MANAGEMENT STRATEGIES IN POTATO FOR NEMATODES AND SOIL-BORNE DISEASES IN SUBTROPICAL FLORIDA

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ABSTRACT

Weingartner, D. P., R. McSorley, and R. W. Goth. 1993. Management strategies for nematodes and soil-borne diseases in subtropical Florida. Nematropica 23:233–245.

A winter-spring potato (*Solanum tuberosum*) crop of 379 200 MT valued at nearly 100 million $U.S. is produced annually on 17 600 ha in Florida. The most important production regions are southeastern and northeastern Florida. There are important differences between these two regions in the soil types, pests, and pathogens present, cultivars planted, cultural methods used, and markets targeted. *Meloidogyne incognita* is the most important pathogen in southeastern Florida and is a problem in northeastern Florida as well. Other important nematodes and soil-borne diseases in northeastern Florida include *Belonolaimus longicaudatus*, corky ringspot (caused by trichodorid nematode-transmitted tobacco rattle virus), and bacterial wilt (caused by *Pseudomonas solanacearum*). Management strategies differ depending upon the pathogens, nematodes, and insects present, market destination of the crop (*i.e.*, fresh or processed potatoes), and soil conditions. Management options include use of summer cover crops, timing of cover crop production relative to potato, delaying potato harvest, soil fumigation, foliar and soil applications of nonvolatile nematicides, and cultivar resistance.

Key words: bacterial wilt, *Belonolaimus longicaudatus*, corky ringspot, *Criconemella onoensis, Meloidogyne incognita, Pseudomonas solanacearum, Rotylenchulus reniformis, Paratrichodorus minor*, potato, *Solanum tuberosum, Sorghum bicolor* × *S. arundinaceum* var. *sudanense*, spraing, trichodorids, *Trichodorus proximus, Trichodorus viruliferous.*

RESUMEN

Weingartner, D. P., R. McSorley y R. W. Goth. 1993. Estrategias para el manejo de nematodos y enfermedades del suelo en la región subtropical de Florida. Nematrópica 23:233–245.

El cultivo de la papa (*Solanum tuberosum*) de invierno y primavera en el estado de Florida, EE.UU., abarca 17 600 ha. La producción anual es de 379 200 TM y está valorada en 100 millones de dolares U.S. Las áreas productoras más importantes son el sureste y noreste de Florida. Existen importantes diferencias entre las dos regiones en tipos de suelo, plagas y patógenos presentes, cultivares utilizados, prácticas agronómicas empleadas y mercados de destino. *Meloidogyne incognita* es el patógeno más importante en el sureste de Florida y también constituye un problema en el noreste del estado. Otros nematodos y enfermedades de suelo importantes en el noreste incluyen *Belonolaimus longicaudatus*, "corky ringspot" causado por el "tabacco rattle virus" (TRV) transmitido por nematodos trichodóridos, y la marchitez bacteriana causada por *Pseudomonas solanacearum*. Las estrategias de manejo difieren dependiendo de los patógenos, nematodos e insectos presentes, mercados de destino de la cosecha (consumo fresco o procesado) y condiciones de suelo. Las opciones de manejo incluyen el uso de cultivos de cobertera de verano, adelanto o retraso de cultivo, retraso en la cosecha de la papa, fumigación de suelo, aplicaciones al suelo y foliares de nematicidas no-volatiles y uso de cultivares resistentes.

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Palabras clave: Belonolaimus longicaudatus, corky ringspot, *Criconemella onoensis*, marchitez bacteriana, *Meloidogyne incognita*, papa, *Paratrichodorus pseudorobustus, Paratrichodorus minor, Pseudomonas solanacearum, Rotylenchulus reniformis, Solanum tuberosum, Sorghum bicolor* × *S. arundinaceum* var. *sudanense*, spraing, tobacco rattle virus, trichodoridos, *Trichodorus proximus, Trichodorus viruliferous.*

INTRODUCTION

Potato (*Solanum tuberosum*) is an important vegetable crop in Florida. During 1986–1990 an average of 379 200 MT of potatoes valued at $U.S. 99.1 million were produced on 17 600 ha in the state. The importance of the potato industry in Florida is based primarily on climatic conditions that permit farmers to produce fresh potatoes during months when other potato producing regions in the U.S. do not. Although Florida's potato crop during 1989–1991 was only 2.2% of the U.S. total, it provided 35.7% of all fresh potatoes sold during the winter-spring production season. As a result, Florida's potato crop usually commands premium prices relative to other states. The average value of Florida potatoes in 1987–1990 was $6 707/harvested ha and $285/MT, compared, respectively, to U.S. average values of $3 909/harvested ha and $124/ MT (8–10). The relatively high value of Florida potatoes enables farm managers to utilize disease and pest management strategies which may be cost prohibitive in other regions. This review discusses the nematodes, associated soil-borne disease problems, and their management in northeastern and southeastern Florida (Fig. 1).

