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Trap Crops and Population Management of *Globodera tabacum tabacum*

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Abstract: Tobacco, eastern black nightshade, and tomato were grown for 3 to 13 weeks to assess differences in invasion, development, and soil density of *Globodera tabacum tabacum* (tobacco cyst nematode) in field plots and microplots over three seasons. Tobacco cyst nematodes invaded roots of resistant and susceptible tobacco, nightshade, and tomato. Nematode development was fastest in nightshade and slowest in tomato, and few adults developed in roots of nematode-resistant tobacco. Soil populations of tobacco cyst nematodes were reduced up to 80% by destroying nightshade or susceptible tobacco grown for 3 to 6 weeks. Nematode populations were reduced up to 96% by destroying tomato or resistant tobacco grown for 3 to 6 weeks. Timing of crop destruction was less critical with tomato and resistant tobacco, as nematode populations did not increase after 13 weeks of growth. These studies demonstrate that trap cropping, through crop destruction, can significantly reduce *G. t. tabacum* populations.

Key words: eastern black nightshade, fallow, *Globodera tabacum tabacum,* hatch, *Lycopersicon esculentum, Nicotiana tabacum,* resistance, *Solanum ptycanthum,* tobacco, tobacco cyst nematode, tomato, trap crop

The tobacco cyst nematode *Globodera tabacum tabacum* is an important pathogen of shade tobacco in the Connecticut River Valley of Connecticut and Massachusetts (11). Currently, this nematode is controlled by soil fumigation with 1,3-dichloropropene (10). Because of the high input associated with establishing and maintaining shade tents for field production, rotations long enough to reduce nematode densities below damaging levels may not be practical.

Trap cropping, through destruction of a crop before nematode maturation as a means of reducing nematode densities, was demonstrated as early as 1939 (3) and may aid in cyst nematode management (1, 3,6). This method of trap cropping may accelerate the decline of cyst nematodes which hatch poorly in the absence of host plants and has been exploited by using potatoes to reduce potato cyst nematode (*Globodera rostochiensis* and *G. pallida*) densities in soil (1,3,8,15,18). The destruction of potato plants before nematode reproduction can reduce densities by up to 80% (8,15). Many cyst nematodes may be stimulated to hatch by root exudates of host plants (4–6,20), and cyst nematode decline in the absence of a host is often much lower than when a host is present. *Globodera rostochiensis* and *G. pallida* decline under fallow or nonhost crops generally ranges from 20 to 40% (8,15,17). Tobacco cyst nematode decline under fallow is about 40% annually (12), and hatch is increased in response to root exudates of tobacco, tomato, and eastern black nightshade, *Solanum ptycanthum* Dun. (12).

The experiments reported here were performed to determine if the use of trap crops in a rotation year would result in a tobacco cyst nematode decline comparable to fumigation. Because the duration of trap cropping can influence nematode population dynamics (18) and timing of destruction of susceptible plants can be critical, the development of *G. t. tabacum* over time in different trap crops was also investigated.

Materials and Methods

Experiments were conducted in 1992, 1993, and 1994 at the Connecticut Agricultural Experiment Station Valley Laboratory in Windsor, Connecticut. All experimental plots were established in a cloth-

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covered shade tent (16) in Merrimac fine sandy loam field soil (Entic Haplorthod; 71.8% sand, 23.0% silt, 5.2% clay, pH 6.2, 4.0% organic matter) naturally infested with *G. t. tabacum*. One day before planting, a conventional tobacco fertilizer (10-8-10 N-P-K cottonseed meal base, 140 kg N/ha) was broadcast over the plots and incorporated by tilling to 15 cm deep. A preplant application of diazinon (2.2 kg a.i./ha) and metalaxyl (0.2 liter a.i./ha) was incorporated into all plots 24 hours before transplanting, according to standard commercial practice for control of soilborne insects and fungi.

