



Interaction of western harvester ants with southeastern Montana soils and vegetation
by Jeffrey Lawrence Birkby

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Botany

Montana State University

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Abstract:

Mounds of the western harvester ant (*Pogonomyrmex occidentalis*) located on rangeland in southeastern Montana were examined to determine the possible causes of a ring of lush vegetation that surrounded the denuded mound disc. Nutrient and soil water content samples were collected along a transect from the center of the mounds to a control area three meters distant. Significantly high values of nitrate, phosphorus, sulfate and soil water were found in the denuded disc area. Root biomass data indicated that some roots penetrated the denuded disc area, providing a means for transporting available nutrients and soil water to the edge-vegetation. A change in species composition was also noted. While *Bouteloua gracilis* dominates in the study area, *Stipa comata* dominated in the edge-vegetation. The change in species composition and the increased availability of nutrients and soil water resulted in a high production of the edge-vegetation that more than compensated for the denudation of the mound by the ants.

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Bozeman, Montana

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Date 13/June/1983

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Abstract

Mounds of the western harvester ant (Pogonomyrmex occidentalis) located on rangeland in southeastern Montana were examined to determine the possible causes of a ring of lush vegetation that surrounded the denuded mound disc. Nutrient and soil water content samples were collected along a transect from the center of the mounds to a control area three meters distant. Significantly high values of nitrate, phosphorus, sulfate and soil water were found in the denuded disc area. Root biomass data indicated that some roots penetrated the denuded disc area, providing a means for transporting available nutrients and soil water to the edge-vegetation. A change in species composition was also noted. While Bouteloua gracilis dominates in the study area, Stipa comata dominated in the edge-vegetation. The change in species composition and the increased availability of nutrients and soil water resulted in a high production of the edge-vegetation that more than compensated for the denudation of the mound by the ants.

INTRODUCTION

Alteration of ecosystems by burrowing animals has been studied for more than a century (Darwin, 1882). Soil modification and corresponding changes in production and species composition of the surrounding vegetation are documented for pocket gophers (Thomomys talpoides, McDonough, 1974; Laycock, 1958), woodchucks (Marmota monax monax, Merriam and Merriam, 1965), moles and voles (Talpa europaea and Microtus arvalis, Gozczynska and Goszyzynski, 1977), and other mammals. Ecosystem modifications by several ant species have also been examined, including Lasius flavus (King, 1977), Myrmica spp. (Czerwinski et al, 1969), Formica obscuripes (Beattie and Culver, 1977), Formica exsectoides (Salem and Hole, 1968), Formica cinerea (Baxter and Hole, 1968), Pogonomyrmex badius (Gentry and Stiritz, 1972), and Pogonomyrmex occidentalis (Rogers and Lavigne, 1974). The western harvester ant, Pogonomyrmex occidentalis, was chosen as the subject of this study.

Range managers consider P. occidentalis colonies destructive because they denude large areas around their dome-shaped mounds, seemingly reducing available livestock forage. The diameters of these denuded areas vary from less than one meter in heavily vegetated areas to nine meters or more in sparsely vegetated grasslands of Oklahoma (Wight and Nichols, 1966). Hull and Killough (1951) estimated that 33,500 hectares had been denuded by P. occidentalis in the Big Horn Basin of Wyoming, while Scott (1951) calculated that over six million mounds exist in the Wind River Basin.

A ring of lush vegetation has been observed around the disc denuded by P. occidentalis (Rogers and Lavigne, 1974; Wight and Nichols, 1966). Based on these observations, as well as my own, I hypothesized that the vigor of the edge-vegetation may compensate for the absence of plant production within the denuded disc areas. To test this hypothesis, root and shoot production were examined along a transect from the center of each denuded disc to a control area three meters distant. In addition, species composition, soil nutrient concentration and soil water content were analyzed along the

same transects to determine what factors might be responsible for the observed changes in plant productivity.

STUDY AREA

I conducted my research at the USDA Livestock and Range Research Station in southeastern Montana, ten kilometers south of Miles City near the Tongue River ($46^{\circ}17'30''\text{N}$, $105^{\circ}45'00''\text{W}$). Soil Conservation Service personnel (Nichols, 1978) classified the study site an Ustic Torriorthent (fine-loamy, frigid, calcareous), sloping less than one percent on an alluvial terrace. A calcium rich C_{ca} horizon occurred twenty centimeters below the surface. Annual precipitation at Miles City averaged 36 cm, with 26 cm falling between April and September. Temperatures averaged 23°C in July and 9°C in January (USDC, 1979). Bouteloua gracilis, Buchloe dactyloides and Stipa comata dominated the site, which lies within Kuchler's (1964) Bouteloua-Stipa-Agropyron vegetation zone (Type 64). Cattle grazed the study area periodically until a year prior to my observations, when a fence was erected around the site to exclude them.