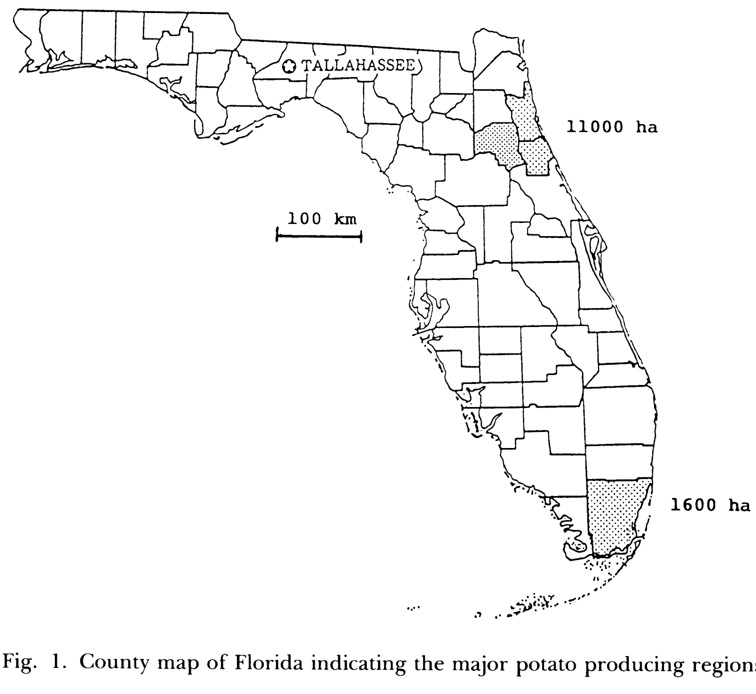

Fig. 1. County map of Florida indicating the major potato producing regions.

SUBTROPICAL POTATO PRODUCTION SYSTEMS OF FLORIDA

Northeastern Florida

Production is concentrated in St. Johns, Putnam, and Flagler Counties. Soils are sandy flatwoods series and are typically composed of 90–95% sand, < 2.5% clay, and < 5% silt with < 2.0% organic matter and pH 5.2–7.0. Fields are sublayered at a depth of 60–120 cm with a zone of impervious clay. The clay layer facilitates seepage irrigation, which is accomplished through a series of water furrows placed at 18.3-m intervals, coupled with ridged rows (102 cm apart) where the potatoes are planted. The crop is planted from the last week in December until early March and is lifted during mid April to mid June. Approximately 85% of the crop is sold to potato chip processors through preseason contracts. The chipping cultivar Atlantic is planted on *ca.* 65% of the hectarage with the remainder being planted to the cultivars Sebago, Superior, LaChipper, and several red-skinned varieties. A summer cover crop is planted after potatoes are harvested. During the past 15 years the most widely planted cover crop has been a sorghum-sudangrass hybrid (*Sorghum bicolor* × *S. arundinaceum* var. *sudanense*). Most northeastern Florida potato fields are monocultured to a spring potato crop with a summer cover crop; in some fields this has been practiced for more than 85 years.

Southeastern Florida

Most of the production in this area occurs in Dade County in Perrine marl soil (Typic Fluvaquent). This unusual soil type originates from oolitic limestone, and is characterized by a pH of 7–8 (2). A recent analysis from a typical potato field in the area revealed 30–32% sand, 32–34% silt, and 34–36% clay (R. McSorley, unpublished). Due to land limitations, the same sites may be used for potato production each year. Potatoes are planted during November and December and harvested in March and April. Usually a small red cultivar such as LaRouge is grown for the fresh market. During the summer, land is either planted to cover crops such as sorghum (*Sorghum bicolor*), sorghum-sudangrass, or corn (*Zea mays*), or is left fallow, with or without weed control.

