Population Dynamics of Plant-Parasitic Nematodes in Golf Course Greens Turf in Southern New England

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ABSTRACT

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The distribution, frequency, and population levels over time of plant-parasitic nematodes were surveyed on 114 greens from 38 different golf courses throughout southern New England. Sampling took place in the spring, summer, and fall of 2003 and 2004. The predominant genera of phytoparasitic nematodes recovered from soil samples were *Tylenchorhynchus*, *Helicotylenchus*, *Cricone-mella*, *Hoplolaimus*, and *Heterodera*. *Tylenchorhynchus* and *Helicotylenchus* spp. were the most common, found in all 38 golf courses sampled. Population levels were significantly higher ($\alpha = 0.05$) in 2004 than in 2003 for *Cricone-mella*, *Tylenchorhynchus*, and *Heterodera* juveniles. There was a significant effect of season on population levels of *Cricone-mella*, *Tylenchorhynchus*, and *Heterodera* juveniles in the 2003 sampling year, and on *Helicotylenchus*, *Tylenchorhynchus*, and *Heterodera* juveniles in 2004. Population levels were highest in the fall for all genera except for *Tylenchorhynchus*, which were highest in the summer for both years. The results of this study suggest that parasitic nematodes are present in relatively high numbers in golf course turf soils in southern New England, and that there are variations in the dynamics of population levels among the different genera found in the area.

Nematodes are known to be important pests of turfgrass in the southern regions of the United States (14,24), but their importance in the north is not as clearly understood (15). Nematodes attack the roots of turfgrass plants, leading to a decrease in the uptake of water and nutrients. Over time, affected plants exhibit a reduction in vigor. In the southern United States, turf is grown year-round, providing a constant source of food for plant-parasitic nematodes. This allows for year-long reproduction and, consequently, the potential for high population levels to be reached in a relatively short period of time (10). Nematodes are rarely considered to be a problem of turfgrass in the northern regions of North America, in part due to the delayed onset of symptoms, which makes it difficult to link damage to nematode feeding. However, under stressful situations such as extreme soil compaction, excessive traffic, and particularly drought, the decrease in root mass caused by nematode damage leads to a fairly rapid decline in plant health. Unfortunately, definitive diagnosis of the problem still may be difficult because the symptoms of nematode damage—including yellowing and thinning of

turf and reduced resistance to stresses—are relatively nonspecific (12,16). When nematodes are found to be the cause of decline in turf quality, turfgrass managers have a limited number of control methods at their disposal (12). A keen understanding of the trends in population changes over time, along with a knowledge of the predominant parasitic nematodes that are present in soils in the region, can aid in proper management and, if necessary, control of these pathogens (1,6). Population dynamics surveys conducted in various regions of central and northern United States have indicated the presence of numerous genera of plant-parasitic nematodes on turfgrass (3,11,17–20). Murdoch et al. (11) recovered 10 genera of phytoparasitic nematodes from putting greens throughout New York, while 11 known plant-parasitic nematode genera were recovered from putting greens in Kansas (19). Similar studies have shown a high diversity of genera of parasitic nematodes in regions of Canada as well (25). To date, there have been two published studies of nematode population dynamics in the New England region (20,23). Since the time of these publications, golf has become increasingly popular and, in the mid- to late 1990s, there was a boom of golf course construction in the New England region (National Golf Foundation, *personal communication*). Additionally, management practices have become more intense on golf courses in the past few decades, as has the trend toward sand-based greens construction (4). These changes tend to be

favorable for an increase in nematode populations and the potential for damage to turfgrass (12). The purpose of this study was to survey the distribution and frequency of occurrence of plant-parasitic nematodes on a variety of golf course greens in southern New England and to determine the dynamics of nematode populations over time, both within a growing season and between two different seasons.

