Research *You Can Use*

Biology and Management of Nematodes on Turfgrass in Northern California

A variety of microscopic roundworms lurking just beneath the surface poses a challenge for putting surfaces.

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Nematode damage on *Poa annua* putting greens has been a recurring problem on Northern California golf courses. Nematodes typically found causing damage to turf include: root knot (*Meloidogyne* sp.), ring (*Mesocriconema* sp.), dagger (*Xiphinema* sp.), lesion (*Pratylenchus* sp.), stubby root (*Trichodorus* sp.), pin (*Paratylenchus* sp.), and sting nematode (*Belonolaimus longicaudatus*). In addition, we have recovered large numbers of spiral nematode (*Helicotylenchus* sp.) from problem turfgrass locations.

In 1982, from San Francisco, San Mateo, and Monterey counties of California, *Anguina pacificae*, a seed and leaf gall nematode, was first identified from *Poa annua* galls located at the bases of stems. Since this finding, *A. pacificae* has been considered to be the primary nematode causing problems on coastal golf courses in Northern California.

The organophosphate nematicide Nemacur (fenamiphos) has been used in the management of *A. pacificae* and other nematodes on turfgrass in California (Winterlin *et al.*, 1986). Recently, the nematode problem has become increasingly more noticeable both on courses that have used Nemacur and on those that have not. Nemacur will be withdrawn from the market in the near future, and replacement management techniques are needed.

Up to this point, the life cycle of *A. pacificae* has not been completely understood. To further the development of environmentally sensitive programs for nematode management, a survey was conducted to determine the distribution of *A. pacificae* and other nematodes on coastal golf courses in Northern California. Following the survey, two golf courses were selected for biweekly monitoring of nematode populations. Additionally, a trial comparing the effectiveness of six potential products as replacements for Nemacur was conducted on a golf course green in Northern California.

Anguina pacificae lives within these galls visible at the base of the plant.

SETTING UP THE TRIALS

To survey for nematodes, one or more cores were taken with a cup cutter from at least one green on 14 golf courses in Monterey, San Francisco, and San Mateo counties (Table 1). Galls were individually removed from the cores and dissected.

Following the survey, a single green was selected at the Olympic Club Golf Course in San Mateo County and

Table 1

Populations of various nematodes found on golf courses in Northern California.

	Nematodes Per Liter of Soil		
Golf Course	**Spiral**	**Ring**	**Root-Knot**
Bayonet	6,200	50	150
Cypress Point	22,500	4,200	300
Del Monte	9,600	38,400	650
Lake Merced	13,260	10	0
Monterey Peninsula	90,240	12,000	0
Northwood	5,760	9,120	1,450
Olympic Club	6,857	1,600	29,400
Pacific Grove	3,600	1,800	0
Pebble Beach	4,200	33,000	50
Poppy Hills	12,900	1,800	1,200
Presidio	9,200	0	0
Quail Lodge	9,600	27,900	0
San Francisco	4,114	2,229	350
Spyglass	600	1,350	50

Table 2

Number of *Anguina* galls and nematode populations within galls following nematicide applications.

Treatment	Rate/Acre	Galls		Females		Males		Immature Adults		Juveniles		Eggs		Total Adults		Total Nematodes	
Untreated		13.0		13.3		8.5		19.0		105.5		1,745.3		40.8		146.3	
Nemacur 10G	66.7 lb/A	2.8	0.09	2.5	0.02	1.3	0.03	12.3	0.13	0.5	0.35	63.0	0.01	16.0	0.01	16.5	0.03
Ditera DF	100 lb/A	17.3	0.77	14.0	0.68	8.8	0.98	8.0	0.34	12.5	0.74	1,422.3	0.01	30.8	0.64	43.3	0.55
A-1641	20 lb/1K	11.8	1.00	8.0	0.74	4.3	0.44	15.0	0.74	1.3	0.46	2,486.3	0.20	27.3	0.58	28.5	0.39
A-1641	15 LB/1K	17.0	0.67	16.5	0.56	6.5	0.73	7.8	0.11	123.3	0.90	902.3	0.29	30.8	0.75	154.0	0.92
Quillaja 35%	1.5 GPA	12.8	0.72	4.3	0.17	1.8	0.10	17.5	0.69	12.0	0.62	940.0	0.46	23.5	0.09	35.5	0.33
Quillaja 35%	2.5 GPA	16.5	0.97	7.5	0.27	5.0	0.22	13.0	0.64	1.0	0.40	1,697.8	0.71	25.5	0.47	26.5	0.35
XRM 5053	3 GPA	14.5	0.78	15.0	0.66	3.8	0.25	10.8	0.08	124.0	0.89	2,554.5	0.99	29.5	0.70	153.5	0.92
Fore	28 liters	25.7	0.41	20.5	0.40	14.0	0.80	12.8	0.35	62.5	0.72	2,700.5	0.98	47.3	0.73	109.8	0.92
Fosthiazate	3 lb AI/A	1.5	0.03	0.5	0.01	0.0	0.01	4.8	0.01	238.5	0.51	0.0	0.67	5.3	0.01	243.8	0.21