METHODS AND MATERIALS

Seven mounds of similar diameter were subjectively selected for intensive sampling. The mounds averaged 55 cm in width, with each surrounded by a denuded disc averaging 250 cm in diameter. Immediately outside of the disc was a ring of lush vegetation that contrasted strikingly with adjacent vegetation.

Vegetation and soils were sampled in August 1978 from the center of the mound, from the edge-vegetation area, 20 cm on either side of the edge-vegetation, 65 cm on either side of the edge, and from an area 3 m from the mound center, which served as a control (Fig. 1). Soil nutrient, soil water and root samples were collected from the sampling areas with a soil coring tube 2.05 cm in diameter. Vertical distribution of nutrients, soil water and roots was studied by partitioning soil cores into 0-10, 10-30, 30-50, and 50-100 cm fractions.

Data from three transects radial to each mound for each position and depth were pooled to reduce the variance of the soil nutrient, soil water, and the root

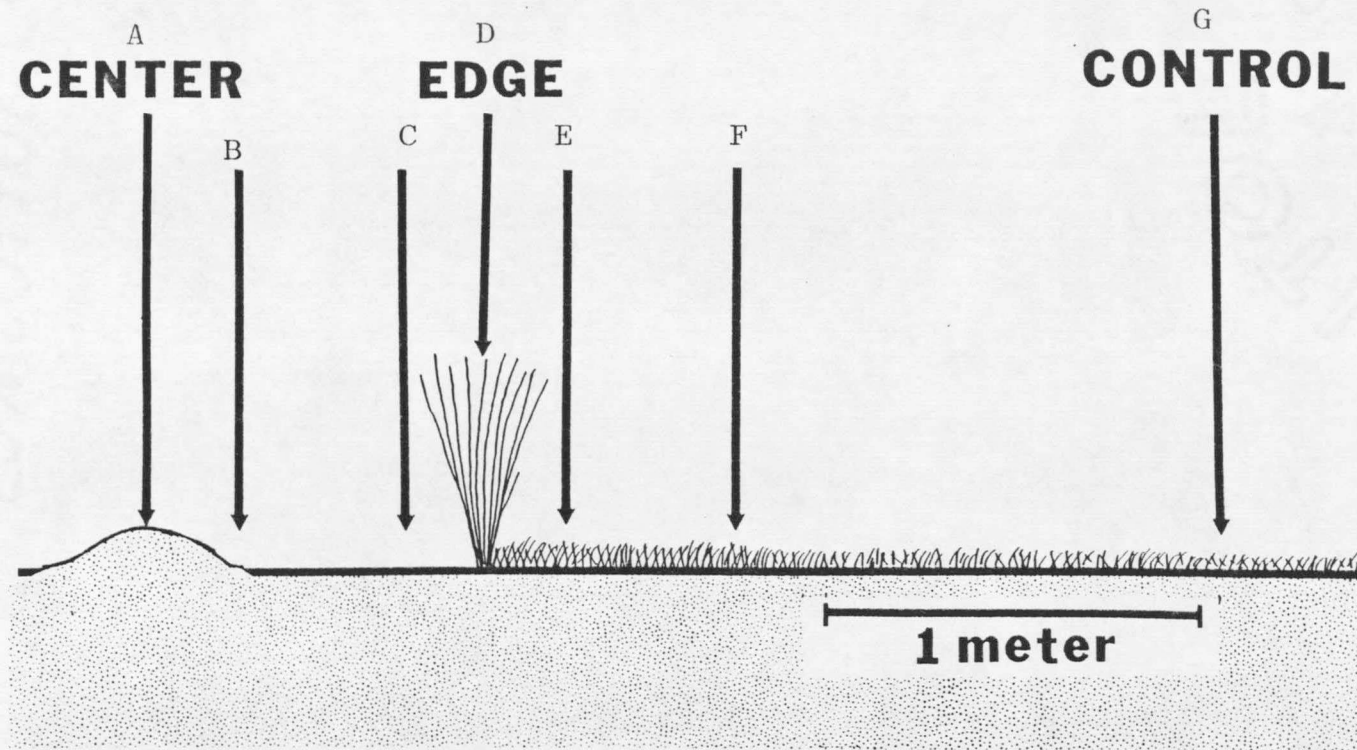


Figure 1. Sampling points along the ant mound transect. Arrows indicate samples taken from A) mound center, B) 65 cm in from disc edge, C) 20 cm in from disc edge, D) edge-vegetation, E) 20 cm out from edge-vegetation, F) 65 cm out from edge-vegetation, and G) a control area 300 cm from the mound center.

data. Soil water and root biomass were sampled from all seven mounds. Due to the high cost of nutrient analyses, soils of only three mounds could be analyzed for nutrients in the 0-10 cm layer, and only two mounds were analyzed for nutrients in the 10-30, 30-50, and 50-100 cm layers. These samples were pooled in the same manner as the root biomass and soil water samples.

