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HABITS AND CONTROL

of the

ORIENTAL EARTHWORM

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Castings of the Oriental earthworm in heavily infested turf on golf course green.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, NEW HAVEN

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HABITS AND CONTROL OF THE ORIENTAL EARTHWORM

John C. Schread[1]

INTRODUCTION

The value of earthworms in increasing fertility of the soil is too well known to require discussion. From the time of Charles Darwin, they have been recognized as the most beneficial of all soil-inhabiting animals. There are situations, however, in which the good done by earthworms is outweighed by the damage and inconvenience that they cause. For example, earthworm castings injure the turf and interfere seriously with play on tennis courts, golf greens and bowling greens. Those responsible for maintenance of such turf areas have for years used chemical treatments to kill earthworms.

In recent years a new species, the Oriental earthworm, has appeared in Connecticut and other eastern states. It has proved to be a much more serious pest than native species, and also is more or less immune to treatments used to kill native earthworms. This publication describes the habits of the new earthworm, and experiments on its control in specialized turf areas.

DESCRIPTION

The Oriental earthworm *Pheretima hupeiensis* has been present in the eastern United States for at least 15 years. It has been most abundant and destructive in Westchester County, New York, and in 1949 was found to be a nuisance in Stamford, Connecticut. The species represents a genus native to eastern and southern Asia. The means of its introduction into the United States is unknown, but it could have been transported in the soil around the roots of imported plants.

The mature Oriental earthworm varies in length from 150 to 220 mm., with an average diameter of 5 mm. It is generally light green on the upper side, but varies from greenish buff anteriorly to light green at the posterior end. The dorso-median line is purplish green. The ventral portion of the worm is pale gray. The clitellum, which is the area where the cocoon or egg capsule develops, is milky or light chocolate in color.

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[1] Entomology Department.

LIFE HISTORY AND HABITS

Study of the life history and habits of the worm has not been completed. Preliminary observations indicate that there may be more than one generation a year, and that there are 20 or more individuals per egg capsule. Most earthworm species produce only one or two ova per cocoon.

Earthworms do not remain constantly at any one level of the soil. Temperature and moisture are important factors affecting their movement. Table 1 gives a summary of the findings in diggings in infested turf in golf courses. In diggings made when the topsoil was moist, the Oriental earthworm was present in the upper layers of the soil. When the soil was very dry, it moved to the lower levels. The native species were not so much affected by absence of soil moisture.

The Oriental earthworm was most abundant on the greens, where the pH, moisture content and amount of organic matter were relatively high. The infestation on Fairway 3 (Table 1) was high, but the area sampled was

TABLE 1. DISTRIBUTION OF EARTHWORMS IN GOLF COURSE SOILS

Location	Soil Level in Inches	Total Earthworms Found	
		Oriental	Native Species
Fairway 1	0-20	0	present
July 5	20-40	10	0
Green 1	0-10	21	5
July 11			
Green 2	0-2	22	1
July 18	2-6	32	1
	6-10	5	2
	10-14	0	1
Fairway 1a	0-2	0	0
July 29	2-6	0	13
	6-10	0	19
	10-14	2	2
	14-20	1	1
Fairway 3	0-2	21	9
July 18	2-6	8	20
	6-10	2	30
	10-14	0	2

TABLE 2. SOIL MOISTURE, ORGANIC MATTER AND pH IN THREE OF THE LOCATIONS IN TABLE 1

Location	Soil Level in Inches	Average Per Cent		pH
		Moisture	Organic Matter	
Fairway 1a	0-2	16.5	9.16	5.35
	2-6	13.6	5.35	5.03
	6-10	15.5	3.80	4.75
	10-14	19.9	3.56	4.72
	14-20	15.8	2.58	4.81
	20-40	13.4	1.01	4.72
Green 1	0-2	22.6	5.87	6.23
	2-6	20.0	4.51	6.35
	6-10	20.7	5.02	6.32
	10-14	20.6	5.11	6.29
	14-20	15.4	2.75	6.40
Green 2	0-2	23.6	4.37	6.01
	2-6	24.8	4.34	6.13
	6-10	20.1	2.31	5.82
	10-14	17.5	.73	5.80
	14-20	19.2	.37	5.49

really an apron of the green. Abundance was least in the roughs. A summary of the amounts of soil moisture, organic matter and pH measurement of three of the four locations in Table 1 is given in Table 2. The principal differences between Fairway 1a, which was very lightly infested, and the two heavily populated greens were in soil moisture and pH.