Each figure is the mean of 4 replicates.
Each mean is followed by the probability that it is statistically different from the untreated.
Rate indicates amount of product applied for each of 3 applications at 4- to 6-week intervals.
Galls indicates galls counted per inch of soil core.
Other figures are total counts per 10 galls per replicate.
Total adults is the sum of females plus males plus immature adults.
Total nematodes is the sum of total adults plus juveniles.

another at Poppy Hills Golf Course in Monterey County to monitor the population cycling of the four nematodes found most commonly during the survey. Three cup-cutter cores were taken biweekly from each green. Nematodes were extracted from soil around roots and were identified to genus and counted under a dissecting microscope.

For the management trial, a green at the Olympic Club that was heavily infested with *A. pacificae*, spiral nematode, ring nematode, and root-knot nematode was selected. The treatments were: untreated, Nemacur 10G (Bayer), DiTera DF (Valent), two rates of A-1641 (mustard bran, Uniroyal/Crompton), two rates of Quillaja 35% (Desert King), XRM 5053 (1,3-dichloropropene plus emulsifier, DowAgro Sciences), and Fore (mancozeb, Dupont) (Table 2). Applications were followed by 0.5 inch of irrigation via overhead sprinklers. During the trial, the green was maintained by the course following standard cultural practices.

Each treatment was applied a total of three times at 4- to 6-week intervals. Turf quality was evaluated and nematode samples were taken 6 weeks following the final application. Applications were conducted on September 30, October 30, and December 12, 2003. Nematode samples were taken on January 20, 2004.

Nematodes were extracted from soil around roots and the number of galls per inch of surface area was counted. Ten galls were individually removed from the cores and dissected under a dissecting microscope. From each dissected gall, the number of adult males and females, immature adults, juveniles, and eggs was determined.

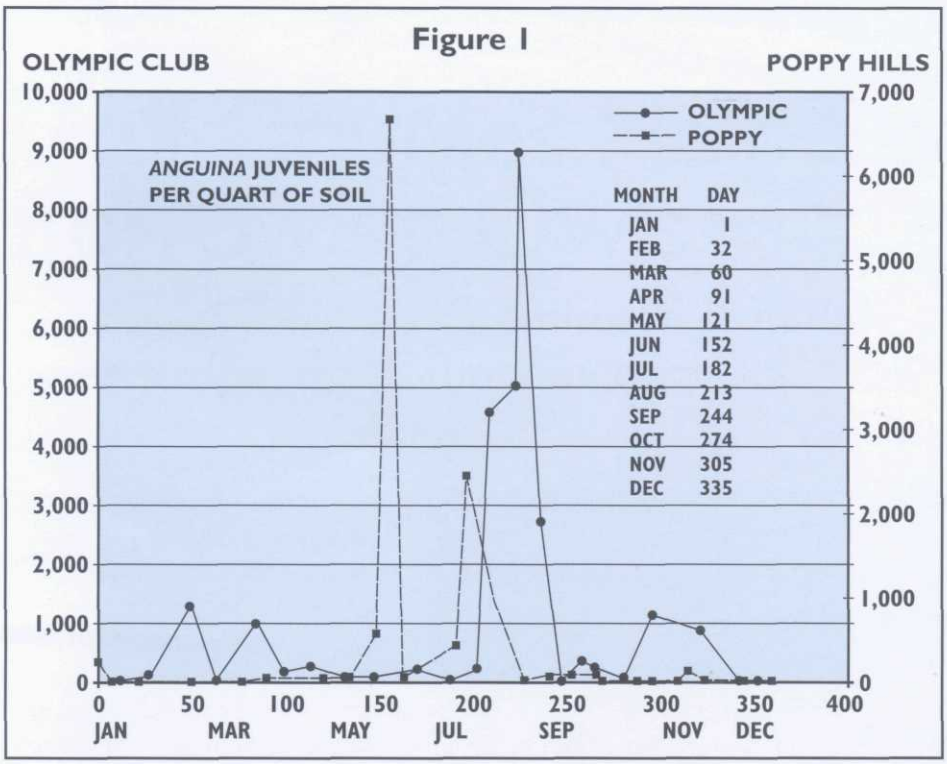
Turf quality was visually determined by the golf course superintendent based on standards acceptable for that location. Digital photos were taken from a slope overlooking the plot and a representative photo in which all replicates were visible in full sun was selected for digital analysis of turf quality. The digital analysis was conducted with the histogram function of Adobe Photoshop set for RGB analysis.

