JOURNAL OF THE KENTUCKY ACADEMY OF SCIENCE
ISSN 1098-7096
Continuation of
Transactions of the Kentucky Academy of Science
Volume 61 Spring 2000 Number 1

J. Ky. Acad. Sci. 61(1):1–5. 2000.

Earthworms (Oligochaeta: Lumbricidae) in High-Maintenance and Low-Maintenance Lawns in Lexington, Kentucky

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ABSTRACT

We sampled earthworms in Lexington, Kentucky, and compared populations in high-maintenance lawns (maintained by professional lawn-care companies) to those in low-maintenance lawns (maintained by individual owners without the use of lawn-care chemicals). We sampled 15 high-maintenance and 15 low-maintenance lawns with similar distributions in terms of geographic location within Lexington, age of house, and length of time the lawn was managed under the current maintenance regimen. Earthworms were collected during the period 6 Apr–10 Apr 1998 in each lawn by using formalin as an extractant. Significantly more earthworms per unit area were collected from high-maintenance as from low-maintenance lawns. Conversely, low-maintenance lawns had significantly greater earthworm dry mass per unit area and dry mass per individual earthworm. These results suggested that high-maintenance lawn care resulted in stunted growth of earthworms. Since earthworms are one of the most important members of the soil fauna, we suggest that organic methods and alternative plant systems be substituted for chemically maintained lawns.

INTRODUCTION

There are more than 25 million acres of lawn in the United States (PLCAA 1999). In 1997, 22% of households employed professional lawn-care companies to maintain their lawns, and the demand for professional lawn care was increasing at an annual rate of ca. 3% (PLCAA 1999). Over 70 million pounds of chemicals are applied annually to lawns with the annual application rate increasing 5–8% per year (Jenkins 1994, p. 186). By the mid to late 1980s, the average lawn owner in the U.S. was using higher concentrations of chemicals than farmers (Jenkins 1994, p. 186) and more synthetic chemical fertilizers were being applied to these lawns than were being applied to all food crops in India (Jenkins 1994, p. 142).

It is recognized that soil animals in general, and soil invertebrates in particular, are essential to healthy soils (e.g., Brady and Weil 1996). In the eastern U.S., especially in disturbed ecosystems, earthworms (Oligochaeta: Lumbricidae) account for a large proportion of the total soil invertebrate biomass and play an essential role in many natural cycles (Edwards and Bohlen 1996; Lee 1985). Earthworms may therefore be considered effective biological indicators of soil quality (Blair et al.

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1996). In turf ecosystems, including lawns, earthworms are positively associated with many favorable soil characteristics including low amounts of thatch, low bulk density, high water infiltration and percolation rates, high organic matter concentrations, deep rooting, low plant wilting proneness, low plant disease severity, and uniform dispersion of microbes (Christians 1998; Turgeon 1999).

Professional lawn-care services utilize many types of chemicals including fertilizers, fungicides, herbicides, insecticides, and plant growth regulators. Standard sources (e.g., Christians 1998; Vengris and Torello 1982) recommend as many as nine fertilizer applications and six herbicide applications annually, with insecticides applied as needed. Even when used at labeled rates some registered lawn-care chemicals are highly toxic to earthworms and other soil invertebrates, while others are less toxic but still cause chronic effects and significant mortality (Potter 1994; Potter et al. 1990). To date, much research dealing with the toxicity of lawn care chemicals has been performed in laboratories or under controlled conditions at research facilities. Edwards and Bohlen (1996, Appendix A), for example, provided a summary of the specific effects of about 200 individual chemicals on earthworms, and Potter et al. (1990, 1994) described the effects of 40 commonly used pesticides and plant growth regulators on earthworms in turf.

Unlike controlled research plots, real lawns are simultaneously subject to many types of chemicals and to other types of stress such as dessication and compaction. In our study, we sampled earthworms in real lawns and compared populations in high-maintenance lawns (maintained by professional lawn-care companies using synthetic chemicals) to those in low-maintenance lawns (maintained by individual owners by mowing but without using chemicals).

MATERIALS AND METHODS

Study Area

Our study was conducted in Lexington, Fayette County, the second largest city in Kentucky. Lexington, founded about 1779, presently occupies about 12,000 ha and has a population of ca. 242,000. The landscape is a rolling karst plain underlain by phosphatic Lexington Limestone of Ordovician age. Although the study area is largely urbanized, native soils are mapped as the Maury-McAfee Association (Sims et al. 1968). About 85% of the map unit is deep and moderately deep, well-drained soils in residuum on uplands, with silt loam A horizons, silty clay loam B horizons, and clay C horizons (Alfisols and Ultisols in the USDA taxonomy); the remaining 15% is silt loam soils in alluvium in sinkholes and drains (Mollisols and Inceptisols).

