EARTHWORM CASTING MANAGEMENT

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Introduction

How can earthworms, which benefit the soil environment in so many ways, be such a nuisance for golf course superintendents? It is well documented that earthworms improve soil structure, increase the availability of plant nutrients, break down thatch, and provide channels for increased infiltration, air movement, and root development. Unfortunately, earthworms have one nasty habit - casting on the turfgrass surface. Casting occurs when earthworms ingest organic matter, decaying leaf tissue, and mineral soil, mix the fractions within their guts, and excrete the material as mounds of soil on the surface. In essence, the mineral soil serves as "teeth" to grind the decaying tissue and organic matter to extract nutrients. Extensive earthworm casting on golf course fairways interferes with proper maintenance practices, the playability of the turfgrass, and the overall aesthetic value of the fairways. Specifically, casts cause an uneven playing surface, surface sealing which reduces infiltration, and a muddy mess when the casts are mowed over (Kirby and Baker, 1995). It is not unusual in the Pacific Northwest to see areas where 50% or more of the turf is covered by castings.

There are several reasons why populations can reach damaging levels on golf courses. Fairways are typically planted on fine textured soils that receive regular irrigation and nitrogen fertilizer applications, which provide optimal growing conditions and a continuous food supply for earthworms. The turfgrass canopy also helps provide favorable temperatures by insulating the soil from extreme weather conditions. The climate in the Pacific Northwest offers relatively mild winters, wet springs and falls, and warm dry summers. Earthworm activity is greatest when the soil moisture content is near field capacity. Peak earthworm activity and casting occurs during the cooler, wetter weather in the spring and late fall through early winter. Damage is most severe in late fall and winter due in part to reduced recuperative ability of the turf. Earthworms are generally intolerant of drought and frost conditions, which drive them deeper into the soil.

Earthworm Biology

There are over 200 species of earthworms in North America with varying behaviors and habitat preferences. On Northwest golf courses, the primary species observed include *Lumbricus terrestris*, *Aporrectodea calignosa*, and *Aporrectodea longa*. It is important to note that most species of earthworms do not deposit casts on the surface. Many earthworm species excrete material within the soil profile or simply do not excrete casts at all. Based on numerous field observations, *L. terrestris*, also known as night crawler, is the primary casting culprit on golf courses throughout the Pacific Northwest, and probably in many locations across the northern United States.

Lumbricus terrestris typically builds permanent vertical burrows which vary in diameter from about an 1/8 " up to 1/2", that in certain situations can extend up to 12 feet deep in the soil. However, due to regular irrigation and constant food supplies (clippings and thatch) on fairways, they tend to remain closer to the surface, migrating up and down in the soil with fluctuations in moisture content, soil temperature, and atmospheric pressure. There is a misconception that earthworms surface during heavy rainfall to avoid drowning. Earthworms can survive extended periods in saturated soils, in fact they can tolerate being submerged in water if the water is well aerated. Often, earthworms retreat to the bottom of their burrows during extremes in temperature or soil moisture content. Typically when it's wet, they surface to find a mate or to feed, because moisture provides security and allows them to move around, but they always leave their tail end in contact with the burrow opening. Moisture stress is what earthworms must avoid; drying out kills them.

Breeding activity is greatest in the spring and fall. Night crawlers on average breed once every two weeks, producing up to 20 offspring with each cycle. Optimal living conditions in fairways can lead to shorter cycles, more offspring, and fast maturation. It has been reported that one mature night crawler can produce over 1000 offspring in one year under optimal conditions. Since the night crawler has such a long productive life span, observed for up to 20 years, it's easy to see how earthworm populations and casting can get out of control.

Several environmental and cultural factors affect earthworm activity, populations, soil distribution, and species. The most critical soil properties for earthworms include an adequate food supply, moisture, temperature, texture, and pH (Lee, 1985). Cultural factors can be used to manipulate the soil and turf environments to create conditions less conducive to earthworm activity. A few of the turfgrass management practices which have been reported as antagonistic to earthworm activity include the use of ammonium sulfate fertilizer to acidify the soil (Potter et al., 1985; Jefferson, 1955), avoiding lime applications in the fall (Escritt and Lidgate, 1964), clipping removal (Dawson, 1959; Kirby and Baker, 1995), pesticide applications (King and Dale, 1977), and increasing sand topdressing (Lee, 1985).