MATERIALS AND METHODS

Sample collection. Samples were collected from 114 mixed bentgrass (both creeping [*Agrostis palustris* Huds.] and velvet [*A. canina* L.]) and annual bluegrass (*Poa annua* L.) putting greens at 38 golf courses throughout the southern New England region (Table 1) during the 2003 and 2004 growing seasons. The geographical distribution of the sampling sites is shown in Figure 1. Samples were taken in May, June, and September of both years. Golf courses were chosen based on previous nematode data obtained from the University of Rhode Island turfgrass diagnostic clinic. Sites were chosen such that there was a relatively even mix of courses that had historically high levels of nematodes and those that had low levels. Three greens from each golf course were chosen at random or at the discretion of the superintendent on site. Greens were sampled by collecting 20 to 30 cores—depending on green size—evenly spaced throughout the green using a 1.9-cm-diameter soil probe. Cores were taken to a depth of 10.2 cm, and the top 2.5 cm of turf and thatch were removed and returned to the green. Cores were placed in a plastic sample bag to create one composite sample for each green. All samples were kept at 4°C and were extracted within a 2-week period.

Nematode extraction and identification. Composite samples were sieved through a 0.635-cm sieve and mixed thoroughly. A 25-cm³ subsample was used for extraction. Nematodes were extracted using a modification of the sugar flotation centrifugal method (8). Nematodes were identified to genus level using a dissecting microscope and data was recorded as the number of nematodes per 100 cm³ of soil.

Data analysis. Analysis of population levels of each genus between golf courses, sampling seasons within each year, and sampling years was performed. All data were tested for analysis of variance assumptions. Comparisons between golf

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courses were made using the general linear models procedure and the Waller-Duncan means comparison test in SPSS (Chicago). Data for sampling season and year were

found to be non-normal; therefore, the Kruskal-Wallis and Mann-Whitney non-parametric tests were performed in SPSS to compare treatment differences.

Table 1. Site key to golf courses sampled^z

Site no.	Golf course	Location	Greens sampled
1	Wee Burn CC	Darien, CT	4, 12, 14
2	Woodway CC	Darien, CT	2, 14, 15
3	Oak Hills Park GC	Norwalk, CT	2, 12, 16
4	Patterson CC	Fairfield, CT	5, 9, 11
5	Manchester CC	Manchester, CT	8, 12, 13
6	Cedar Ridge GC	East Lyme, CT	3, 12, 17
7	Pequot GC	Stonington, CT	1, 9, 18
8	Misquamicut Club	Watch, Hill, RI	2, 12, 15
9	Weekapaug Golf Club	Westerly, RI	3, 5, 6
10	Foxwoods Golf & CC	Richmond, RI	1, 2, 9
11	Beaver River Golf Club	Richmond, RI	4, 8, 12
12	Laurel Lane CC	W. Kingston, RI	7, 10, 14
13	Jamestown CC	Jamestown, RI	7, 8, 9
14	Green Valley CC	Portsmouth, RI	3, 15, 18
15	Sakonnet Golf Club	Little Compton, RI	2, 15, 18
16	Rhode Island CC	Barrington, RI	2, 18, PG
17	Potowomut CC	East Greenwich, RI	8, 16, 18
18	Woodland Greens Golf Club	North Kingstown, RI	5, 7, 8
19	Quidnessett CC	North Kingstown, RI	1, 2, 9
20	Midville Golf Club	West Warwick, RI	1, 5, 6
21	West Warwick CC	West Warwick, RI	4, 6, PG
22	Cranston CC	Cranston, RI	3, 9, PG
23	Warwick CC	Warwick, RI	4, 6, PG
24	Foster CC	Foster, RI	11, 17, 18
25	Glocester CC	Glocester, RI	1, 2, 9
26	Pawtucket CC	Seekonk, MA	9, 12, 16
27	Firefly GC	Seekonk, MA	4, 9, 13
28	Ledgemont CC	Seekonk, MA	2, 8, 10
29	Crestwood CC	Rehoboth, MA	2, 4, 10
30	Milton Hoosic Club	Canton, MA	2, 8, 9
31	Blue Hill CC	Canton, MA	11, 12, 13
32	Duxbury CC	Duxbury, MA	4, 10, 17
33	Dedham Country & Polo Club	Westwood, MA	9, 11, PG
34	Oakley CC	Watertown, MA	2, 12, 13
35	Bear Hill CC	Stoneham, MA	1, 5, 7
36	Pine Brook CC	Weston, MA	7, 9, 11
37	Ferncroft CC	Danvers, MA	6, 7, 10
38	Myopia Hunt Club	South Hamilton, MA	7, 12, 15

^z CC = country club, GC = golf course.