The climate is temperate, humid, and continental. Mean annual temperature and precipitation, respectively, are 13°C and 1148 mm. Weather during the 5-day sampling period of 6 Apr–10 Apr 1998 was normal, with maximum and minimum daily temperatures of 18°C and 7°C, and 30 mm of total precipitation. Soils were near optimal moisture content during the sampling period since there had been no extended dry periods and since rainfall during the preceding 12 months was ca. 8% above average (University of Kentucky Agricultural Weather Center 1999).

Lawn Care Survey

A Lawn Care Survey was used to locate cooperators and to provide a pool of potential experimental lawns. The survey asked whether the lawn was maintained using lawn-care chemicals (herbicides, fertilizers, etc.), and, if so, if the lawn was maintained by a professional lawn-care service. In addition, the survey identified age of the house, length of time the lawn was maintained under the current maintenance regimen, and other factors that could influence our research. A total of 340 survey forms was distributed through the administrative offices of the Math, Science & Technology Center and the University of Kentucky. Two hundred and four completed survey forms were returned. To minimize variability in maintenance regimen, we first eliminated all lawns that were maintained by owners themselves using lawn-care chemicals. We also eliminated lawns with underground irrigation systems and fenced-in pets. We then carried out a stratified-random sampling of the remaining lawns to select 15 high-maintenance and 15 low-maintenance lawns with about equal distributions in terms of geographic location within Lexington, age of

Table 1. Characteristics of earthworm populations and of mature and immature earthworm specimens in lawns maintained by individual owners without the use of lawn care chemicals (low-maintenance) and in lawns maintained by professional lawn care services (high-maintenance) in Lexington, Kentucky. Within a row, different letters indicate that the characteristic differed between maintenance types at the indicated level of significance (*P*) using Mann-Whitney tests; n = 15 of each type lawn.

Earthworm characteristic	Low-maintenance	High-mainenance	*P*
	Median value		
Number (no/sample frame)	3.7 b	6.0 a	0.03
Total dry mass (mg/sample frame)	320 a	187 b	0.02
Individual dry mass, mature (mg/individual)	130 a	68 b	0.007
Individual dry mass, immature (mg/individual)	43 a	19 b	<0.001

house, and length of time the lawn was managed under the current maintenance regimen. Thirty lawns were chosen since this was the number that could be sampled within 1 week, the maximum sampling period that we judged still short enough to avoid variability in weather or other factors that could cause earthworms to move deep into the soil or to aestivate. All experimental lawns were associated with single-family homes, were regularly mowed, and were less than 4000 m^2 in size.

Field and Laboratory Methods

Earthworms were collected during the period 6 Apr–10 Apr 1998. The sequence of sampling alternated between high-maintenance and low-maintenance lawns, with randomized order within each type of lawn. On each lawn, a single random point was chosen away from the influence of structures, walkways, trees, and plant beds. Grass was clipped and thatch removed from a small area surrounding the point, and a square 0.1-m^2 frame was located on the prepared area. Next, 4 liters of 0.05% formalin was poured into the soil within the frame. This chemical acts as an irritant that causes many types of earthworms to emerge from soil (Lee 1985) and is considered the single best method for routine monitoring of lumbricids (Blair et al. 1996). We collected all earthworms flushed from the soil within the frame during a 10-minute period immediately after adding the formalin solution. We used the dry mass of these earthworms as the experimental variable to test for difference in earthworm abundance in high- and low-maintenance lawns.

Specimens were returned to the laboratory and anaesthetized in 10% EtOH. Each specimen was identified to genus (immature) or species (mature); anaesthetized length and average diameter were measured.

Calculations and Statistical Analysis

Dry mass of each specimen was calculated by using anaesthetized length and diameter to calculate volume, assuming the anaesthetized shape to be a right circular cylinder. Volume was then converted to dry mass using Edward's (1967) average values for density (1.064 g/cm^2) and percentage dry matter (26%) of lumbricids.

Non-parametric Mann-Whitney tests were used to compare high-maintenance versus low-maintenance lawns in terms of the number and total dry mass of earthworms collected per plot and the dry mass of individual earthworms. This was done for all specimens together and for immature and mature specimens separately. Spearman's correlations were used to examine relationships between number and mass of earthworms, age of house, and length of management regimen. Results of all procedures were evaluated at the 0.05 level of significance. All statistical analyses were done with the SPSS computer program (SPSS 1997).