NEMATODES AND SOIL-BORNE DISEASES ASSOCIATED WITH POTATOES IN FLORIDA

Northeastern Florida

At least 12 genera of phytoparasitic nematodes occur in potato fields (17,18, 20–25). The most important are *Meloidogyne incognita* (Kofoid & White) Chitwood, *Belonolaimus longicaudatus* Rau, *Paratrichodorus minor* (Colbran) Siddiqi, *Trichodorus viruliferous* Hooper, and *T. proximus* Allen. Heavy losses in tuber yields result from root damage caused by *M. incognita* and *B. longicaudatus*, whereas *Trichodorus* spp. and *P. minor* are mainly important as vectors of tobacco rattle virus which causes corky ringspot disease, known as spraing in Europe (20,25). Corky ringspot occurs on about 3 200 ha in northeastern Florida and causes severe internal necrosis rendering many tubers unmarketable. Bacterial wilt, caused by *Pseudomonas solanacearum* E. F. Smith, has been a problem since the start of the potato industry in northeastern Florida in the early 1900's (18). The severity of bacterial wilt has been reported to be aggravated by *Meloidogyne* spp. (4,18,21).

Southeastern Florida

Plant-parasitic nematodes commonly found include *M. incognita, Rotylenchulus reniformis* Linford & Oliveira, *Helicotylenchus dihystera* (Cobb) Sher, *Criconemella onoensis* (Luc) Luc & Raski, *Quinisulcius acutus* (Allen) Siddiqi, and *Tylenchorhynchus martini* Fielding (5,7,11). *Belonolaimus longicaudatus* and *P. minor*, both serious pests of potatoes in northeastern Florida, have not been found in the Perrine marl soils in southeastern Florida. *Meloidogyne incognita* is the most damaging nematode pest. Root-knot galling of tubers is not tolerated by the local market, and results in a substantial downgrading in tuber quality, reducing grower profits. The reniform nematode, *R. reniformis*, is a known pathogen of potatoes (12) and can be common locally if weed hosts are allowed to grow (7). No pathogenic effects of *H. dihystera, Q. acutus*, or *T. martini* on potato have been reported.

The ring nematode, *C. onoensis*, can increase to more than 1 000 per 100 cm^3 of soil following cover crops of sorghum grown in marl soils (6). However, greenhouse tests have indicated that *C. onoensis* may have little influence on potato (6). In one field test with initial densities of *ca.* 1 100 *C. onoensis* per 100 cm^3 of soil, fumigation with metam sodium reduced densities to < 5% of the initial level, but yields were not increased in fumigated plots (6).

NEMATODE AND SOIL-BORNE DISEASE MANAGEMENT IN FLORIDA

Northeastern Florida

Nematodes: Since the early 1970's chemical control has been the primary nematode control measure in northeastern Florida. In the 1960's dramatic increases in tuber yields in research plots following preplant fumigation with 1,3-D (dichloropropene), DD (1,3-D, 1,2-dichloropropane and related hydrocarbons), and EDB (ethylene dibromide) prompted rapid grower acceptance. In the 1970's certain nonvolatile nematicides, especially aldicarb, became widely used alone and in combination with soil fumigants by northeastern Florida potato growers (17,23–25). Nematode control efficacy and typical crop returns have been substantial (Table 1, Fig. 2). In northeastern Florida fumigants tend to be more effective than nonvolatile nematicides when soil moisture is < 10% by weight whereas nonvolatile nematicides are more effective when soil moisture is > 10% by weight.

In northeastern Florida certain nematodes, especially *B. longicaudatus*, trichodorids, and *Pratylenchus zeae* Graham increase on the sorghum-sudangrass summer cover crop (D. P. Weingartner, unpublished). Another potential management option in northeastern Florida is the planting of cover crops other than

Table 1. Comparisons of average tuber yields and percentage of tubers with corky ringspot disease in potato cv. Sebago grown in untreated plots and in plots treated with 1,3-D, aldicarb, or 1,3-D + aldicarb in field tests performed in northeastern Florida from 1977 to 1985.