Soil nutrient cores were dried at 60°C for 48 hours immediately after collecting, and were then analyzed by the Montana State University Soil Testing Laboratory. Nitrate content was determined by the phenoldisulfonic acid technique (Snell and Snell, 1936); phosphorus was measured by a modified Bray method (Olsen and Dean, 1965); potassium, magnesium, calcium and sodium were extracted with a 1M solution of ammonium acetate and then analyzed with an atomic absorption spectrophotometer; ammonium was determined by microKjeldahl distillation (Bremner, 1965); sulfate sulfur was extracted with ammonium acetate, precipitated with barium chloride (BaCl_2) and read spectroscopically (Black, 1965); soil organic matter was measured colorimetrically after dichromate oxidation (Sims and Haby, 1970); pH was

determined using a 1:2 soil-water paste and a soil pH meter (Black, 1965); and percent soil water was determined gravimetrically (Black, 1965).

Root biomass cores were dried for 24 hours at 60°C immediately after collecting. The samples were then soaked overnight in a sodium hexametaphosphate (Calgon) solution to loosen the roots from the soil particles. A 1 mm screen was used to separate the wet samples from the softened soil particles. Sand was removed by soaking the washed and sieved samples in water and then decanting the organic material. Visual estimates were then made of the percentage of roots in each sieved sample. Root samples were dried at 60°C, weighed, and ashed at 600°C to correct for the weight of the inorganic contaminants (Weaver, 1977).

Species composition of the vegetation surrounding the disc was measured using the canopy-coverage method of Daubenmire (1959). Frames measuring 20 by 50 cm were placed at 120° intervals in the edge-vegetation of the seven mounds, and canopy-coverage classes of 0-5%, 5-25%, 25-50%, 50-75%, 75-95% and 95-100% were recorded.

The midpoints for each class were used to calculate the means and standard errors. Canopy-coverage was also measured at 120° intervals 20 cm, 65 cm and 2 m outside the edge of the disc. After determining the canopy coverage of each plot, the shoot material was clipped at ground level, dried at 60°C for 24 hours, and weighed. Quantitative differences between depths and sampling positions for all factors were examined by paired-t tests (Snedecor and Cochran, 1967).

RESULTS

The distribution of soil water, phosphates, nitrates, sulfur and soil organic matter, as well as the above- and below-ground biomasses are shown in Fig. 2.

Soil moisture was significantly greater in the center of the mound at all four sampling depths than in the control location ($p < .05$). Soil moisture content was greatest 50-100 cm below the mound, averaging 11% as compared to 7% at the same depth in the control area. Soil moisture decreased in the shallower soil horizons, with the driest soils (4% soil moisture)