Field plots: Two-month-old seedlings of the tobacco cyst nematode-susceptible shade tobacco '0–40', the nematode-resistant tobacco 'B–49', 'Rutgers' tomato, and a population of eastern black nightshade, *Solanum ptycanthum*, collected in Windsor, Connecticut, were transplanted on 3 June 1992 and 27 May 1993 to single row plots 5 m in length 1 m apart with 30 cm between plants in rows (15 plants/row). Crops were killed by rototilling plots with a 60-cm-width rototiller 3, 4, 5, or 6 weeks after transplanting or grown for a full season (13 weeks) before tilling. There were four replicate plots of each treatment-time combination in a randomized design blocked by time of crop destruction. To determine the stage of *G. t. tabacum* development in roots, randomly selected plants were destructively sampled from plots at 3- to 6-week intervals prior to tilling. Two 1-g root samples were selected and stained. Juvenile and adult nematodes present in root tissues were counted, after staining individual samples in acid fuschin (2), and expressed as nematodes per g fresh root.

Globodera t. tabacum densities in soil were determined by removing and bulking 10 2.5-cm-diam. cores, taken 15 cm deep, per plot. After harvest and rototilling, soils again were sampled. All soils were air dried, mixed well, and *G. t. tabacum* cysts were extracted from 250 cm^3 of soil with a modified Fenwick can. Cysts were crushed in water, and two aliquots of nematodes in suspension were counted to determine the number of free second-stage juveniles (J2) and J2 in eggs per cm^3 of soil. Population changes over a season were expressed as the ratio of final (Pf) to initial (Pi) juveniles per cm^3 of soil. Initial *G. t. tabacum* densities ranged from 108 to 247 J2/cm^3 of soil in 1992 and 39 to 659 J2/cm^3 of soil in 1993. Plots were planted to the same crops and destroyed at the same times in 1993 as in 1992.

On 26 May 1994, 2-month-old seedlings of shade tobacco cultivar '0–40', the tobacco cyst nematode-resistant shade line '21–2', 'Rutgers' tomato, and *S. ptycanthum* were transplanted to 5-m × 5-m plots in a different location than in 1992 or 1993. There were four rows per plot, and plants were 30 cm apart within rows (15 plants/row). Fallow plots were left free of plants. Plots were tilled to kill the plants at 4, 5, or 6 weeks after transplanting. There were four replicate plots of each plant treatment for each time period. Nematodes in roots and soil (50 cores/plot) were determined as described above. Initial *G. t. tabacum* densities ranged from 11 to 237 J2/cm^3 of soil.

Microplots: Sixty microplots consisting of plastic waste cans (37.5-cm-top diam., 30-cm-bottom diam., and 45-cm deep, open at the bottom) (11) filled with Merrimac fine sandy loam field soil were placed 0.3 m apart in a single row in the center of a shade tent (16). *Globodera t. tabacum* populations were estimated before transplanting and again after harvest. Soil in microplots was thoroughly mixed to 20-cm deep with a trowel and sampled by removing 10 2.5-cm-diam. cores to 15-cm deep per plot. All soil samples were air dried, and *G. t. tabacum* cysts were extracted as described above. Initial *G. t. tabacum* densities ranged from 26 to 670 J2/cm^3 of soil. Fertilization and pesticide applications were performed as above. Two-month-old seedlings of shade tobacco cultivars 0–40, 21–2, Rutgers tomato, and *S. ptycanthum* were transplanted to three replicate microplots for each of four crop removal times. Plant shoots were cut and plots were tilled to kill plants at 3, 4, 5, or 6 weeks after transplanting or the plants were grown for a full season of 13 weeks.

Data were subjected to analysis of vari-

TABLE 1. *Globodera tabacum tabacum* stages per gram root and population changes over one season following trap crops destroyed 3 to 6 weeks after transplanting or grown full season—1992 and 1993.