Fig. 1. Distribution of golf courses sampled throughout southern New England.

RESULTS

Plant-parasitic nematodes were found in all of the samples tested. The five dominant genera recovered from the soil samples were *Tylenchorhynchus*, *Helicotylenchus*, *Criconebella*, *Hoplolaimus*, and *Heterodera* juveniles. There also were a small number of samples that had *Meloidogyne* juveniles and other stylet-bearing nematodes, including *Pratylenchus* and *Tylenchus*. The results show significant variability in the population levels of phytoparasitic nematodes between the golf courses tested (Table 2). Data on the frequency of occurrence of each genus on the golf courses and in the samples, as well as which nematodes were found above threshold levels (based on data from R. Wick at the University of Massachusetts), are displayed in Table 3. *Tylenchorhynchus* spp. were found in all golf course samples tested and were above threshold in approximately one-third of the samples tested. *Helicotylenchus* and *Criconebella* spp. were the next most frequent, followed by *Hoplolaimus* and *Heterodera* spp. *Meloidogyne* spp. and other stylet-bearing nematodes were found in only one-third of the samples tested, and in small quantities at each site. Seasonal fluctuation was observed in the first sampling year within the genera *Criconebella*, *Tylenchorhynchus*, and *Heterodera* ($P < 0.01$; Fig. 2). *Tylenchorhynchus* population levels were highest in the June sampling date, whereas *Criconebella* and *Heterodera* levels were highest in September. The other two predominant genera showed no significant change from one sampling period to the other in 2003. In the 2004 season, there was a significant effect of sampling date on nematode populations for *Helicotylenchus*, *Tylenchorhynchus*, and *Heterodera* spp. ($P < 0.05$). *Criconebella*, *Helicotylenchus*, and *Heterodera* population levels all were highest in September, and *Tylenchorhynchus* levels were highest in June. Seasonal fluctuation for *Meloidogyne* spp. is not reported because root-knot nematodes were counted only during the fall 2004 sampling date. Non-stylet-bearing nematodes also were counted during the 2004 season in an attempt to determine seasonal fluctuation of nonphytoparasitic nematodes, and to see if there was any correlation between levels of plant-parasitic nematodes and non-stylet-bearing nematodes. The non-stylet-bearing nematodes increased significantly in the summer sampling and remained constant in the fall sampling date (Fig. 2). Levels of non-phytoparasitic nematodes were positively correlated with *Criconebella* populations ($r^2 = 0.129$, $P = 0.017$) and *Tylenchorhynchus* nematode populations ($r^2 = 0.491$, $P = 0.000$). There was a significant effect of sampling year as well. Population levels of *Tylenchorhynchus*, *Criconebella*, and *Heterodera* spp. all were significantly higher in the 2004 season ($P = 0.000$).

Although nematode levels appeared higher in *Helicotylenchus* and *Hoplolaimus* spp. as well, these differences were not significant.

DISCUSSION

Studies involving population dynamics often are conducted in an attempt to predict nematode behavior in a particular field or in a larger region in the hopes of extrapolating that information to other regions of similar characteristics (crop, average temperature, moisture, and so on; 13). Additionally, information obtained about population fluctuations can be used to accurately time chemical applications or to adjust management practices in areas where nematodes may be a threat to healthy turf (1). Comparison of data from one region to another allows for wider projection of data and more accurate interpretations of the data obtained in an individual study.

The genera of plant-parasitic nematodes found in this survey were similar to those

found in other studies done in the northern and central regions of the United States (11,19,23), as well as in some parts of Canada (7). The high prevalence of *Tylenchorhynchus* spp. in the New England region was consistent with findings by Troll and Tarjan (20), although the other nematodes frequently found in that study,

including *Pratylenchus* and *Tylenchus* spp., were not as prevalent in this one. The results of this study suggest that nematodes are found in high numbers in the southern New England region of the United States, and that the number of samples with nematodes above threshold could indicate a potential problem in this region.