RESULTS

There was no significant difference between high-maintenance and low-maintenance lawns in the age of the house ($P = 0.68$) or the length of time the lawn was managed under the current maintenance regimen ($P = 0.08$). Median values for house age and length of maintenance, respectively, were 26 yr and 12 yr. The genera *Lumbricus*, *Aporrectodea*, and *Eiseniella* were recorded, with *Lumbricus* dominant in both types of lawns, accounting for 89% of the specimens collected. There was no significant difference ($P = 0.19$) between the two types of lawns in the proportion of specimens that were immature; the median value was 72%. Maximum earthworm lengths were 60 and 65 mm, respectively, in high-maintenance and low-maintenance lawns; large specimens of *L. terrestris* were not collected. Significantly more earthworms per unit area were collected from high-maintenance versus low-maintenance lawns (Table 1). Conversely, low-maintenance lawns had significantly greater earthworm dry mass per unit area and dry mass per individual earthworm (Table 1). Neither number nor dry mass of earthworms was significantly correlated with house age or length of management.

DISCUSSION

> The conclusion I formed was that the lawn earthworm is a starved earthworm. . . . The lawn earthworms were much smaller and were not nearly so vigorous in their movements. . . . The wonder was that worms should be found living in such numbers in the lawn soil in these somewhat unnatural conditions.
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> W. H. Hudson 1919, p. 345–346

Our study of high- and low-maintenance lawns supports the conclusion reached 80 years ago by W. H. Hudson (see quote above). The mass of individual earthworms from low-maintenance lawns was similar to the normal range reported by Lee for Lumbricidae (1985, Table 7) whereas the mass of individual earthworms from high-maintenance lawns was about half normal. Although it is difficult to estimate earthworm densities using the formalin extraction technique (Lee 1985; Edwards and Bohlen 1996), densities calculated from our Table 1 of ca. 80 and 120 individuals/m^2, respectively, for low-maintenance and high-maintenance lawns are far below the 100 to >2000 individuals/m^2 recorded by Lee for Lumbricidae in temperate pastures (1985, Table 7). We interpret this as indicating that earthworm growth in our study was more likely stunted by the lawn-care chemicals used in high-maintenance lawns than by competitive interactions or overcrowding. Other research also supports this conclusion by showing that some lawn and agricultural chemicals may adversely affect non-target organisms including earthworms and other soil invertebrates (Potter 1994; Potter et al. 1990). In addition to direct toxicity, such adverse effects may be sublethal and chronic, resulting in slow growth or weight loss (Edwards and Bohlen 1996). Since low-maintenance and high-maintenance lawns were similar in terms of house age and length of time each maintenance regimen had been in use, the direct effect of maintenance regimen was not confounded by residues from past practices or by unequal representation of old and new houses.

Invertebrates such as earthworms have both utilitarian and intrinsic value (Samways 1994). The utilitarian value of earthworms as one of the most important members of the soil fauna is widely recognized (Blair et al. 1996; Christians 1998; Edwards and Bohlen 1996; Lee 1985; Turgeon 1999). In addition, it may be argued that ethical consideration of the intrinsic value of all species requires that humans, at a minimum, avoid causing death or pain to other species when such avoidance has little or no effect on human welfare (Samways 1994). This means that chemicals harmful to earthworms and other soil invertebrates should be avoided unless essential to human survival, health, or opportunity for fulfillment.

Pimentel et al. (1992) reviewed a wide variety of literature and concluded that the environmental and public health costs of using pesticides were so high that even the contributions of pesticides to economic profitability of agriculture was questionable. Furthermore, it was concluded that in agriculture it was possible to reduce pesticide usage by one-half with only minor effects on food prices since, in large part, pesticide use was driven by high cosmetic standards rather than by nutritional standards or plant health requirements (Pimentel et al. 1991). This suggests that lawn maintenance, which is clearly less essential to humans than agriculture, should be based on safer and less damaging practices than presently used. In particular, utilization of organic methods for restoring and maintaining soil fertility and health, or of native flora or other plant types that can be more naturally and easily maintained than turf, may be reasonable substitutes for the present system of chemical-based lawn care. Organic lawn care should become more popular with homeowners as information on organic practices (e.g., WSHU-FM and Duesing 1999) and commercial services (e.g., Bass Custom Landscapes, Inc.

1999) becomes available through the internet (e.g., WSHU-FM and Duesing 1999) and as recommendations on specific techniques become available through government organizations such as the USDA Cooperative Extension Service (e.g., Bruneau et al. 1997).

ACKNOWLEDGMENTS

We thank all the people who gave us permission to sample their lawns, Janet Powell for help with the literature, and Elizabeth Kikuchi and Walter Koetke for material and moral support. This is a publication of the Kentucky Agricultural Experiment Station.

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