbers of *R. reniformis* and free-living nematodes as affected by crop sequence after harvest at Hidalgo County, Texas. Crop sequences were: 1) spring cotton-fall corn every year, 2), spring corn-fall fallow every year, and 3) spring sorghum-fall fallow (1995), spring cotton-fall fallow (1996), spring corn - fall fallow (1997). Means followed by the same capital letter (free-living) or lower case letter (*R. reniformis*) are not significantly different according to the Duncan's new multiple range test at $P = 0.05$.

appear to be significant regulators of decomposition and nutrient release in natural ecosystems through their interactions with the microflora (Coleman *et al.*, 1984; Santos *et al.*, 1981). A report on the effect of 5 years of continuous conventional tillage and no-tillage systems showed that tillage affected nematode trophic structure and total abundance (Parmelee and Alston, 1986). Plant-parasitic nematodes were higher in the no-tillage system during the summer months compared with conventional tillage. The effect of tillage on the trophic structure of the nematode community is important to understand to also reveal the indirect roles of nematodes in processes affecting crop production. Biological control agents such as the entomopathogenic nematode *Steinernema riobravis*, which was discovered in our area (Cabanillas *et al.*, 1994) and has become commercially available, also could become important in controlling susceptible plant-parasitic nematodes and crop insect pests.

Conventional tillage decreased reniform nematode numbers compared to those in reduced tillage in this study. Our results corroborates previous findings on the effects of tillage on various plant parasitic nematodes (Parmelee and Alston, 1986; Fortnum and Karlen, 1985; Stinner and Crossley, 1982; Thomas, 1978). Although there is extensive information on the adverse economic effects of *R. reniformis* on crops in the United States and around the world (Heald and Robinson, 1990; Robinson *et al.*, 1997), we are unaware of other reports of the effects of minimum or no tillage on reniform nematode. Limited research on conservation tillage indicates that its use may result in nematode problems never before encountered. Because of the rapid acceptance of conservation tillage (Bull and Sandretto, 1996), it is imperative that further research be implemented to fully assess its impact on nematode management

Our study provides new information on the nematode community, including plant-parasitic and free-living nematodes as affected by the tillage system, soil type, crop stand, and crop sequence after sorghum harvest. Our research results should be of value as a guide to future research in implementing new farming practices and pest management programs in the Lower Rio Grande Valley of Texas.

ACKNOWLEDGMENTS

We thank Drs. James Everitt, Thomas Isakeit, and Craig Wiegand for reviewing this manuscript and Larry Koester for assisting in soil sampling.

LITERATURE CITED

BARKER, K. R. 1985. Sampling nematode communities. Pp. 3-17 *in* K. R. Barker, C. C. Carter, and J. N. Sasser, eds. An Advanced Treatise on *Meloidogyne* Vol. II. N.C. State University Graphics, Raleigh, NC, U.S.A.

BEEN, T. H., and C. H. SCHOMAKER. 1998. Quantitative Studies on the Management of Potato Cyst Nematodes (*Globodera* spp.) in the Netherlands. IPO-DLO, Wageningen, Netherlands.

BONGERS, T. 1990. The maturity index: an ecological measure of environmental disturbance based on nematode species composition. Oecologia 83:14-19.

BRODIE, B. B. 1976. Vertical distribution of three nematode species in relation to certain soil properties. Journal of Nematology 8:243-247.

BULL, L., and C. SANDRETTO. 1996. Crop residue management and tillage system trends. Statistical Bull. No. 930. U.S.Department of Agriculture, Washington, DC, U.S.A.

CABANILLAS, H. E., G. O. POINAR, Jr., and J. R. RAULSTON. 1994. *Steinernema riobravis* n. sp. (Rhabditida: Steinernematidae) from Texas. Fundamental and Applied Nematology 17:123-131.

CABANILLAS, H. E., and J. R. RAULSTON. 1994. Evaluation of the spatial pattern of *Steinernema riobravis* in corn plots. Journal of Nematology 26:25-31.

CLAFLIN, L. E., and J. L. STARR. 1986. Nematodes. Pp. 50-53 *in* R. A. Frederiksen, ed. Compendium of Sorghum Diseases. American Phytopathological Society, St. Paul, MN, U.S.A.

COLEMAN, D. C., R. V. ANDERSON, C. V. COLE, J. F. McCLELLAN, L. E. WOODS, J. A. TROFYMOW, and E. T. ELLIOT. 1984. Roles of protozoa and nematodes in nutrient cycling. Pp. 17-28 *in* Microbial-plant Interactions. Soil Science Society of America, American Society of Agronomy, and Crop Science Society of America, Madison, WI, U.S.A.

FORTNUM, B. A., and D. L. KARLEN. 1985. Effect of tillage system and irrigation on population densities of plant nematodes in field corn. Journal of Nematology 17:25-28.

FRECKMAN, D. W., and C. H. ETTEMA. 1993. Assessing nematode communities in agroecosystems of varying human intervention. Agriculture, Ecosystems and Environment 45:239-261.