Nematicide treatment[y]	Tuber yield[z] (MT/ha)	Corky ringspot[z] (%)
1,3-D	23.2 b	50.3 a
Aldicarb	22.7 b	15.3 c
1,3-D + aldicarb	26.4 a	12.5 c
None	16.8 c	36.7 b

[y]1,3-D and aldicarb applied at 56 L/ha and 3.4 kg a.i./ha, respectively. Values within a column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's multiple range test.

[z]Tuber yields and percentage tubers with CRS are averaged across eight and nine seasons, respectively.

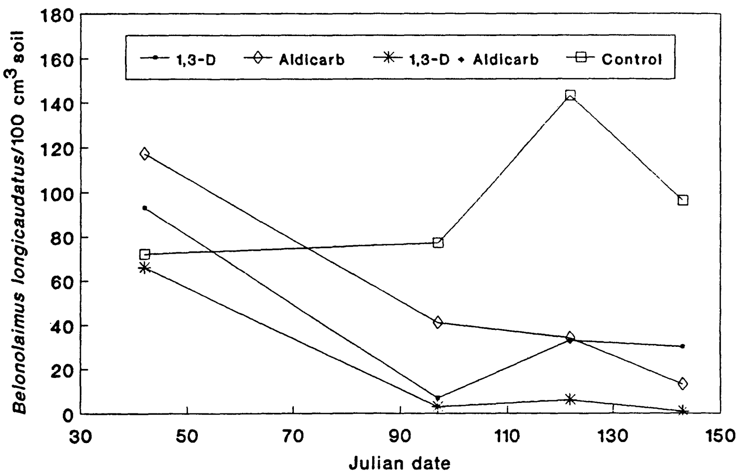

Fig. 2. Typical changes in population densities of *Belonolaimus longicaudatus* in nematicide treated and non-treated plots. The soil fumigant 1,3-D was applied on Julian day 25 at 54 L/ha and aldicarb at the time of planting on Julian day 48 at 3.4 kg a.i./ha in the planting row with 102-cm spacing between rows.

sorghum-sudangrass. One possible substitute for sorghum-sudangrass is the tropical legume, hairy indigo (*Indigofera hirsuta*). Hairy indigo reduced densities of *B. longicaudatus* (Fig. 3), and improved tuber yields and appearance ratings by 72% and 15.2%, respectively (16). There are several drawbacks, however, to planting hairy indigo. It is highly sensitive to metribuzin, the standard herbicide used in northeastern Florida, and its seed must be hot water treated for optimum germi-

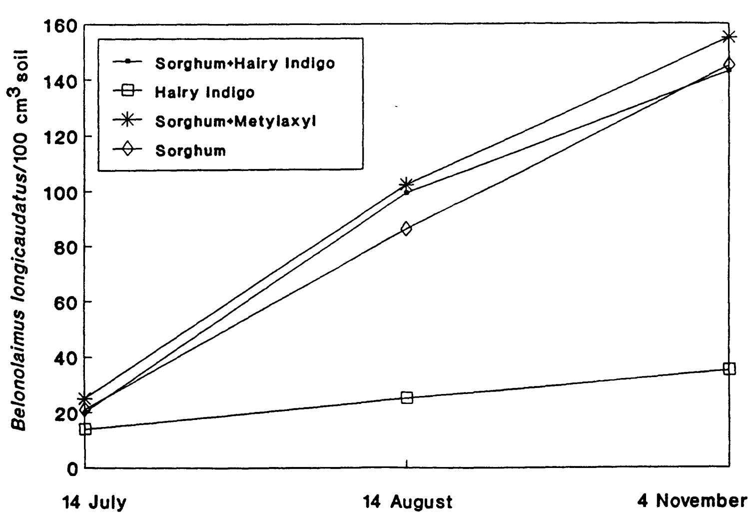

Fig. 3. Effect of summer cover crops of hairy indigo, sorghum-sudangrass, hairy indigo + sorghum-sudangrass, and sorghum-sudangrass + metalaxyl applied at 4.5 kg a.i./ha on population densities of *Belonolaimus longicaudatus*.

nation. Also, it is open pollinated; as a result nematode resistance can vary widely in a given field population (1). Moreover, planting hairy indigo immediately after harvesting potatoes requires that planting the legume be delayed 6–8 weeks beyond the optimum April planting period, often resulting in erratic plant stands due to high soil temperatures and frequent heavy rains.