RESULTS AND DISCUSSION

A. pacificae was found on *Poa annua* greens in all golf courses (12) surveyed in Monterey, San Francisco, and San Mateo counties (Table 1). For two additional courses with bentgrass greens (Lake Merced and Presidio), *A. pacificae* was not found on the greens but was present in surrounding areas. In addition, all courses surveyed had abundant populations of spiral nematode, 13 had ring nematode, and 9 had root-knot nematode. Other nematodes found occasionally and in lower populations were: needle (*Longidorus* sp.), pin (*Paratylenchus* sp.), stubby root (*Trichodorus* sp.), sheath (*Hemicycliophora* sp.), lesion (*Pratylenchus* sp.), and cyst (*Heterodera* sp.). These findings indicate that although *A. pacificae* is widespread in coastal Northern California golf courses, there is potential for other nematodes to be causing problems as well.

When sampled at 2- to 6-inch increments, nematodes were abundant at all depths (data not shown). This indicates that although the galls of *A. pacificae* are located close to the surface, methods to kill populations of other nematodes will need to be effective to greater depths. Although they were not alive, *A. pacificae*, spiral, and ring nematodes were recovered from a water sample taken from a pipe draining a green, indicating the ability of nematodes to move in drainage systems.

Two of the nematodes, *A. pacificae* and root-knot, monitored in the biweekly survey are endoparasitic nematodes. Juvenile nematodes penetrate plant tissues, and the adults mature and



In the nematode management trial, by visual observation, it was evident that turfgrass quality in Nemacur- and fosthiazate-treated plots was superior to all other treatments. Some improvement in quality was visible in the DiTera-treated plots compared to the untreated, while the remaining treatments could not be visibly distinguished from the untreated. The digital photograph analysis conducted using the histogram function of Adobe Photoshop supported the visual analysis (data not shown). The red analysis indicated that Nemacur and fosthiazate treatments were superior to the untreated. Of the products tested, only Nemacur 10G, DiTera DF, and Fore are currently registered for use on turf in California.

Several treatments reduced populations of *A. pacificae* (Table 2). Nemacur reduced the number of males, females, lay eggs within the plant. The data reported are for populations of juveniles found within soil around roots. These are the populations most likely to be affected by nematicide applications. Spiral and ring nematodes are ectoparasites of turf, always being found outside of roots in the soil.

Populations of all four nematodes fluctuated throughout the year. Ring nematode populations were considerably higher at the Olympic Club than at Poppy Hills. Populations at the Olympic Club were highest in September, and at Poppy Hills in November. As with ring nematodes, populations of root-knot nematodes were typically higher at the Olympic Club than at Poppy Hills, with peak populations occurring in April and September. Peak populations of root-knot nematodes at Poppy Hills were reached in September and November. Levels of spiral nematodes were similar at both locations, with the highest populations occurring at the Olympic Club in mid-August and at Poppy Hills in early November. Populations of *A. pacificae* peaked in June at Poppy Hills and in August at the Olympic Club.

Population sampling for nematodes was conducted by Dr. Becky Westerdahl at several courses in the San Francisco and Monterey Bay areas.

Damage to a *Poa annua* golf course green caused by the nematode *Anguina pacificae*.

eggs, total adults, and total nematodes. Fosthiazate reduced the number of galls, females, males, immature adults, and total adults. DiTera reduced the number of eggs. None of the treatments reduced populations of root-knot, spiral, or ring nematodes (data not shown). For several treatments, populations of spiral nematodes were significantly higher than for the untreated. Increased nematode populations could occur if the treatments permitted the development of a healthier root system that could sustain higher populations of nematodes. This was also the case for one treatment with ring nematodes.

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