Table 3. Frequency of occurrence of nematodes and nematodes above threshold on golf courses and greens

Nematode genus	With nematodes (%)		Samples above threshold (%) ^y
	Golf courses	Greens	
<i>Criconemella</i>	97.4	95.6	7.0
<i>Helicotylenchus</i>	100.0	98.2	2.6
<i>Tylenchorhynchus</i>	100.0	100.0	35.1
<i>Hoplolaimus</i>	89.5	85.1	9.6
<i>Heterodera</i> ^z	94.7	84.2	7.9
<i>Meloidogyne</i> ^z	50.0	31.6	1.8
Other parasitic genera	76.3	39.5	NA

^y Threshold data based on findings from University of Massachusetts Turf Diagnostics Lab refers to nematode levels above threshold at any of the six sampling dates in 2003 and 2004; NA = not applicable.

^z Value refers to juveniles recovered from soil.

Table 2. Mean nematode values at each course for each nematode genus or type identified, based on peak population sampling date for each nematode

Site ^z	Nematode, season ^y											
	<i>Cric</i> , fall		<i>Helic</i> , fall		<i>Tylen</i> , summer		<i>Hoplo</i> , fall		<i>Het J</i> , fall		<i>Melo J</i> , fall	NSB
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2004	2004
1	275 abcde	893 e	243 ab	1,407 c	153 abc	593 abcde	80 abcd	147 abcde	13 a	7 a	0 a	647 fghij
2	313 abcde	720 cde	1,180 d	3,827 d	92 ab	1,060 ef	0 a	33 ab	67 bc	47 a	0 a	420 cdefg
3	77 ab	447 abcde	185 a	1,027 bc	17 a	127 abc	11 a	73 abcd	16 abc	127 abc	0 a	523 efghi
4	59 a	203 abcd	9 a	50 a	21 a	263 abcd	0 a	10 a	55 abc	223 c	0 a	770 hij
5	911 gh	2,860 g	8 a	253 a	5 a	244 abcd	13 ab	60 abc	3 a	13 a	0 a	150 abc
6	97 abc	149 abcd	1 a	11 a	12 a	113 abc	51 abc	87 abcd	3 a	1 a	5 ab	119 abc
7	45 a	107 abc	123 a	1,313 c	11 a	253 abcd	12 ab	33 ab	0 a	27 a	47 ab	270 abcde
8	181 abc	283 abcde	787 abc	550 ab	69 ab	683 bcde	7 a	17 a	0 a	80 abc	17 ab	880 jk
9	0 a	0 a	584 bc	579 ab	52 ab	47 a	13 ab	17 a	0 a	0 a	17 ab	273 abcde
10	1 a	0 a	0 a	4 a	0 a	21 a	0 a	0 a	0 a	0 a	0 a	144 abc
11	0 a	1 a	0 a	4 a	0 a	1 a	0 a	0 a	0 a	0 a	0 a	20 a
12	25 a	100 abc	212 a	289 a	11 a	227 abcd	0 a	0 a	0 a	8 a	3 ab	170 abcd
13	61 a	365 abcde	44 a	3 a	15 a	104 abc	0 a	0 a	0 a	132 abc	53 abc	231 abcde
14	1,267 h	1,953 f	47 a	33 a	20 a	67 ab	173 cde	100 abcde	7 a	20 a	107 c	380 bcdefg
15	0 a	9 a	33 a	31 a	732 ef	1,400 f	7 a	5 a	0 a	41 a	7 ab	473 defgh
16	1 a	17 a	132 a	393 a	571 de	940 ef	87 abcd	120 abcde	0 a	57 ab	47 ab	333 abcdef
17	201 abcd	334 abcde	1 a	8 a	1,488 h	3,413 h	55 abc	41 abc	15 ab	83 abc	0 a	347 bcdefg
18	587 efg	503 abcde	53 a	50 a	23 a	231 abcd	40 ab	25 ab	160 d	146 abc	11 ab	150 abc
19	83 ab	87 ab	24 a	216 a	180 abc	1,053 ef	17 ab	45 abc	1 a	88 abc	0 a	373 bcdefg
20	545 def	764 de	16 a	12 a	35 ab	187 abcd	27 ab	7 a	0 a	3 a	164 d	433 cdefg
21	733 fg	700 bcde	13 a	7 a	193 abc	800 def	140 bcde	237 de	0 a	30 a	20 ab	680 ghij
22	157 abc	240 abcd	112 a	221 a	61 ab	203 abcd	1 a	13 a	13 ab	45 a	4 ab	337 abcdef