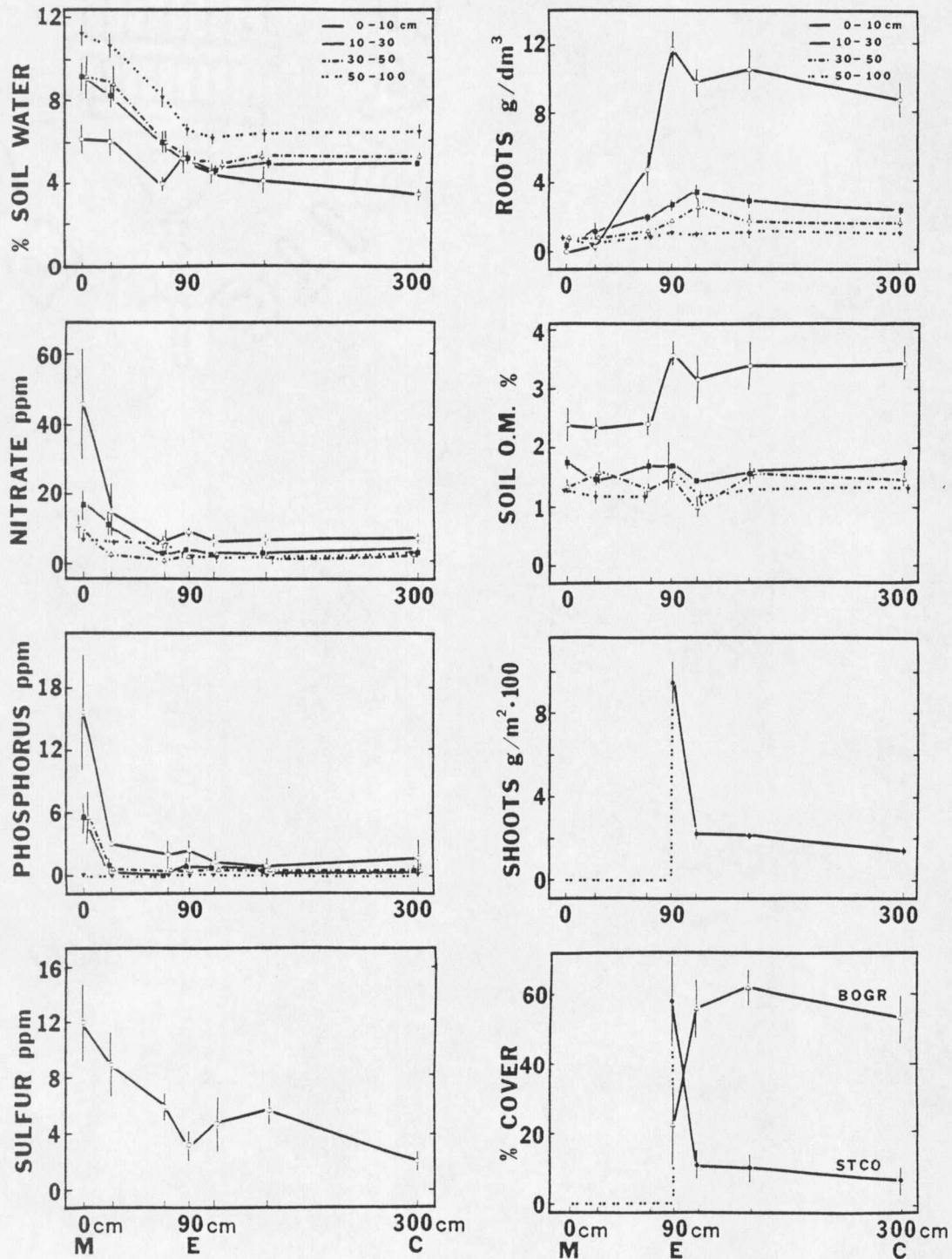


Figure 2. Soil and vegetation parameters along a transect from mound center (M) through the edge-vegetation (E) to a control point 300 cm from the mound center (C). Vertical cross-bars indicate one standard error. O.M. represents organic matter.

the 0-10 cm layer sampled from just inside of the disc edge, as well as in the control. The increase in soil water content in the mound as compared to the control agrees with the findings on P. occidentalis effects in Colorado (Rogers and Lavigne, 1974).

Phosphate, nitrate, and sulfate concentrations were also significantly altered within the mound area (Fig. 2). Dramatic increases in nutrient concentrations occurred in the center surface layers of the mound, where nitrate and phosphate concentrations increased fourfold relative to the control area ($p < .05$). Ant excreta and imported foodstuffs account for most of the increase in nutrients in the surface layers of the mounds (Gentry and Stiritz, 1972; Rogers and Lavigne, 1974), although some sulfate may have been translocated from the sulfate-rich horizon located between 50 and 100 cm. Defecation by grouse, coyotes or other animals might also increase the nutrients in the surface layers of the mounds (Giezantanner and Clark, 1973), although wildlife were never observed in the study area. Other soil measurements (pH, Ca, Na, Mn, K) did not vary significantly along the transect from the mound center to the

control area (see Appendix A). Average pH for all samples was 8.3.

Concentrations of soil organic matter in the surface soil layers were lower in the denuded disc and mound area than in the edge and control areas. However, organic matter was a relatively constant 1-2% in the subsurface layers. The observed low values of surface organic matter may be due to several factors. Erosion of organic-matter-rich soils from the denuded discs, as well as high respiration of the soil organic matter exposed on the mounds' surface may explain some of the decrease. Forcella (1977) demonstrated that mounds are often constructed of subsurface soils that have a lower organic matter content than surface soils. The low values observed on the mounds may be caused in part by the deposition of these subsurface soils within the top 10 cm of the mound.

Shoot yield was negligible in the disc, but was over three times greater in the lush edge-vegetation than in the control area ($p < .01$). In addition, shoot production 20 cm and 65 cm out from the edge also increased

relative to the control ($p < .05$), suggesting that mound influences extend past the disc edge.