CASTS

Weather permitting, *P. hupeiensis* may surface, cast, or do both during any season of the year. For a week following a period of relatively high temperatures, February 13 to 20, 1949, tremendous casting occurred on an aldrin-treated (December 3, 1948) green at Pelham Country Club.[1] This earthworm probably does not hibernate. Consequently, when weather permits, as it did on February 20, the animal becomes active. Air temperatures of 60° F. or better (preferably 70° F. or above) accompanied by or following moderate to heavy rain and high humidity will bring the worms to the surface. There are, however, few or no immediate castings.

Usually, abundant castings are not seen until the second morning after rain has fallen. Worms remain on the surface only as long as it is raining and retreat immediately into their burrows when it stops. Casting may then continue each day thereafter, providing the soil remains moist and the temperature and humidity are sufficiently high. Repeated castings are assured during a rainy season when storms may occur several times a week. When conditions are ideal, casting takes place repeatedly during the daylight hours, a habit peculiar to the species and not apparent among native earthworms. Hourly castings for six to eight hours of 25,000 to

[1] Westchester County, New York.

35,000 in 5,000 square feet are not uncommon. In a normal year such a pattern of activity is more certain during the spring and autumn, when evaporation is less, than during the summer.

Evans (1) reports that the weight of castings thrown onto the surface of a measured area of ground depends, not only on the extent of the earthworm population present, but also on the size of the individuals. In experiments conducted by Evans the weight of castings varied from 1 to 25 tons per acre annually. It was calculated, furthermore, that from 4 to 36 tons of soil per year pass through the bodies of the total earthworm population present. (Not all castings are thrown onto the surface of the ground; some are produced in the permanent runways below the surface.)

Based on an average weight of 0.485 grams per air dry casting (average of 100 castings taken at random from a green), the weight of soil which may be cast up per green of 5,000 square feet and also per acre has been estimated (Table 3).

TABLE 3. DRY WEIGHT OF WORM CASTINGS

No. of Castings Per Square Foot	Weight Per Average Size Green 5,000 sq. ft. (pounds)	Weight Per Acre (pounds)
1	5.34	45.9
5	26.70	229.5
15	80.10	688.5
25	133.50	1147.5

Figuring the weight of castings of 59 worms per square foot,[1] if an average of three series of castings are made in 24 hours, the weight of dry soil cast up on 5,000 square feet of green, if all the worms cast each time, would be 240.30 pounds; on an acre, 2065.5 pounds. If such a performance occurred only once a week (as it frequently does) during the spring and again in the autumn (18 weeks), the minimum weight of castings per 5,000 square foot green in one year would be 2.16 tons; per acre, 18.58 tons.

The chemical contents and physical nature of worm castings are important. Lunt and Jacobson (4) examined forest soils in Connecticut taken from four locations (all were described as stony, fine, sandy loam) and also their respective earthworm casts (not *P. hupeiensis)*. The results of the analyses of the casts and of the surrounding soil mass are tabulated in Table 4. It would appear that "in nearly all cases (forest soil and its earthworm casts) the casts showed higher values than the 0-6 inch layers, which in turn were higher than those of the 8-16 inch depth". The values of the casts from the forest soils are also compared with those of the casts of the Oriental earthworm from a golf course green (Table 4).[2] With the exception of the pH, all of the values of the casts from the forest soils are significantly higher than those of the golf green casts. Regrettably, soil samples were not taken from this green.

[1] The largest number found in any digging.
[2] Analyses made by Soils Department.

TABLE 4. ANALYSES OF EARTHWORM CASTS AND OF THE SURROUNDING SOIL MASS[1]

Source	Calcium p.p.m. Average	Potassium p.p.m. Average	Magnesium p.p.m. Average	Exchange Hydrogen Average	Base Exchange Capacity Average	Per Cent Nitrogen Average	Per Cent Organic Matter Average	Per Cent Moisture Average	pH Average
Forest soil[2]	11.5	138	2.10	10.3	15.1	0.327	5.9	30.1	4.62
Native earthworm casts[2]	38.5	231	8.07	11.4	30.5	0.625	15.6	52.9	5.26
Casts from golf course greens	10.99	120.7	1.121	2.06	12.03	0.255	5.571	42.2	5.84

[1] With the exception of per cent moisture, which is field moisture, all data are in m. e./100 g. of over-dry soil.

[2] Lunt and Jacobson (4).

