Applied Soil Ecology 121 (2017) 161–171

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Nematode communities on putting greens, fairways, and roughs of organic and conventional cool-season golf courses

Elisha Allan-Perkins[a], Daniel K. Manter[b], Robert Wick[c], Scott Ebdon[a], Geunhwa Jung[a,*]

[a] Stockbridge School of Agriculture, University of Massachusetts Amherst, 206 Paige Laboratory, 161 Holdsworth Way, Amherst, MA 01003, United States
[b] USDA-ARS, 2150 Centre Avenue, Building D, Suite 100, Fort Collins, CO 80526, United States
[c] Stockbridge School of Agriculture, University of Massachusetts Amherst, 105 Fernald Hall, 230 Stockbridge Road, Amherst, MA 01003, United States

ARTICLE INFO

Keywords:
Turfgrass
Soil
Maturity indicies
Ecological indices

ABSTRACT

Nematodes are an important component of the golf course ecosystem. Many species provide benefits to turfgrass, while others can cause significant damage. Previous studies on golf courses have focused only on herbivore nematodes, mostly on putting greens. This study aimed to characterize all nematode trophic groups and nematode maturity and ecological indices under different management intensities (depicted by roughs, fairways, and putting greens) of three golf courses representing conventional and organic management types over two seasons in 2013 and 2014. The putting greens on all three golf courses had lower diversity and herbivore (plant-parasitic) index (PPI) values than the other management areas. The relative abundance of herbivores, bacterivores, and structure index (SI) values differed among organic and conventional management. Canonical correspondence and multiple stepwise regression analyses revealed pH, phosphorous, and organic matter were positively related to increased herbivores and negatively related to increased bacterivores. The results of this study can be used to develop alternative management practices aimed at decreasing problematic herbivore populations on putting greens and increasing potentially beneficial bacterivores.

1. Introduction

Nematodes can cause significant damage on golf courses, especially on putting greens, resulting in diminished uniformity on the putting surface. Plant pathogenic nematodes (herbivores) are ubiquitous on golf courses and feed on turfgrass roots, which damages tissues and removes photosynthates from the plant. When herbivore populations reach sufficient densities, they can cause wilting, stunted growth, yellowing, thinning, or death, all of which affect aesthetics and game play (Nelson, 1995). In the past herbivore populations were controlled by nematicides and in extreme cases soil fumigation (Walker et al., 2002). However, many of these products have been banned or have restricted use on turfgrass (Crow, 2007; Martin, 2015). New nematicides are currently being developed, but none have been as effective as previous chemistries, such as fenamiphos, or are only registered in certain states (Martin, 2015; Nelson, 1995). The integration of alternative management strategies is needed to manage herbivore populations.

Nematodes also provide many beneficial functions to turfgrasses. Low levels of herbivory promote growth of host plants (Bardgett et al., 1999; Neher, 2010). In addition to the herbivores, the bacterivores, fungivores, carnivores, and omnivores drive important soil ecosystem processes, such as spreading microbes throughout the soil, aiding in decomposition, and preying on pathogens (Cheng et al., 2008; Neher, 2001, 2010). Bacterivores can increase rhizobacteria in the soil (Briar et al., 2007; Knox et al., 2003). Carnivores and bacterivores increase nitrogen mineralization, thus increasing its availability to plants, promoting plant growth (Briar, 2007; Ekschmitt et al., 1999; Ferris et al., 1998; Ingham et al., 1985). Therefore, there is potential to increase turfgrass health by developing management strategies that encourage beneficial nematodes.

Nematodes have been used as indicators of overall soil health since the late 1980's. These indices may provide insight into how management strategies affect other invertebrates and microbes (Neher, 2010). They have been selected as the ideal soil organism for predicting overall soil community health due to their central position in the soil food web and effect on microbes and decomposition pathways (Bongers and Bongers, 1998; Ferris and Matute, 2003; Freckman, 1988; Moore and de Ruiter, 1991; Neher, 2001, 2010). Additionally, nematodes react to disturbance quicker than larger organisms but slower than microbes (Bongers and Bongers, 1998; Neher, 2001). After identification and classification at the genus or family level, nematodes are assigned to their trophic group and colonizer-persister (cp) value (Bhusal et al.,

* Corresponding author.
E-mail addresses: eballan@cns.umass.edu (E. Allan-Perkins), daniel.manter@ars.usda.gov (D.K. Manter), wick@umass.edu (R. Wick), ebdon@umass.edu (S. Ebdon), jung@umass.edu (G. Jung).

http://dx.doi.org/10.1016/j.apsoil.2017.09.014
Received 13 March 2017; Received in revised form 5 September 2017; Accepted 7 September 2017
Available online 13 October 2017
0929-1393/ Published by Elsevier B.V.

2014; Bongers, 1990; Bongers and Bongers 1998). Ecological indices, such as free-living maturity including cp1 (MI) and excluding cp1 (MI25), herbivore maturity (PPI), combined maturity (ΣMI25), enrichment (EI), structure (SI), and channel (CI), can be calculated and used to predict soil conditions (Bongers, 1990; Ferris et al., 2001; Korthals et al., 1996; Neher et al., 2004). Additionally, many nematologists calculate nematode trophic diversity, using the Hills N1 equation (N1), to determine how diverse the nematode communities are, which is based on the presence of rare nematode trophic groups (fungivores, carnivores, and omnivores) compared to the dominant nematode groups (bacterivores and herbivores) (Neher, 2001).