Corky ringspot disease (CRS): All fumigants that have been tested in northeastern Florida, including DD, 1,3-D, DD MENCS, metam sodium, EDB, and methyl bromide, have proved ineffective in controlling corky ringspot (20–23 and D. P. Weingartner, unpublished). Additionally, broadcast equivalent rates of 1,3-D, EDB, and metam sodium applied with multiple chisels per row, deep injection of methyl bromide, and methyl bromide under plastic, failed to control CRS in this system (20–23 and D. P. Weingartner, unpublished). Reductions in incidence of CRS were obtained in 1993, however, with deep (45 cm) placement of 56 L of 1,3-D/ha using a rip chisel (D. P. Weingartner, unpublished). The nonvolatile nematicides fenamiphos, ethoprop, fensulfothion, and phorate, each applied at 3.4 kg a.i./ha are also ineffective in controlling CRS. The carbamates aldicarb, oxamyl, and carbofuran, however, have provided economic control (17) (Table 1).

Under field conditions the cultivars Pungo, Superior, "New" Superior, Oceania, and Hudson, and to a lesser extent, Green Mountain (15) typically exhibit very low levels of CRS in infected fields (Table 2). It is not known whether so-called field resistance of these cultivars is due to escape from infection, genetic resistance to the trichodorid nematode vector, or genetic resistance to tobacco rattle virus. Unfortunately, Pungo, Superior, and "New" Superior are highly susceptible to

Table 2. Percentage of tubers of potato cultivars with corky ringspot in an experiment performed in northeastern Florida during 1992.

Cultivar	Percentage of tubers with corky ringspot
Atlantic	78
Green Mountain	21
Hudson	0
LaChipper	54
LaRouge	82
Kennebec	71
New Superior	0
Oceania	1
Ontario	66
Red LaSoda	64
Sebago	94
Superior	0
LSD ($P = 0.05$)	25

Plots were neither fumigated nor treated with nonvolatile nematicides. Data are typical for these cultivars in northeastern Florida.

bacterial wilt. In Pungo and Superior, early and late blight diseases are also severe. Oceania is highly susceptible to blackleg caused by *Erwinia carotovora* E. F. Smith. All of these cultivars yield less than Atlantic and their tubers lack the high specific gravity of Atlantic tubers which is desired by potato chip processors (18). Additionally, Pungo and Green Mountain tend to produce dark-colored potato chips (D. P. Weingartner, unpublished data).

Bacterial wilt: In potato, bacterial wilt causes tubers to rot, often after harvesting, a condition referred to as brown rot. The disease has increased in importance in recent years, apparently due to widespread use of the susceptible cv. Atlantic (18). The disease can be more severe when root-knot nematodes occur concomitantly (4,13,21). Management practices studied have included cultivar resistance, soil fumigation, delayed harvest intervals in infested fields, and biocontrol. Widening the spacing between liquid fertilizer chisels also helps by minimizing root damage (D. P. Weingartner, unpublished data).

Economic losses due to bacterial wilt are increased if the disease escapes detection in infected tubers during grading because the crop can be rejected by the buyer after transport, causing the producer to lose both the crop and the cost of shipping. Delaying harvest to allow infected tubers to rot in the field before lifting can be used to reduce losses. The effect of delayed harvest on the percentage of tubers with undetected brown rot has been found to vary with cultivar (Fig. 4). In Superior undetected brown rot progressively decreased each week (from 22.5% to *ca.* 5%) whereas in Red LaSoda and LaChipper the amount decreased

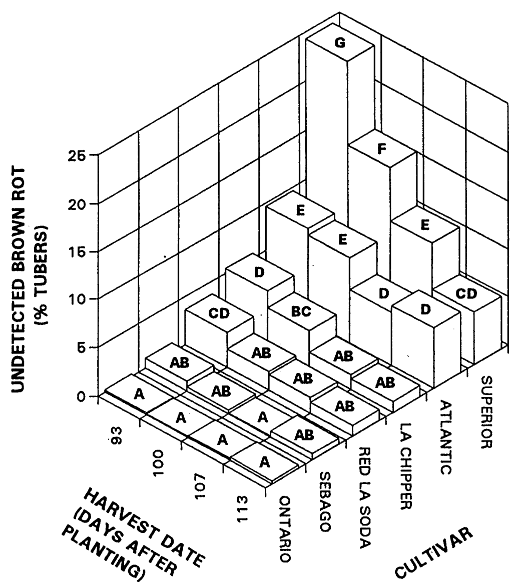

Fig. 4. Effects of delayed harvest and potato cultivar on incidence of undetected brown rot in northeastern Florida. Percent tuber values for the harvest date × cultivar interactions with common letters do not differ significantly ($P = 0.05$).

during the first week and then leveled off. Delaying harvest 2–3 weeks in most cultivars seems to decrease the percentage of brown rot undetected at harvest.