Several authors have reported declines in earthworm populations directly related to declining soil pH (increasing acidity). Apparently, burrowing earthworms are typically not present in soils with a pH less than 4.5. It is also possible that instead of population reduction, species shifts occur to non-casting earthworms that are more tolerant of acid conditions. Jefferson (1955) established that earthworms are scarce in soils with pH's of 5.0 or less, and worm populations are greatest between pH's of 6.5 and 7.0. However, he also noted that the response curve of earthworms to soil acidity is not the same for all worm species. Lee (1985) reported that when ammonium sulfate is consistently used, the soil pH can be lowered to a range intolerable for earthworms. In the Pacific Northwest, Goss et al. (1977) reported no earthworm activity on plots of creeping bentgrass treated with sulfur. Research conducted by Baker et al. (1996) using sulfur and aluminum sulfate produced significant reductions in earthworm casting activity.

Earthworms feed on dead and decaying plant material and the free bacteria and fungi present during the decay of the tissue. In a turf environment, they often pull leaf clippings down into the mouth of the burrow, where the tissue can soften and be eaten at a later date. Previous research has shown that the amount of food on the surface can directly influence earthworm populations. Evans (1947) found that the earthworm species *L. terrestris* does not burrow deep into the soil profile if there is an adequate food source near the surface.

Worm populations are greatest in light and medium loam soils. Smaller populations of earthworms are found in both heavy, poorly drained clay soils and coarse, abrasive, sandy soils. It is believed that the abrasiveness of sand particles and sand's susceptibility to drought influences both species composition and earthworm numbers in the soil (Lee, 1985). Russell (1973) points out that earthworm populations are low in soils containing heavy clays that are compacted, puddled, or overgrazed. In addition, soil in fairways that may be compacted due to heavy traffic force *L. terrestris* to expel the majority of their castings on the surface. This is probably one reason we often see more excessive casting in the clean-up areas on the edges of the fairways.

Current Research

At Washington State University-Puyallup and Oregon State University, our objective is to incorporate several traditional cultural practices and new techniques into an Integrated Casting Management Program. Our goal is to decrease the amount of surface casting in order to preserve turf quality and playing conditions on golf course fairways, while at the same time maintaining soil quality. It would be undesirable to reduce populations too drastically, however, because we do not want to lose the many benefits that earthworms provide.

The project was initiated in October of 1997 and includes a series of short and long-term field studies. To meet our objective, the first phase of the initial investigation focuses on: 1) identifying which species are present and learning more about the biology of these earthworm species that cause casting problems in western Washington and western Oregon, 2) reevaluating several cultural practices that have been shown in previous research to be detrimental to earthworm activity in other regions of the world, and 3) experimenting with new strategies that have not been previously evaluated for casting reductions. For the second phase of the project, several superintendents with severe casting problems have committed to help us to implement integrated casting management programs on entire fairways.

Objective 1 has been accomplished as described above. Objective 2 is being addressed with research at WSU-Puyallup Farm 5, the Louis Brown Turfgrass Facility at OSU, and at three golf courses: Inglewood Country Club (Seattle, WA), Oswego Lake Country Club (Portland, OR), and Trysting Tree Golf Course (Corvallis, OR). The golf course sites were established in October 1997 as randomized block split-plot designs with four replications. Whole plot treatments include four fertilizer sources and a low nitrogen control. The whole plots are a minimum of 6 m by 27 m depending on the width of the fairway. Sub-plot treatments are half the length of the whole plots and will receive 100 lb lime/1000 ft^2/yr vs. no lime. Treatment applications are made in 0.5-1.0 lb N/1000 ft^2 increments to obtain approximately 4–5 lb N/1000 ft^2/yr. Supplemental applications of potassium and phosphorous will be made equally to all treatments using muriate of potash and diammonium phosphate. Below is a list of the treatments:

Whole Plots
Ammonium Sulfate (21-0-0) (24% Sulfur)
Elemental Sulfur (99.5% S) + Urea (46-0-0)
Polymer Coated Urea
Control (low nitrogen with no sulfur)

Sub Plots
Lime at 100 lb/1000 ft^2/yr (applications made in 25 lb /1000 sq ft^2 increments)
No lime

Prior to treatment, pH and organic matter were quantified and will be monitored throughout the study. Earthworm casting counts serve as an indirect measurement of earthworm activity. The counts will be completed using a 1 m x 1 m frame quadrant sectioning device (constructed of 1.5 inch PVC) divided into 25 sections. Castings will be counted on four-week intervals during the fall and winter months when casting damage is severe. A total of eight random counts will be made from each plot, four per sub-plot. Visual analysis of turf quality will be made three times per year on a scale of 0-9, with nine being highest quality.