The relative scarcity of root biomass beneath the disc is also evident. Few roots were present in the center of the mound, but some roots from the edge-vegetation apparently penetrated more than 20 cm into the disc at all four sampling depths. Most of the root material occurred in the 0-10 cm layer, and decreased exponentially with depth outside of the disc, a phenomenon also observed in undisturbed grasslands (Weaver, 1977). Peak root biomasses (as with peak shoot biomasses) were associated with the disc edge. Roots were most numerous in the 0-10 cm level beneath the robust edge vegetation, as well as in the 10-30 and 30-50 cm levels at the sampling point 20 cm out from the disc edge. Few roots occurred below 50 cm, but root biomass below that depth did not differ significantly across the transect.

Canopy-coverage data show that Stipa comata replaces Bouteloua gracilis as the dominant species in the lush edge vegetation. Both grasses are deep-rooted perennials, and the seeds of both species are harvested by P.

occidentalis (Rogers, 1974). The change between the species' canopy-cover from the edge of the mound to the control area is striking. S. comata covers almost 60% of the area at the edge of the mound, but declines to only 10% coverage outside of the disc. In contrast, B. gracilis coverage increases from 20% at the edge to over 52% at all locations more than 20 cm out from the disc.

DISCUSSION

Soil nutrient and soil water concentrations were noticeably influenced within the vicinity of the P. occidentalis mounds. The changes in nutrient and soil water concentrations may account for the species composition shift near the edge of the mound, as well as the increased productivity of the edge vegetation.

The observed increase in S. comata's canopy-coverage near the ant mound is consistent with Bonham and Lerwick's (1976) findings on prairie dog towns in Colorado. S. comata increased in total canopy-coverage near the towns, but decreased in control areas away from the towns, while B. gracilis responded reciprocally. This

change was attributed to changes in soil characteristics and to the redistribution of run-off water within the town.

The relatively high soil water content under the P. occidentalis mounds may be due to either the plant-removing behavior of the ants or to the redistribution of run-off water. Forcella (1977) suggested that ants remove transpiring vegetation from within the disc area specifically to raise soil humidity in their subsurface chambers. This fallowing activity may result in a redistribution of the soil water as compared to the control area--the ants simultaneously increase the availability of water to the robust plants growing at the disc edge, while reducing the total water available to plants in the mound region. Edge-vegetation may be using not only the soil water outside of the disc, but also consuming water up to 30 cm within the disc edge, as indicated by the presence of root biomass in the outer portion of the disc. The consumption of the ant mound water is apparently limited to only the outer regions of the disc, since few roots exist in the more central (and more humid) portions of the mound.

High concentrations of nitrogen, phosphorus and sulfur in the mound area may also affect the species composition and productivity of the edge-vegetation. Gentry and Stiritz (1972) showed that Diodia teres seedlings grow better in soils taken from the edge of harvester ant mounds than those grown in control soils.

The cumulative effect of the species shift to S. comata, the increase in nutrients and the increase in soil water available to the edge-vegetation results in a considerable increase in the edge shoot production (Fig. 2) as compared to the normal rangeland. In fact, the increased shoot yield of the edge-vegetation more than compensates for the denudation of the disc by the ants. When total shoot biomass in the edge plus the denuded disc is compared to the biomass of an equivalent control area, the production in the ant-influenced area averaged 3.4 times more than the control (Table 1). Similar comparisons on P. occidentalis mounds in Colorado showed a 40% decrease in the production of the ant area relative to the control, but the mounds in that study were predominantly surrounded by B. gracilis. Apparently, in range ecosystems where myrmecophilous plants like S.

TABLE 1

<u>MOUND</u>	<u>AREA (m²) DISC PLUS EDGE VEGETATION</u>	<u>STANDING CROP (gm/m²) IN AREA OF COLONY INFLUENCE</u>	<u>STANDING CROP (gm/m²) IN CONTROL AREA OF EQUAL SIZE</u>	<u>ANT BENEFIT COLUMN 3/ COLUMN 4</u>
1	3.9	2022	495	4.1
2	7.1	5036	1484	3.4
3	2.7	601	502	1.2
4	7.1	3272	1172	2.8
5	5.5	3872	1029	3.7
6	5.7	3354	656	5.1
<u>7</u>	<u>4.5</u>	<u>1344</u>	<u>405</u>	<u>3.3</u>
$\bar{X}$	5.2	278.9	820.4	3.4

Table 1. Aboveground standing crop for areas around each ant mound and for equivalent control areas. The final column, obtained by dividing the standing crop of the ant-influenced area by the standing crop of an equal-sized control area, represents the standing crop increase in the ant-influenced area.

comata exist, the concentrated fallowing and fertilizing activities of the ants and the species shift to S.

comata are both necessary to increase range productivity.