HEALD, C. M., and A. F. ROBINSON. 1990. Survey of current distribution of *Rotylenchulus* in the United States. Supplement to Journal of Nematology 22:695-699.

HOUSE, G. H., and R. W. PARMELEE. 1985. Comparison of arthropods and earthworms from conventional and no-tillage agroecosystems. Soil Tillage Research 5:351-360.

JONES, F. G. W., and R. A. KEMPTON. 1978. Population dynamics, population models and integrated control. Pp. 333-361 *in* J. F. Southey, ed. Plant Nematology. Ministry of Agriculture, Fish. and Food Technology Bulletin 7, Her Majesty's Stationery Office, London, U.K.

KOENNING, S. R., S. A. WALTERS, and K. R. BARKER. 1996. Impact of soil texture on the reproductive and damage potentials of *Rotylenchulus reniformis* and *Meloidogyne incognita* on cotton. Journal of Nematology 28:527-536.

MCSORLEY, R., and J. J. FREDRICK. 1996. Nematode community structure in rows and between rows of a soybean field. Fundamental and Applied Nematology 19:251-261.

MINTON, N. A. 1986. Impact of conservation tillage on nematode populations. Journal of Nematology 18:135-140.

MINTON, N. A., and M. B. PARKER. 1987. Root-knot nematode management and yield of soybean as affected by winter cover crops, tillage systems, and nematicides. Journal of Nematology 19:38-43.

NORTON, D. C. 1978. Ecology of Plant-Parasitic Nematodes. John Wiley and Sons, New York, NY, U.S.A.

PARMALEE, R. W., and D. G. ALSTON. 1986. Nematode trophic structure in conventional and no-tillage agroecosystems. Journal of Nematology 18: 403-407.

POINAR, G. O., Jr. 1983. The Natural History of Nematodes. Prentice-Hall, Inc., NJ, U.S.A.

POINAR, G. O., Jr. 1990. Taxonomy and biology of Steinernematidae and Heterorhabditidae. Pp. 23-61 *in* R. Gaugler, and H. K. Kaya, eds. Entomopathogenic Nematodes in Biological Control. CRC Press, Boca Raton, FL, U.S.A.

ROBINSON, A. F., C. M. HEALD, S. L. FLANAGAN, W. H. THAMES, and J. AMADOR. 1987. Geographical distribution of *Rotylenchulus reniformis, Meloidogyne incognita,* and *Tylenchulus semipenetrans* in the Lower Rio Grande Valley as related to soil texture and land use. Supplement to the Journal of Nematology 19:20-25.

ROBINSON, A. F., and C. M. HEALD. 1989. Accelerated movement of nematodes from soil in Baermann funnels with temperature gradients. Journal of Nematology 21:370-378.

ROBINSON, A. F., R. N. INSERRA, E. P. CASWELL-CHEN, N. VOVLAS, and A. TROCCOLI. 1997. *Rotylenchulus* species: Identification, distribution, host ranges, and crop plant resistance. Nematropica 27:127-180.

SANTOS, P. F., J. PHILLIPS, and W. G. WHITFORD. 1981. The role of mites and nematodes in early stages of buried litter decomposition in a desert. Ecology 62:664-66.

SAS INSTITUTE INC. 1990. SAS User's Guide, version 6, fourth edition. Cary, NC, U.S.A.

SHANER, G., E. L. STROMBERG, G. H. LACEY, K. R. BARKER, and T. P. PIRONE. 1992. Nomenclature and concepts of pathogenicity and virulence. Annual Review of Phytopathology 30:47-66.

SMART, R. J., and J. M. BRADFORD. 1996. No-tillage and reduced tillage cotton production in South Texas. Pp. 1397-1401 *in* Beltwide Cotton Conference, Jan. 9-12. Nashville, TN, U.S.A.

STARR, J. L., C. M. HEALD, A. F. ROBINSON, R. G. SMITH, and J. P. KRAUSZ. 1993. *Meloidogyne incognita* and *Rotylenchulus reniformis* and associated soil textures from some cotton production areas of Texas. Supplement to the Journal of Nematology 25:895-899.

STINNER, B. R., and D. A. CROSSLEY, Jr. 1982. Nematodes in no-tillage agroecosystems. Pp. 14-28 *in* D. W. Freckman, ed. Nematodes in Soil Ecosystems. University of Texas Press, Austin, TX, U.S.A.

THOMAS, S. H. 1978. Population densities of nematodes under seven tillage regimes. Journal of Nematology 10:24-27.

TURNER, A. J. 1982. Soil Survey of Willacy County, Texas. U. S. Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station, Government Printing Office, Washington DC, U.S.A.

WHITE, C. F. 1927. A method for obtaining infective larvae from cultures. Science 66:302-303.

WINTER, J. P., R. P. VORONEY, and D. A. AINSWORTH. 1990. Soil microarthropods in long-term no-tillage and conventional tillage corn production. Canadian Journal of Soil Science. 70:641-653.

Received: / *Recibido:* *14.XII.1998*

Accepted for publication: / *Aceptado para publicación:* *20.VI.1999*