23	307 abcde	267 abcde	87 a	21 a	808 efg	3,060 h	527 f	444 f	73 c	42 a	8 ab	813 ijk
24	172 abc	208 abcd	24 a	92 a	4 a	27 a	0 a	0 a	31 abc	152 abc	14 ab	253 abcde
25	449 cdef	350 abcde	7 a	33 a	19 a	127 abcd	32 ab	23 ab	0 a	10 a	10 ab	253 abcde
26	316 abcde	763 de	40 a	30 a	861 fg	2,153 g	24 ab	30 ab	0 a	63 abc	0 a	887 jk
27	120 abc	397 abcde	7 a	33 a	16 a	144 abc	35 ab	215 cde	0 a	93 abc	54 bc	275 abcde
28	39 a	67 a	8 a	0 a	1,471 h	4,173 i	188 de	197 bcde	0 a	53 ab	7 ab	633 fghij
29	424 bcdef	2,080 f	13 a	127 a	67 ab	507 abcde	53 abc	7 a	0 a	7 a	20 ab	493 efg
30	28 a	31 a	20 a	48 a	372 cd	720 cde	265 e	551 f	0 a	213 bc	0 a	283 abcde
31	65 ab	55 a	5 a	5 a	239 abc	903 ef	57 abc	61 abc	20 abc	75 abc	0 a	247 abcde
32	60 a	87 ab	7 a	117 a	412 cd	783 def	53 abc	70 abcd	13 ab	30 a	0 a	280 abcde
33	0 a	0 a	72 a	95 a	883 fg	37 a	108 abcd	25 ab	67 bc	61 abc	0 a	72 ab
34	133 abc	760 de	27 a	217 a	307 bd	773 de	5 a	13 a	28 abc	3 a	0 a	416 cedfg
35	79 ab	120 abc	97 a	20 a	1,031 g	2,110 g	0 a	27 ab	0 a	80 abc	0 a	1,107 k
36	147 abc	200 abcd	27 a	167 a	167 abc	1,013 ef	7 a	20 a	13 ab	147 abc	0 a	867 jk
37	51 a	140 abcd	15 a	0 a	20 a	28 a	0 a	0 a	0 a	0 a	0 a	93 ab
38	15 a	17 a	32 a	7 a	15 a	77 ab	193 de	263 e	0 a	24 a	0 a	248 abcde

^y Genera: *Cric* = *Criconemella*, *Helic* = *Helicotylenchus*, *Tylen* = *Tylenchorhynchus*, *Hoplo* = *Hoplolaimus*, *Het J* = *Heterodera* juveniles, *Melo J* = *Meloidogyne* juveniles, and NSB = non-styler-bearing, summer. Letters represent means comparison groups within each column based on Waller-Duncan test ($\alpha = 0.05$).

^z Site numbers refer to individual golf courses sampled as listed in Table 1.

There was a substantial amount of variability in nematode population levels between the golf courses surveyed. However, mean separation may have been more distinct had more samples been surveyed from each site. The variability that was observed did not appear to be due to geographical differences because there were numerous sites in all three states surveyed that had either relatively high or low levels of parasitic nematodes. A majority of the sites that had higher than average levels of nematodes were from the courses that had historically high levels in the past, based on previous diagnostic data. This would indicate that, in the absence of chemical treatment, nematode population trends are relatively stable over time. In addition, many of the sites with higher levels of

nematodes were from older greens, on courses that had been established for over 20 years. It has been suggested that green age could be a determining factor in nematode populations levels (21); therefore, this may be a reason for some of the differences observed in this survey.