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APPENDICES

APPENDIX A

SOIL NUTRIENT DATA

		DISTANCE FROM MOUND CENTER (cm)						
DEPTH MOUND (cm)	SAMPLE	0	25	70	90	110	155	300
0-10	1	31.7	4.4	10.2	9.5	9.5	10.2	9.1
	2	28.2	9.3	4.0	7.4	6.9	6.9	7.4
	3	77.4	23.5	6.1	10.2	3.2	4.4	4.4
	X $\pm$ SE	45.8 $\pm$ 15.8	15.4 $\pm$ 8.7	6.8 $\pm$ 1.8	9.0 $\pm$ 0.8	6.5 $\pm$ 1.8	7.2 $\pm$ 1.7	7.0 $\pm$ 1.4
10-30	1	12.4	4.8	3.4	5.3	3.8	4.3	4.9
	2	21.9	7.9	3.1	2.2	1.6	2.0	2.0
	X $\pm$ SE	17.2 $\pm$ 4.8	11.0 $\pm$ 2.8	3.3 $\pm$ 0.2	3.8 $\pm$ 1.6	2.7 $\pm$ 1.1	3.2 $\pm$ 1.2	3.0 $\pm$ 1.0
30-50	1	6.4	2.2	1.8	2.2	2.7	2.7	2.6
	2	16.6	2.6	0.2	2.1	0.9	1.6	0.9
	X $\pm$ SE	11.5 $\pm$ 2.8	2.4 $\pm$ 0.2	1.0 $\pm$ 0.8	2.2 $\pm$ 0.1	7.8 $\pm$ 0.9	2.2 $\pm$ 0.6	1.8 $\pm$ 0.9
50-100	1	4.3	6.9	7.6	2.7	3.3	3.3	3.6
	2	8.9	5.7	2.6	0.2	0.0	0.0	0.0
	X $\pm$ SE	6.6 $\pm$ 2.3	6.3 $\pm$ 0.6	6.1 $\pm$ 3.5	1.5 $\pm$ 1.4	1.7 $\pm$ 1.7	1.7 $\pm$ 1.7	1.8 $\pm$ 1.8

Table 2. Nitrogen (nitrate) content (ppm) of soil samples in the ant mound area. Each sample represents three pooled field samples.

		DISTANCE FROM MOUND CENTER (cm)						
DEPTH MOUND (cm)	SAMPLE	0	25	70	90	110	155	300
0-10	1	13	4	4	4	4	3	4
	2	8	3	2	1	0	0	1
	3	26	3	0	2	0	0	0
	$\bar{X} \pm SE$	15.7 ± 5.4	3.3 ± 0.3	2.0 ± 1.2	2.3 ± 0.9	1.3 ± 1.3	1.0 ± 1.0	1.7 ± 1.7
10-30	1	4	2	0	2	1	1	1
	2	7	0	0	0	0	0	0
	$\bar{X} \pm SE$	5.5 ± 1.5	1.0 ± 1.0	0.0 ± 0.0	1.0 ± 1.0	0.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5
30-50	1	3	1	1	1	1	1	1
	2	8	0	0	0	0	0	0
	$\bar{X} \pm SE$	5.5 ± 2.5	0.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5
50-100	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	$\bar{X} \pm SE$	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

Table 3. Phosphorus (phosphate) content (ppm) of soil samples in the ant mound area. Each sample represents three pooled field samples.

DEPTH MOUND (cm)	SAMPLE	DISTANCE FROM MOUND CENTER (cm)						
		0	25	70	90	110	155	300
0-10	1	17.6	15.2	8.4	6.3	9.4	8.4	3.8
	2	7.9	5.7	4.5	4.9	5.9	5.1	5.5
	3	13.7	10.1	9.2	2.5	2.8	3.2	4.8
	X $\pm$ SE	13.1 $\pm$ 2.8	10.3 $\pm$ 2.7	7.4 $\pm$ 1.5	4.6 $\pm$ 1.1	6.0 $\pm$ 1.9	6.9 $\pm$ 1.0	4.7 $\pm$ 0.5
10-30	1	23.3	3.8	3.8	3.1	3.6	4.2	4.2
	2	1.0	5.9	1.7	2.4	2.7	1.7	2.4
	X $\pm$ SE	12.2 $\pm$ 11.2	4.9 $\pm$ 1.1	2.8 $\pm$ 1.1	2.8 $\pm$ 0.4	3.2 $\pm$ 0.5	3.0 $\pm$ 1.3	3.3 $\pm$ 2.3
30-50	1	6.7	7.8	5.5	11.8	6.7	8.3	7.5
	2	14.7	11.7	7.6	6.4	7.2	5.1	7.6
	X $\pm$ SE	7.0 $\pm$ 3.8	9.8 $\pm$ 2.0	6.6 $\pm$ 1.1	9.1 $\pm$ 2.7	7.0 $\pm$ 0.3	6.7 $\pm$ 1.6	7.6 $\pm$ 0.1
50-100	1	39.4	31.6	76.4	42.8	63.7	91.8	34.9
	2	15.2	18.3	15.8	99.2	14.7	16.3	15.2
	X $\pm$ SE	27.3 $\pm$ 12.1	24.9 $\pm$ 6.7	46.1 $\pm$ 30.3	71.0 $\pm$ 28.2	39.2 $\pm$ 24.5	54.1 $\pm$ 37.8	27.3 $\pm$ 12.1