These indices have been used to understand nematode and soil communities from many different ecosystems including agricultural fields and natural grasslands. Studies have compared organic and conventional management practices to determine if organic practices have positive effects on soil communities. Pesticides have differing effects on nematodes depending on the product and amount used, but studies have found an increase in herbivores and a decrease in bacterivores, fungivores, omnivores, and carnivores following the application of different pesticides (Griffin and Anderson, 1978; Sipes and Schmitt, 1989; Thoden et al., 2011; Yardim and Edwards, 1998; Zhao et al., 2013). Despite the many studies on nematodes in native grasslands and agricultural fields, there have been few studies on nematode communities on golf courses.

Past golf course studies have generally focused only on the abundance of herbivores, since they are of economic importance to the turfgrass industry, leaving out the potential beneficial nematodes, such as the bacterivores (Jordan and Mitkowski, 2006; Morris et al., 2013; Walker et al., 2002). However, by understanding how all nematode trophic groups interact under different turf management programs and intensities we may be able to develop new management strategies to decrease herbivores and increase beneficial nematodes.

The objectives of this study were to determine if nematode communities differ among highly managed turf areas (represented by the putting greens), moderately managed turf areas (fairways), and lowly managed turf areas (roughs). We chose three golf courses representing organic, reduced input (denoted as "hybrid"), and conventional management programs to see if management program interacted with intensity to change nematode communities. However, since there is only one truly organic golf course in the United States we are only able to draw inferences for the differences among management areas. We hypothesized that the roughs and fairways would contain higher amounts of free-living nematodes than the more intensely managed putting greens. Additionally, the putting greens would show the lowest SI and MI, but a higher PPI than the less disturbed roughs and fairways. Since golf course fairways and putting greens receive high nutrient inputs, we hypothesized that both areas would have high enrichment index values.

2. Materials and methods

2.1. Collection sites

Three golf courses on Martha's Vineyard, Massachusetts, United States of America located within 15 km of one another were selected for study. The exact location and identification of the courses is withheld per request of the golf courses' managers. One golf course has been maintained using an organic program and two golf courses have been maintained using conventional programs. The organic course was built in 2002 and has sand-based putting greens constructed according to United States Golf Association (USGA) specifications (U.S. Golf Association Green Section Staff, 2004). It has never received synthetic pesticides or fertilizers. Fertilizer applications were made using seaweed extract and animal by-products, such as blood and bone meal. The organic pesticides applied were CivitasONE™ (active ingredients were petroleum byproduct, synthetic isoparaffin, and a copper-based pigment, Suncor Energy, Inc., Alberta, Canada), Rhapsody™ (active ingredient was *Bacillus subtilis,* Bayer CropScience, North Carolina, United States of America), Serenade™ (active ingredient was *Bacillus licheniformis*, Bayer CropScience, North Carolina, United States of America), and Waipuna Weed Control System™ (active ingredients were hot water and foaming detergent, Waipuna Systems LTD, Illinois, United States of America). The conventional courses were established in 1926 and 1939 with native push-up putting greens and have used synthetic pesticides and fertilizers since their construction. The course established in 1939 represents conventional management on the putting greens and reduced input management on the fairways and roughs, so we have designated this course as "hybrid" management. The course had reduced pesticide applications, one synthetic fungicide application in eighteen years, Secure™ (active ingredient was fluazinam, Syngenta Crop Protection, Greensboro, North Carolina, United States of America) on its fairways and applied the biological control product, *Pseudomonas aureofaciens* TX-1, to the fairways through the irrigation lines. The organic and the two conventional golf courses received sand-based topdressing on the putting greens at least twice per year.

The courses were sampled in mid May and early September of 2013 and 2014. The mean temperatures in May 2013 was 11.7 °C and 14.4 °C in 2014. In September of 2013 and 2014 the mean temperatures were 18.9 °C and 22.2 °C, respectively. The grass composition on the putting greens of all three courses was *Agrostis stolonifera* (creeping bentgrass) with some *Poa annua* (annual bluegrass) encroachment on the conventional and hybrid courses. The fairways were a mixture of creeping bentgrass, annual bluegrass, and some *Lolium perenne* (perennial ryegrass). The roughs were a mixture of annual bluegrass, perennial ryegrass, fescues (*Festuca* spp.), and some weed species.

2.2. Sampling strategy

Three golf course holes (representing one area of play from tee box to putting green) per course were randomly selected and sampled using a 2.5 cm diameter soil core at a depth of 10 cm below the thatch to provide biological replicates of each golf course. All three management areas (roughs, fairways and putting greens) were sampled per hole. Four approximately equidistant transects were used to sample the fairways and roughs (Fig. 1a). Three sampling locations were set up along each transect within the fairway and three samples were taken at each location and pooled for a total of twelve samples per fairway. Each transect extended 4.6 m from the edge of the fairway into one side of the rough. Eight samples were taken at each rough sampling location and pooled for a total of four samples per rough (Fig. 1a).

Two concentric circle transects were established on the putting greens (Fig. 1b). The outermost transect was set up 1.5 m from the edge of the putting green and the inner transect was set up 4.6 m from the edge of the putting green (Fig. 1b). Four sampling locations were set up on each transect and four samples were taken at each location and pooled for a total of eight samples per putting green (Fig. 1b). Global positioning system (GPS) coordinates were taken at each sample location and the distances between sample transects and irrigation heads were recorded to ensure repeated sampling at the same locations for May and September of 2013 and 2014. In September of 2014 the organic golf course began the process of renovating their putting greens and we were unable to sample our third hole for a fourth time. Therefore, we sampled a different putting green from a nearby hole. All holes on all the golf courses had similar shade, grass species, and cultural practices with a few exceptions. The roughs had more variable grass species and shade amounts. The organic putting greens were rolled each day, but the conventional and hybrid courses' putting greens were not. All samples were immediately placed on ice and transported back to the laboratory and were stored at 4 °C.

2.3. Nematode analysis

Soil samples were pooled within a management area per hole for a