Host	Weeks after transplanting	1992 J2–4	1992 Adult	1992 Pf/Pi	1993 J2–4	1993 Adult	1993 Pf/Pi
Tobacco (S)	3	736	27.8	0.61	931	39.0	0.32
	4	862	48.0	0.26	424	162.0	0.28
	5	519	158.5	0.62	255	203.5[a]	0.20
	6	79	221.8[a]	0.84	142	139.5	0.41
	13	—	—	1.09	—	—	1.33
Tobacco (R)	3	152	0.3	0.41	623	4.5	0.36
	4	185	0.0	0.42	545	13.5	0.32
	5	36	0.0	0.26	488	0.0	0.14
	6	11	0.5	0.50	89	2.0	0.33
	13	—	—	0.41	—	—	0.19
Nightshade	3	2165	102.5	0.40	1975	74.0	0.22
	4	827	272.8	0.29	887	538.0[a]	0.20
	5	585	642.0[a]	0.51	258	251.0	0.31
	6	48	307.5	0.64	67	102.0	0.88
	13	—	—	5.14	—	—	1.19
Tomato	3	743	8.0	0.32	933	25.0	0.22
	4	537	33.5	0.32	707	64.0	0.09
	5	627	17.5	0.18	859	52.0	0.04
	6	144	82.3	0.36	373	39.5[a]	0.06
	13	—	—	0.21	—	—	0.56
Source of variation (*P*)							
Crop		0.001	0.001	0.001	0.001	0.001	0.001
Week after transplanting		0.001	0.001	0.001	0.001	0.001	0.001
Interaction		0.001	0.001	0.001	0.001	0.001	0.001

Data are the means of four replications. The Pf/Pi were arcsine-transformed before analysis. Means of untransformed data are presented.
[a] Females with eggs first present in stained roots.

ance, and means were separated by the protected least-significant difference procedure. The ratios of final to initial nematode densities were arcsine-transformed before analysis to stabilize variance.

RESULTS

Globodera tabacum tabacum juveniles invaded roots of nematode-resistant or -susceptible tobacco, tomato, and nightshade (Tables 1,2). Juvenile infection generally peaked at 3 to 4 weeks after transplanting and was greater for nightshade than tobacco or tomato. Nematode development proceeded in susceptible tobacco, nightshade, and tomato, but few adults, primarily males, occurred in roots of resistant tobacco. Nematode development was fastest in nightshade and slowest in tomato; females with eggs were present in sampled roots at 4 weeks after transplanting for nightshade, after 5 weeks for susceptible tobacco, and approximately 6 weeks after transplanting for tomato.

Tobacco cyst nematode development on crops that were destroyed at various intervals was reflected in Pf/Pi values determined at the end of the growing season (Tables 1–3). The effects of each trap crop on nematode populations varied with the timing of crop destruction. *G. t. tabacum* population reduction was optimal (54–80%, mean 65%) after 4 weeks of nightshade growth, after 4 weeks of susceptible tobacco growth (39–74%, mean 62%), after at least 5 to 6 weeks of tomato (64–96%, mean 84%, and after 5 weeks of resistant tobacco growth (52–86%, mean 64%). Full-season crop growth increased nematode populations under susceptible tobacco and nightshade, but resistant tobacco and tomato crops reduced nematode populations more than bare fallow.

DISCUSSION

Currently, control of the tobacco cyst nematode in shade tobacco relies on the

TABLE 2. *Globodera tabacum tabacum* stages per gram root and population changes over one season following trap crops destroyed 4 to 6 weeks after transplanting—1994.

Host	Weeks after transplanting	J2	J3–4	Females	Males	Pf/Pi
Tobacco (S)	4	182.8	222.0	19.8	21.8	0.61
	5	57.0	112.0	57.5[a]	172.5	0.59
	6	4.3	29.3	22.5	58.8	0.51
Tobacco (R)	4	175.8	7.0	0.0	3.5	0.77
	5	138.0	162.3	7.3	64.3	0.57
	6	108.8	92.3	0.0	4.0	0.47
Nightshade	4	295.0	839.0	139.5[a]	143.0	0.46
	5	63.8	105.5	96.8	198.0	0.52
	6	34.0	141.0	57.0	269.0	0.87
Tomato	4	482.0	173.5	6.8	8.5	0.45
	5	279.5	272.0	44.5	350.5	0.22
	6	240.8	302.3	8.0[a]	158.3	0.14
Fallow		—	—	—	—	0.62
Source of variation (*P*)						
Crop		0.03	0.001	0.001	0.001	0.001
Weeks after transplanting		NS	0.004	0.001	NS	0.001
Interaction		NS	NS	0.001	NS	NS