Soil fumigation using standard rates of fumigants applied with a single chisel per row can reduce incidence of bacterial wilt. Also, increasing rates of fumigants to broadcast levels reduced the incidence of bacterial wilt in the susceptible cv. Atlantic to the level observed in the tolerant cv. Sebago fumigated with the standard rate (Table 3). In these experiments broadcast application was simulated by using three application chisels per row, each delivering the standard rate of fumigant. Regression analyses suggest that reductions in bacterial wilt following soil fumigation in this study were mainly due to control of *M. incognita* (21).

Biocontrol of bacterial wilt was inconsistent in field experiments performed in 1984 and 1985, perhaps due to interactions with *M. incognita* (4).

The different nematode and soil-borne disease management options available to northeastern Florida potato growers can be summarized in a management matrix (Table 4). Axes of the matrix list the po-

Table 3. Effect of potato cultivar and of fumigant rate and placement on incidence of bacterial wilt during 1983.

	Wilted plants per plot[y]	
Cultivar	Single chisel[z]	Three chisels[z]
Atlantic	9.4 c	2.5 b
Sebago	2.1 b	0.4 a

Means followed by a different letter are statistically different ($P = 0.05$).

[y]28 total plants per plot.

[z]Standard in-row rates of fumigants were applied using a single chisel per row. The same rates applied through each of three chisels per row provided a simulated broadcast.

Table 4. Management options for nematodes and soil-borne diseases in northeastern Florida.

Problem	Management options: Fresh market potatoes, < 10% soil moisture	Fresh market potatoes, > 10% soil moisture	Processed potatoes (chip stock), < 10% soil moisture	Processed potatoes (chip stock), > 10% soil moisture
Nematodes	Fumigation OR fumigation + oxamyl[x] OR fumigation + ethoprop[x]	Oxamyl OR ethoprop OR metam sodium (?)[y]	Fumigation	Oxamyl OR ethoprop OR metam sodium (?)
Nematodes plus corky ringspot (CRS)	Fumigation + CRS-resistant cultivar OR fumigation	Oxamyl OR oxamyl + CRS-resistant cultivar OR metam sodium (?) + oxamyl OR metam sodium (?) + CRS-resistant cultivar	Fumigation + CRS-resistant cultivar	CRS-resistant cultivar + (oxamyl or ethoprop) OR metam sodium (?) + CRS-resistant cultivar OR metam sodium (?) + oxamyl
Nematodes plus bacterial wilt (BW)	Fumigation + BW-resistant cultivar OR 3× fumigation[z]	BW-resistant cultivar + (ethoprop or oxamyl) OR 3× metam sodium (?)	Fumigation + BW-resistant cultivar OR 3× fumigation	BW-resistant cultivar + (ethoprop or oxamyl) OR 3× metam sodium
Nematodes plus corky ringspot plus bacterial wilt	Fumigation + BW-resistant cultivar + oxamyl OR 3× fumigation + CRS-resistant cultivar	BW-resistant cultivar + (oxamyl or metam sodium) OR 3× metam sodium	BW-resistant cultivar + oxamyl OR 3× fumigation + CRS-resistant cultivar	BW-resistant cultivar + oxamyl OR 3× metam sodium (?) + oxamyl OR 3× metam sodium (?) + CRS-resistant cultivar

See text for nematode species involved.
[x]Registration of soil applied chemicals is constantly changing. The carbamate nematicides aldicarb, carbofuran, and oxamyl control CRS, whereas the organophosphatic compounds ethoprop, phorate, and phenamiphos do not. Consult labels and use restrictions before using a nematicide.
[y](?) indicates insufficient data; however, soil moisture constraints for other soil fumigants may not apply to metam sodium.
[z]3× = fumigate with broadcast equivalent rates applied with multiple chisels per row.