Table 4. Sulfur (sulfate) content (ppm) of soil samples in the ant mound area.
Each sample represents three pooled field samples.

		DISTANCE FROM MOUND CENTER (cm)						
DEPTH MOUND (cm)	SAMPLE	0	25	70	90	110	155	300
0-10	1	3.6	3.3	3.6	3.9	3.6	4.3	4.6
	2	3.3	2.3	2.0	3.3	3.6	3.6	3.3
	3	3.3	2.6	3.3	3.9	3.3	3.9	3.6
	X $\pm$ SE	3.4 $\pm$ 0.1	2.7 $\pm$ 0.3	3.0 $\pm$ 0.5	3.7 $\pm$ 0.2	3.5 $\pm$ 0.1	3.9 $\pm$ 0.2	3.8 $\pm$ 0.4
10-30	1	3.3	3.3	3.3	3.3	3.3	3.3	3.9
	2	2.0	2.3	2.6	2.6	2.6	2.6	3.0
	X $\pm$ SE	2.7 $\pm$ 0.5	2.8 $\pm$ 0.5	3.0 $\pm$ 0.4	3.0 $\pm$ 0.4	3.0 $\pm$ 0.4	3.0 $\pm$ 0.4	3.5 $\pm$ 0.4
30-50	1	4.9	5.9	4.9	4.9	3.9	4.9	4.9
	2	2.6	3.6	3.3	3.9	3.9	3.3	4.3
	X $\pm$ SE	3.8 $\pm$ 1.2	4.8 $\pm$ 1.2	4.1 $\pm$ 0.8	4.4 $\pm$ 0.5	3.9 $\pm$ 0.0	4.1 $\pm$ 0.8	4.6 $\pm$ 0.3
50-100	1	5.9	5.9	6.6	5.6	5.9	5.9	5.6
	2	4.9	4.3	4.6	5.6	4.6	4.9	4.6
	X $\pm$ SE	5.4 $\pm$ 0.5	5.1 $\pm$ 0.8	5.6 $\pm$ 1.0	5.6 $\pm$ 0.0	5.3 $\pm$ 0.7	5.4 $\pm$ 0.5	5.1 $\pm$ 0.5

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Table 5. Magnesium content (ppm) of soil samples in the ant mound area. Each sample represents three pooled field samples.

		DISTANCE FROM MOUND CENTER (cm)						
DEPTH MOUND (cm)	SAMPLE	0	25	70	90	110	155	300
0-10	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	$\bar{X} \pm SE$	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
10-30	1	0	0	0	0	0.1	0	0
	2	0	0.1	0	0.1	0.1	0	0
	$\bar{X} \pm SE$	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
30-50	1	0	0	0	0.1	0.1	0.1	0
	2	0	0	0	0.1	0	0	0
	$\bar{X} \pm SE$	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.0
50-100	1	0.1	0.3	0.7	0.5	0.6	0.6	0.4
	2	0.1	0.2	0.2	0.6	0.3	0.2	0.2
	$\bar{X} \pm SE$	0.1 ± 0.0	0.2 ± 0.1	0.5 ± 0.3	0.6 ± 0.1	0.4 ± 0.1	0.4 ± 0.2	0.3 ± 0.1

Table 6. Sodium content (ppm) of soil samples in the ant mound area. Each sample represent three pooled field samples.

