

## Biology and Management of the Pacific Shoot-Gall Nematode

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### Disease and nematode life cycle

University of California environmental horticulture advisor Larry Costello discovered in 1978 strange symptoms on golf course putting greens with annual bluegrass (*Poa annua*). In contrast to the usually smooth turfgrass surface, produced by the dense growth of *Poa* leaf blades, areas of the greens had an uneven playing surface (Fig. 1).



Fig. 1 Pacific shoot-gall disease patches in annual bluegrass putting green.

Many grass shoots had a gall on their base (Fig. 2), which caused patches of stunted growth. The causal organism was initially identified as *Anguina radiculicola* (Costello, 1983) but later renamed *A. pacifica* based on morphological data (Cid del Prado and Maggenti, 1984). These plant-parasitic nematodes are found almost exclusively in *P. annua* along a thin strip of the northern coast of California. The only other infestation was detected in 2013 on a golf putting green at a County Dublin golf course in Ireland. Second-stage juveniles (J2) of *A. pacifica* from Cypress Point Golf Course, Monterey, CA, were used to produce a complete reference sequence for the ITS1, 5.8s, and ITS2 regions of the ribosomal DNA cistron,

confirming complete homology with the Dublin *Anguina* nematodes (Fleming et al., 2015). The Pacific shoot-gall nematode juveniles require cool and moist conditions to move to the crown in a thin water film on the plant's surface. With increasing distance from the coast and a reduction in humidity, the water film quickly dries, and so do the nematodes. However, those J2 that make it to the crown, and have enough energy reserves, will penetrate the grass tissue. Giat et al. (2008) suggested that the size of the galls depends on the degree of the infection. Inside the plant, the nematodes are safe from environmental hazards, predators, or pathogens. They induce a cavity that enlarges and causes the symptomatic shoot gall (McClure et al., 2008).



Fig. 2 Shoot-galls on *Poa annua*

Inside, the nematodes obtain their nutrition by feeding with their mouth stylet on the surrounding plant cells. After the third and fourth-stage molt, they become adults. Males and females need to mate for fertile off-springs. A female might produce more than 1000 eggs. Many eggs, juveniles, and a few adults can be found in mature galls. When the *Poa* shoots die, and the galls decompose after a couple of months, infectious juveniles leave and search out new crowns (Fig. 3). The nematodes cause significant damage to *P. annua* turfgrass (Westerdahl et al., 2005).

### Previous plant disease mitigation attempts

In the past, NemaCur (fenamiphos, Bayer) helped to mitigate Pacific shoot-gall disease outbreaks (Westerdahl et al., 2005). When the company withdrew the registration in 2008, some golf course superintendents used Neemix 4.5 (Certis), a 4.5% azadirachtin-containing insecticide, as a replacement. The label suggests

its utility in suppressing nematodes. However, in our trials, the product showed no efficacy against soil-dwelling *A. pacifica* or the shoot-gall disease (Petelewicz et al., 2020). The same was true for Quali-Pro Nimitz Pro G Nematicide (a.i., fluensulfone).



Fig. 3 *Anguina pacifica* (© M. Mundo, UCR)

### Recent trials with two new turf products

More recently, we evaluated the efficacy of two novel nematicidal products, Indemnify (Bayer) and Divanem (Syngenta), against the Pacific shoot-gall disease on various California golf courses. During the months after application, the soil-dwelling populations of *A. pacifica* (Fig. 3), spiral (*Helicotylenchus* spp.), and ring (*Criconemoides* spp.) nematodes were monitored by soil sampling, extraction, and counting at the UC Riverside Nematology facilities. Newly developed disease symptoms (shoot-galls) were numbered, while turf health was visually rated on a scale of 1–9 (1 = dead; 6 = minimally acceptable quality; 9 = no disease). At high disease pressure, Pacific shoot-gall disease ratings were taken (0–100%).

The trials were conducted on annual bluegrass with a high infestation of *A. pacifica* and a history of severe Pacific shoot-gall disease. Three coastal California golf courses, Pasatiempo, Santa Cruz, Laguna Seca, Monterey, and Del Monte, Monterey, provided us with testing areas. The design of each trial was a randomized complete block with four replications. Individual plots measured 4 by 6 ft. Divanem (a.i. abamectin) was used at 0.28 fl oz/1000 ft<sup>2</sup> of product with the addition of 0.25% (v/v) Induce®, a nonionic surfactant (Helena Agri-Enterprises). Indemnify (a.i.

fluopyram, Bayer) was utilized at 0.39 fl oz/1000 ft<sup>2</sup>. The products were applied with a CO<sub>2</sub> backpack sprayer. Immediately afterward, Divanem treatments were sprinkler irrigated with at least 0.1-inch water. The Indemnify label recommended a morning application, holding back the next irrigation until the evening. The data were analyzed separately for each golf course using analysis of variance.



Fig. 4 Turfgrass recovery after Indemnify treatment.

### Results

One or two applications of Indemnify gave good protection for new shoots against the Pacific shoot-gall disease (Fig. 4) (Petelewicz et al., 2020). The active ingredient fluopyram is effective at low application rates while having an excellent safety profile. Fluopyram is an inhibitor of succinate dehydrogenase in nematodes but not mammals, insects, and earthworms (Schleker et al., 2022). In direct comparison, Divanem was equally effective against the Pacific shoot-gall disease as Indemnify with four applications (Orlinski et al., 2022).



Fig. 5 Comparison ca 4 months after first application; plots outlined with balls. From left, untreated control, Divanem (4x 0.28 oz/1000 ft<sup>2</sup>), Indemnify (2x 0.2 oz/1000 ft<sup>2</sup>).

Both products do not move much into the soil and consequently do not affect the soil-dwelling populations of *A. pacifica*, spiral, and ring

nematodes. However, the vigor of the *Poa annua* remarkably improved after about 4 to 6 weeks at all test locations (Fig. 5). By protecting against new shoot galls, turfgrass recovery became noticeable when new shoots of the annual bluegrass filled in for the slowly decomposing diseased ones.

### Acknowledgments

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