TABLE 5. ANALYSIS OF CASTINGS OF THE ORIENTAL EARTHWORM

		Average of 10 Samples
Per cent moisture		1.71
Exchangeable hydrogen m. e./100 g.		2.06
Base exchange capacity		
	m. e./100 g.	12.03
	% saturation	84.12
Calcium		
	p.p.m.	2230.60
	m. e./100 g.	11.00
Magnesium		
	p.p.m.	136.80
	m. e./100 g.	1.12
Potassium		
	p.p.m.	120.7
	m. e./100 g.	.308
Per cent organic matter		5.571
Per cent total nitrogen		.255
pH		5.85
Per cent field moisture		42.2

The average field moisture of earthworm castings collected from green No. 2 at Pelham Country Club during July (Table 5) was 42.2 per cent, the average organic matter 5.571 per cent, and the average pH 5.85. The field moisture of soil taken from the top two inches of greens 3 and 14 was 39.3 per cent and 39.7 per cent respectively. The organic matter was 7.60 per cent and 7.29 per cent and the pH 5.98 and 5.53 respectively. The data reveals no significant differences, relative to moisture content and pH, between the earthworm castings and the top two inches of soil. There is, however, some noticeable difference in the percentage of organic matter. In this respect the castings appear to be less rich (Table 5) than the upper two-inch layer of soil (Table 2) in the fairways and putting greens, but not in the nursery greens. The moisture, organic matter and pH declined in soil depths below the topmost two inches (Table 2).

CONTROL

Walton (5) has described some of the chemical control measures used in killing native earthworms in golf greens. Corrosive sublimate, ammonium sulfate, arsenate of lead, and mowrah meal were all effective. Fleming and Hadley (3) reported that all these materials were ineffective in controlling the Oriental earthworm. They tried DDT at the rate of 100 pounds per acre and reported that it, too, was of no value.

Consequently, experiments on control using new insecticides were carried out during 1948 and 1949. All treatments were made on golf courses either in Stamford, Connecticut, or in nearby areas of Westchester

County, New York. Since these golf courses were in constant use, the treatments were applied to entire greens, rather than setting up dosage tests.

Parathion

A heavily infested green was treated accordingly to the schedule in Table 6. Twenty quarts of worms were taken from 5,000 square feet shortly before the first treatment. The results were obtained by counting the castings at the start of the experiment, and at intervals throughout the course of the tests. Table 6 shows that the use of about 100 pounds of parathion per acre in four applications between May 13 and June 24, 1948, reduced the population about 97 per cent. This green was still free of infestation in June, 1951, showing that reinfestation had not occurred.

TABLE 6. PARATHION TREATMENTS, 1948

Date	Pounds Per Acre	Results
May 13	21.5	50 to 60% kill in 2 weeks
May 25	11.0	70% mortality on June 1
June 8	30.0[1]	80% mortality on June 20
June 24	32.0	97% mortality on June 28
Total	94.5	

[1] Plus 17 pounds chlordane.

The last application, on June 24, 1948, burned the turf seriously and some replacement was necessary.

The top inch of soil contained 30 p.p.m. of parathion on July 14, according to analyses made by the Research Laboratories of The American Cyanamid and Chemical Corporation, Stamford, Connecticut. The amount decreased steadily to 3 p.p.m. on September 12, 1949.

Chlordane

Several tests of chlordane in the form of wettable powder and emulsion were made as summarized in Tables 7 and 8. In general, the results were excellent and rapid. The emulsion worked faster than the wettable powder; in a number of cases thousands of dead worms were on the surface a week after treatment. Furthermore, reinfestation did not occur the year following treatment.

TABLE 7. CHLORDANE TESTS—EACH GROUP REPRESENTS A SEPARATE TEST USING WETTABLE POWDER

Date	Pounds Per Acre	Method of Application	Results
June 13, 1948	86	In water	June 29, definite reduction
June 16, 1948	86 (Toxaphene)	Dust, watered in	Oct. 8, no worms or castings
June 22, 1948	43	In water	May 23, 1949, no worms, 8 castings
June 15, 1948	43	In water	Oct. 9, no worms or castings
May 9, 1949	43	Dry in fertilizer	Sept. 14, 1949, 25 castings, no worms
June 15, 1948	43	In water	Oct. 9, no worms or castings
May 9, 1949	43	Dry in fertilizer	Sept. 14, 1949, no worms or castings
July 11, 1948	43	Dust, watered in	May 9, 1949, no worms, few castings
May 9, 1949	64	In water	July 5, 1950, no worms, 43 castings
July 11, 1948	43	Dry in fertilizer	May 9, 1949, no worms, few castings
May 9, 1949	64	In water	May 23, 10,000 dead worms
May 9, 1949	43	In water	Sept. 14, no worms, 15 castings

Note: Untreated greens had both worms and castings on each date results are given.