The seasonal fluctuation observed for each nematode genus is consistent with previous findings for these genera (5,9). Although there was some variability between sampling sites, Davis et al. (5) found that levels of *Criconebella* and *Helicotylenchus* spp. nematodes generally were highest in the spring and fall. In this study, we found that, at most sampling sites, levels of both *Criconebella* and *Helicotylenchus* spp. were similar in the spring and summer, but rose in the fall

sampling (Fig. 2). Lucas et al. (9) observed that *Tylenchorhynchus* levels increased toward the end of the summer and declined into fall, as was the case in our study. Lucas et al. also found that *Hoplolaimus* densities were highest in June, but declined through the summer and rose again into the fall months. We saw no significant increase of *Hoplolaimus* spp. during the entire seasons; however, population levels of this nematode were low relative to the other nematodes studied. In this study, individual data between sampling sites did vary somewhat, especially where counts were well below threshold, but the results of our study combined with the previous studies mentioned suggest that the seasonal fluctuations of most of the nematode genera may be predictable, even over a

Fig. 2. Seasonal fluctuation of nematode populations in 2003 and 2004 expressed as nematodes per 100 cm³ of soil, averaged across all samples.

relatively wide geographical area. These results differ from the findings of Wick (23), who observed that changes in population trends over a season were not consistent from one green to another. However, in Wick's study, he surveyed a broader geographical range of golf courses, including many parts of northern New England, where the climate is much more inconsistent between regions. Those somewhat extreme differences in climate between sampling sites may have increased the variability observed in his study. In this study, we surveyed primarily coastal southern New England, where the differences in climate are much more subtle. Additionally, this study surveyed over three times as many sites as did Wick's study, and that may have led to more consistent findings. Even though the nematode population levels were significantly different between 2003 and 2004 in our study, the pattern of seasonal variability we observed was similar between the 2 years. That indicates that seasonal fluctuation patterns of nematode genera may be constant between different seasons.

The differences in nematode population levels between 2003 and 2004 were consistent for all but two of the genera studied. There were more nematodes in the second season, even as early as the spring sampling, for *Tylenchorhynchus*, *Cricone-mella*, and *Heterodera* spp. We feel that this difference may have been due to extremely high moisture levels in the early part of the growing season of the first sampling year. Weather data was obtained from the National Oceanic and Atmospheric Administration for the various regions that were sampled (*data not shown*) and observed for rainfall and temperature variations. In spring 2003, both prior to and following the first two samplings, total rainfall in much of the southern New England regions was above average. This may not have allowed for the soil to dry out at any time during the spring and summer months. Because nematodes are adversely affected by extreme soil moisture (2,13,22), saturation of the soil likely would inhibit movement and, potentially, survival of the nematodes. In the 2004 season, rainfall was above average only during the month of April, whereas the remaining months had precipitation levels

that were at or below average for most of the areas surveyed. Under natural conditions, the moisture level may have been too dry for nematode survival; however, with the artificial irrigation that golf course greens receive (sometimes daily), the moisture was most likely kept at an ideal level for the nematodes. Differences in average, maximum, and minimum temperatures between the two sampling years were minimal, suggesting that temperature may not have played a role in the differences observed between 2003 and 2004. However, average and extreme temperature readings do not take into account the duration of freezing and thawing periods that may have occurred in either year, which may have impacted the ability of nematodes to successfully overwinter in the 2003 season.

The results of this research suggest that plant-parasitic nematodes are present, often in quantities above threshold levels, on golf course greens in southern New England. Although seasonal fluctuation of nematode populations was found to be relatively stable between sampling sites, there is a high degree of variability in the populations of nematode genera at different sites. This may suggest that other physical or biological factors likely are involved in determining nematode population dynamics in golf course greens soils.

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