Data are the means of four replications. The Pf/Pi were arcsine-transformed before analysis. Means of untransformed data are presented.
[a] Females with eggs first present in stained roots.

availability of a single soil fumigant. Growers may rotate out of tobacco to aid in nematode control, but the annual decline of *Globodera tabacum tabacum* in fallow soil is only 30 to 40% per year (12). Management of this nematode by rotation alone would greatly reduce the number of tobacco crops harvested and would be impractical. Tobacco cyst nematode-resistant tobacco lines are under development (9) but are not yet commercially acceptable.

The results of these experiments demonstrate the effect on tobacco cyst nematodes of trap cropping through destruction of plants after nematode invasion and before nematode maturation. All of the trap crops tested in these experiments reduced *G. t. tabacum* densities by at least 50%, similar to the decline in *Globodera rostochiensis* densities experienced after 4 weeks of a potato trap crop (13). Whitehead (18) reported a 65% decline in potato cyst nematodes after 6 weeks exposure to a potato trap crop, but concluded that the timing of plant destruction and risk of population increase made trap cropping unattractive. *Globodera* spp. eggs in first or second cleavage in young females will continue to develop to maturity when the females are removed from the roots (Brodie, unpubl). Trap crops also have been narrowly defined as plants which allow penetration, yet are poor hosts of the target nematode (6). The use of resistant cultivars or lines, or crops such as tomato which result in limited reproduction, would fit both definitions of a trap crop and greatly reduce the risk of nematode population increase (13). Five weeks of a resistant tobacco or tomato trap crop would reduce populations by 64 to 84%, respectively, approaching levels of control achieved by preplant soil fumigation (10). At moderate initial nematode densities, this level of control could be expected to reduce densities below damage thresholds (11).

The decline of potato cyst nematodes in field plots was markedly less than in pots or directly under plants, possibly due to row and furrow effects (8,14). The experiments reported here were performed in field plots at typical plant spacings. Increasing plant density and reducing the space between plants might further increase the efficacy of trap cropping.

Trap cropping in tobacco might best be used in conjunction with rotation to reduce *G. t. tabacum* densities. Growers pro-

TABLE 3. *Globodera tabacum tabacum* population changes over one season following trap crops destroyed 4 to 6 weeks after transplanting or grown full season (13 weeks) in field microplots—1993.

Host	Weeks after transplanting	Pf/Pi
Tobacco (S)	4	0.38
	5	0.52
	6	0.49
	13	1.14
Tobacco (R)	4	0.44
	5	0.48
	6	0.38
	13	0.35
Nightshade	4	0.46
	5	0.31
	6	0.34
	13	1.13
Tomato	4	0.25
	5	0.20
	6	0.08
	13	0.35
Fallow		0.61
Source of variation (*P*)		
Crop		0.001
Weeks after transplanting		0.001
Interaction		0.001

Data are the means of three replications. The Pf/Pi were arcsine-transformed before analysis. Means of untransformed data are presented.

duce their own transplants and typically overproduce. Extra tobacco transplants or trap crops seeded for that purpose can be set late in fields earmarked for rotation and destroyed after approximately 4 weeks, in time to plant typical cover crops of wheat or rye.

The apparent differences in the rate of tobacco cyst nematode development on tobacco, nightshade, and tomato are interesting and deserve further study. Rutgers tomato was moderately susceptible (12) or very susceptible (7) to *G. t. tabacum* after approximately 3 months in the greenhouse. Resistance to root-knot nematodes in a number of crops appears to be expressed as slower nematode development (19), similar to the slow development of the tobacco cyst nematode in tomato. Tomato may be effective as either a trap crop or a rotation crop due to the slow development of *G. t. tabacum* populations over time. The effect of different tomato varieties on tobacco cyst nematode development is currently being investigated.

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