TABLE 8. CHLORDANE TESTS—EACH GROUP REPRESENTS A SEPARATE TEST USING 48 PER CENT EMULSION

Date	Pounds Per Acre	Method of Application	Results
1949			
May 10	20	In water	May 23, many dead worms
May 23	20	In water	Sept. 14, no worms, 20 castings
May 23	40	In water	Sept. 14, no worms, 100 castings
July 11	40	In water	July 18, covered with dead worms Sept. 14, no worms, no castings

Aldrin

This chemical was used in the form of a dry powder which was watered in, and as an emulsion. Aldrin always stimulated the worms, and heavy casting followed. This continued for several days and observations indicated that worms were not killed until six weeks after application. The treatments and results are given in Table 9. It is obvious that aldrin provided good control after several weeks had elapsed, and that the population remained low for at least a year.

TABLE 9. ALDRIN TREATMENTS—EACH GROUP REPRESENTS ONE TEST

Date	Pounds Per Acre	Method	Results
Aug. 20, 1948	5.0	Dry - fertilizer	Oct. 7, 1948, many worms surfaced
Oct. 4, 1948	10.0	Dry - fertilizer	Apr. 14, 1949, no castings, no worms
May 9, 1949	33.0	Dry - fertilizer	Sept. 1, 1949, 12 castings, no worms
Dec. 3, 1948	22	Dry - fertilizer	Feb. 20, 1949, heavy casting May 7, 1949, 13 castings, no worms July 5, 1950, 17 castings, no worms
May 23, 1949	33	Emulsion in water	July 11, 1949, heavy casting Sept. 1, 1949, 8 castings, no worms July 5, 1950, no castings, no worms
July 11, 1949	33	Emulsion in water	Sept. 14, 1949, no castings, no worms

Note: Heavy casting occurred on untreated plots on every date on which observations were made.

Small Plot Experiments

Plots of about 60 square feet each were laid out in a grass nursery, and treated with several materials. The principal purpose was to determine the effect of the materials on the grass. Worms were present in all plots. The treatments were all made on June 3, 1949. Each was watered in at once and soaked again in 24 and 48 hours. The treatments were as follows:

1. Aldrin, 44 pounds per acre, in an emulsion
2. Aldrin, 20 pounds per acre, and chlordane, 20 pounds per acre, both emulsions
3. Lindane, 20 pounds per acre, in a wettable powder
4. Lindane, 10 pounds per acre, and chlordane, 20 pounds per acre, both emulsions
5. Lindane, 10 pounds per acre; chlordane, 20 pounds per acre; aldrin, 10 pounds per acre, all emulsions
6. Chloroform emulsion, 2 gallons per 1000 square feet
7. Dieldrin, 44 pounds per acre, in an emulsion

All treatments produced some injury to the grass within 48 hours. One week after treatment the plots treated with aldrin, aldrin and chlordane, and lindane had recovered completely. Within two weeks grass recovered in the lindane and chlordane, and lindane, chlordane and aldrin

plots. The chloroform emulsion injured the bent grass severely, but no weeds or crabgrass appeared. With the exception of this one treatment, all plots grew well and the grass clippings weighed at least twice those from untreated areas.

All treatments gave good worm control by August 5 and there was no infestation during 1950. Untreated areas remained heavily infested.

SUMMARY

The Oriental earthworm *Pheretima hupeiensis* has caused serious inconvenience on a golf course in Stamford, Connecticut. It is apparently very prolific, and has infested golf greens more heavily than fairways and roughs.

The production of hundreds of casts following heavy rainfall has seriously damaged golf greens. Hundreds of pounds of castings have been left on each heavily infested green every year.

Control measures used for native earthworms were not effective in controlling the Oriental earthworm.

New insecticides known to be toxic to other animals were used in an effort to control these worms on golf greens.

Parathion applied four times, totaling about 100 pounds per acre, reduced the population about 97 per cent. Some injury was caused by the final application.

Chlordane emulsions were more effective than wettable powders. Single treatments using 40 pounds of chlordane per acre gave a high immediate kill and prevented reinfestation for long periods of time.

Aldrin in the form of either wettable powders or emulsion at the rate of 33 pounds per acre first activated the worms, but provided good control after several weeks.

Small plot tests of lindane at 20 pounds per acre and dieldrin at 44 pounds per acre produced good results.

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