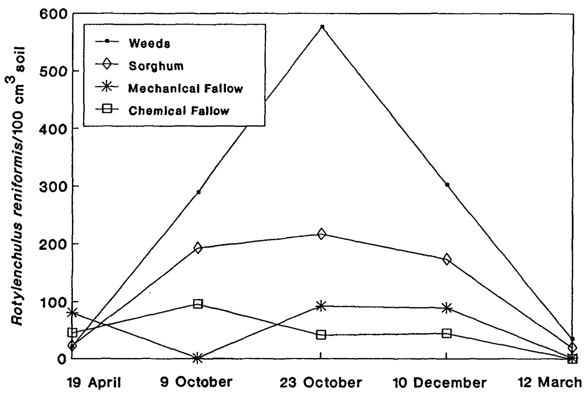

Fig. 5. Seasonal changes in population densities of *Rotylenchulus reniformis* in southeastern Florida, as affected by summer management practices. Orthogonal contrasts between summer fallow (mechanical or chemical) and non-fallow (weeds or sorghum) treatments were significant ($P = 0.05$) on all dates except 19 April. Dates correspond to start of summer management (19 April), first discing (9 October), second discing (23 October), shortly after potato planting (10 December), and potato harvest (12 March).

tential problems within a field, market destination of the crop (*i.e.*, fresh market or potato chip processing), and soil moisture conditions at the time of planting. Items within the matrix present the available management options given the situation described in the two axes.

Southeastern Florida

Nematode management in southeastern Florida is much less complex than in northeastern Florida. Management strategies have been and continue to be directed against *M. incognita.* Until the use of EDB in the U.S.A. was suspended in 1983, potato fields in southeastern Florida were routinely fumigated with EDB. Since 1983, management with nematicides has not been widely used because the performance of systemic nematicides (organophosphates and carbamates) has been poor in the alkaline soils of southeastern Florida (R. McSorley, unpublished). Thus far, suspension of EDB has not caused a resurgence of *M. incognita* in southeastern Florida. Its distribution is sporadic, and it is a problem only in some fields.

Early detection of *M. incognita* in potato fields in southeastern Florida is important, and sampling plans have been developed based on the application of Taylor's power law (14) to sites ranging in size from 0.2 to 1.2 ha (5). It was not possible to devise reliable sampling plans for areas greater than 1.2 ha due to the extremely aggregated nature of *M. incognita* distributions within fields of that size (b of Taylor's power law > 2). The number of cores needed to estimate specified densities of *M. incognita* with a 25% level of precision in a 0.4-ha area decreased from 100 to 24 as nematode density increased from 1.0 to 104 juveniles per 100 cm^3 soil (5). In fallow fields sampled 1–2 months prior to potato planting (the most difficult situation in which to detect *M. incognita*), a conservative sampling plan would call for assuming an initial density of 1.0 juvenile per 100 cm^3 soil and collecting 100 cores per 0.4 ha. Densities are usually higher, and therefore fewer cores are required during April near the end of the previous potato crop.

One reason why densities of *M. incognita* have remained low in southeastern Florida may be the use of clean fallow or cover cropping. Without these practices, *M. incognita* populations can build up on weed hosts (*e.g.*, *Acalypha ostryifolia, A. alopecuroides, Chenopodium* spp.) which grow on these sites during the summer months. Nematode densities throughout the summer and subsequent winter potato season can vary, depending on the nematode species and summer management treatment (6,7). For example, densities of *R. reniformis* were lower following summer fallow than following weeds (Fig. 5). Normally, densities of *R. reniformis* do not increase on sorghum, a non-host (3), but the example (Fig. 5) illustrates the effect of a susceptible weed host (morning glory, *Ipomoea* spp.) which invaded the sorghum crop (7).

In this example (7), total gross weights of potatoes harvested did not differ ($P \leq 0.05$) with summer management treatment (Table 6). However, the amount of potatoes showing damage from wireworms (Elateridae) was lower ($P \leq 0.001$) following summer fallow than following weeds or a sorghum cover crop (Table 6). The levels of wireworm damage shown in this example (Table 6) are unacceptable, and illustrate an adverse side effect to growing a sorghum cover crop for nematode management alone (7).