In addition to studying soil chemistry effects, the effects of removing clippings and reducing the food source is being evaluated. On bentgrass, rates of casting were reduced by 58% when clippings were removed (Kirby and Baker, 1995). Dawson (1959) also reported that earthworm populations can be reduced by restricting their food supply by boxing the mown clippings. Unfortunately, removal of clippings from fairways has a number of factors that must be considered, the least of which are cost and disposal. Aerification and verticutting to reduce thatch levels should help restrict food supplies, thus decreasing worms.

At Oswego Lake Country Club in May of 1998, we established three replications (one rep per fairway) of clippings being removed using triplex approach mowers versus clippings returned with the fairway mowers. Both mowers are set at ½ inch. Casting counts are taken at four-week intervals using a frame quadrant-sectioning device. We are currently in the process of establishing a clipping removal trial at our Farm 5 research facility in Puyallup, WA. We are look at clipping removal alone, in combination with acidifying fertilizers, and tied in with physical removal.

The last cultural practice under evaluation is sand topdressing. Topdressing is applied at a rate of ¾ inch sand/year alone and in combination with other fertilizer treatments to determine if sand effectively reduces casting. If effective, we will determine the amount of sand required before a reduction is observed. The trial was established at our Farm 5 research facility in October of 1997 and is arranged as a randomized complete block design with three replications. Plots are 1.5 m by 1.5 m, and castings are counted using a 1 m by 1 m frame quadrant-sectioning device, which when placed in the center of the plot provides a 1 m buffer between plots.

Objective 3 (new strategies) encompasses reducing earthworm populations through physical removal, otherwise known as "harvesting". There are numerous earthworm harvesting companies already working golf courses in Washington and Oregon. There is a large demand around the world for the type of earthworm located under golf course fairways. These companies appear to vary in their harvesting methods, professionalism, knowledge of the casting problems on golf courses, and expense (some pay for harvesting rights, other charge to remove worms). Currently, harvesting the worms involves bringing the worms to the surface by flooding the soil with water and an irritant and hand picking, which is very labor intensive. There is a company in Oregon that has recently developed a new, highly effective extraction product. It has been EPA approved and is in the patent process, and should be on the market soon. We are in the process of developing efficient methods for superintendents to bring the worms to the surface and remove them by both mechanical and/or hand picked methods. We have currently assessed a core harvester and triplex brush units with a fair amount of success.

The process of physical removal does reduce casting in the short term, but a methodical, long-term approach of repeated harvests is required. For example, there is an 18-hole country club in Western Oregon that hired a company to harvest all 18 of their fairways in the spring of 1998. The final removal count over a four week period was 2.1 million worms. A second complete harvest this fall produced approximately 750,000 worms. This sounds like a lot of worms; but additional harvests are required to reduce earthworms to a threshold level where casting is acceptable. We are evaluating the short and long term effects of physical removal at our Farm 5 research facility and on various golf courses in conjunction with the commercial harvester.

Summary

Earthworm casting is a serious problem on many golf courses in the Pacific Northwest and the United States. There is an urgent need for the development of management strategies that discourage earthworm activity and population growth, and ultimately reduce casting. Our goal is to design a program for golf course superintendents that will: (1) reduce initial earthworm populations to a threshold level where the amount of casting is acceptable, and (2) incorporate a variety of cultural practices that have been proven to reduce casting on northwestern golf courses to lower the earthworm carrying capacity of the soil.

Unfortunately, there are no short-term solutions. Earthworm populations number in the millions under golf course fairways. They are highly adaptable survivors, and they will demand a long-term commitment on the part of the superintendent to reduce casting. Superintendents who implement the proper maintenance practices in producing excellent fairways are also creating an optimal environment for earthworms.

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