INTERACTIONS AMONG MANAGEMENT OPTIONS AND PATHOGENS

A holistic approach is important in the management of soil-borne diseases and nematodes in the subtropical potato cropping systems of Florida. In northeastern Florida, management strategies must consider biotic interactions such as the transmission of tobacco rattle virus by trichodorid nematodes (20,22,25), increased severity of bacterial wilt in fields having high population densities of *M. incognita* (4,21), and negative correlations between populations of *B. longicaudatus*

Table 5. Percentage of tubers of selected potato cultivars with corky ringspot symptoms in a northeastern Florida potato field in untreated plots and following treatment with aldicarb, 1,3-D, and aldicarb + 1,3-D in 1990.

	Percentage of tubers with corky ringspot disease			
	Fumigated[y]		Not fumigated	
Cultivar	Plus aldicarb[z]	No aldicarb	Plus aldicarb[z]	No aldicarb
Atlantic	8	40*	14	78*
Green Mountain	5	59*	5	21
Kennebec	5	59*	21	71*
LaChipper	0	42*	34	54
Sebago	6	65*	21	94*
Red LaSoda	11	78*	42	64

Data are from two experiments. Asterisks indicate that aldicarb and no aldicarb treatments are statistically different ($P = 0.05$).

[y]1,3-D applied at 56 L/ha preplant.

[z]Aldicarb applied at 3.4 kg a.i./ha as 25-cm bands in the row at planting.

Table 6. Effect of summer management practices on wireworm damage and tuber yields of a subsequent potato crop in southeastern Florida.

Summer management treatment	Tuber yield (kg/plot)	Tubers damaged by wireworms (kg/plot)
Weeds	26.2 a[z]	3.0 b
Sorghum	28.5 a	6.3 a
Chemical fallow	33.0 a	1.0 c
Mechanical fallow	29.7 a	0.5 c

[z]Means in columns followed by different letters are statistically different ($P = 0.05$).

and trichodorids, as well as between trichodorids and *M. incognita* (19). Also, interactions between cultivars and treatments may exist wherein cultivars respond quite differently to management practices. Control of corky ringspot by aldicarb, for example, works better in some cultivars than others (Table 5). Incidence of bacterial wilt in the susceptible cv. Atlantic was reduced to that observed in the tolerant cv. Sebago by increasing the fumigation rate and number of application chisels (Table 2) (21). The reduction in incidence of brown rot obtained by delaying potato harvest also varies with cultivar (Fig. 4).

In southeastern Florida, summer management practices appear to be of practical benefit only against *M. incognita. Criconemella onoensis* does not appear to be pathogenic to the potato crop (6), and *R. reniformis*, though affected much by summer management practices, declined on the potato crop following all summer scenarios (Fig. 5). Cover cropping with sorghum in southeastern Florida aggravates problems with wireworms (Table 6), although early harvest of sorghum before wireworms oviposit can alleviate this problem (7).

OUTLOOK

Northeastern Florida

This management system is heavily dependent upon pesticides. The recent withdrawal of aldicarb from use in potatoes has both increased the cost and reduced the effectiveness of soil-borne disease and nematode control. The wide host ranges of the principal nematodes and pathogens, present major challenges in determining alternative management strategies. Efforts to find resistance to corky ringspot and bacterial wilt have received and will continue to receive major research effort. Additional management strategies, such as use of alternative cover crops and green manuring to enhance soil microbial activity, are also being studied. Additional data are needed on economic thresholds of *B. longicaudatus, M. incognita,* and trichodorids as well as on interactions among nematode species.

Southeastern Florida

Problems with *M. incognita* on potato are sporadic. When problem fields are identified, management by summer fallow or a summer cover crop of sorghum may be helpful provided that the sorghum planting is timed judiciously to avoid peak wireworm flights. In southeastern as in northeastern Florida, it appears that planting date and temperature can greatly influence the level of *M. incognita* galling on tubers. In southeastern Florida, for example, early planting (November) and harvest (March) may permit lifting of the infected potatoes before visual symptoms and damage appear. Potatoes harvested in late April are more often damaged, probably because the warmer temperatures permit more rapid development and tuber infection by a later generation of root-knot nematodes (McSorley, unpublished data). However, more research is needed to determine the relationship between planting date and tuber damage, before planting date can be used as a reliable management tool.

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