		DISTANCE FROM MOUND CENTER (cm)						
DEPTH MOUND (cm)	SAMPLE	0	25	70	90	110	155	300
0-10	1	19.8	21.8	21.8	20.2	22.4	20.2	19.0
	2	22.3	21.8	15.2	16.6	18.2	17.8	17.8
	3	16.6	18.6	20.6	15.8	20.6	19.8	19.8
	X $\pm$ SE	19.6 $\pm$ 2.9	20.7 $\pm$ 1.9	19.2 $\pm$ 3.5	17.5 $\pm$ 2.3	20.4 $\pm$ 2.1	19.3 $\pm$ 1.2	18.9 $\pm$ 1.0
10-30	1	24.0	24.0	25.0	25.0	25.4	24.6	26.0
	2	19.8	22.4	21.4	22.8	22.8	20.6	22.8
	X $\pm$ SE	21.9 $\pm$ 3.0	23.2 $\pm$ 1.1	23.9 $\pm$ 1.6	24.1 $\pm$ 1.3	22.6 $\pm$ 2.8	22.6 $\pm$ 2.8	24.4 $\pm$ 1.3
30-50	1	26.0	25.4	24.6	26.0	28.8	26.8	26.8
	2	21.8	25.0	21.8	23.6	23.2	23.6	24.6
	X $\pm$ SE	23.9 $\pm$ 3.0	25.2 $\pm$ 0.3	23.2 $\pm$ 2.0	24.8 $\pm$ 1.7	26.0 $\pm$ 4.0	25.2 $\pm$ 2.3	25.7 $\pm$ 1.6
50-100	1	24.0	24.0	25.4	23.6	26.4	24.6	24.6
	2	22.4	25.0	23.2	24.6	22.8	22.8	21.8
	X $\pm$ SE	23.2 $\pm$ 0.8	24.5 $\pm$ 0.7	24.3 $\pm$ 1.6	24.1 $\pm$ 0.7	24.6 $\pm$ 2.6	23.7 $\pm$ 1.3	23.2 $\pm$ 2.0

Table 7. Calcium conten (ppm) of soil samples in the ant mound area. Each sample represents three pooled field samples.

		DISTANCE FROM MOUND CENTER (cm)						
DEPTH MOUND (cm)	SAMPLE	0	25	70	90	110	155	300
0-10	1	240	201	240	232	201	232	278
	2	247	201	155	278	224	240	193
	3	224	178	178	278	193	186	178
	X $\pm$ SE	<u>237$\pm$6.8</u>	<u>193$\pm$7.7</u>	<u>191$\pm$25.3</u>	<u>262$\pm$15.3</u>	<u>206$\pm$9.3</u>	<u>219$\pm$16.8</u>	<u>216$\pm$31.7</u>
10-30	1	155	155	148	186	163	178	193
	2	148	133	133	140	125	118	133
	X $\pm$ SE	<u>151$\pm$3.5</u>	<u>144$\pm$11.0</u>	<u>140$\pm$7.5</u>	<u>163$\pm$23</u>	<u>144$\pm$19</u>	<u>148$\pm$30</u>	<u>163$\pm$30</u>
30-50	1	163	163	163	148	133	178	148
	2	110	133	110	133	125	125	125
	X $\pm$ SE	<u>136$\pm$26</u>	<u>148$\pm$15.0</u>	<u>136$\pm$26</u>	<u>140$\pm$13</u>	<u>129$\pm$4</u>	<u>151$\pm$26.5</u>	<u>136$\pm$11</u>
50-100	1	170	178	178	163	163	170	148
	2	133	133	125	163	133	118	133
	X $\pm$ SE	<u>151$\pm$18</u>	<u>155$\pm$22</u>	<u>151$\pm$26</u>	<u>163$\pm$0</u>	<u>148$\pm$15</u>	<u>144$\pm$26</u>	<u>140$\pm$7.5</u>

Table 8. Potassium content (ppm) of soil samples in the ant mound area. Each sample represents three pooled field samples.

APPENDIX B

SOIL WATER POTENTIAL DATA

DATE	DISTANCE FROM MOUND CENTER (cm)			
	25	90	155	300
22 May	1	1	0	0
5 June	0	0	0	0
13 June	0	0	0	0
20 June	1	0	1	0
28 June	0	2	1	1
6 July	0	10*	4	4
12 July	1	11*	7	5
21 July	2	2	3	6
26 July	0	6	5	5
1 August	1	4	9*	9*
7 August	1	10*	13*	11

Table 9. Soil water potential at 10 cm depth in the vicinity of the ant mounds, 1978. All data are in negative bars. Each value is the mean of seven replications. Standard errors greater than three bars are indicated with an asterisk (*).

DATE	DISTANCE FROM MOUND CENTER (cm)			
	25	90	155	300
22 May	0	0	0	0
5 June	0	0	0	0
13 June	0	0	0	0
20 June	0	1	0	0
28 June	0	4	0	0
6 July	0	8	1	2
12 July	0	13	3	5
21 July	0	14*	11	13*
26 July	1	13*	10*	10*
1 August	3	15*	17	17
7 August	3	17	20	19

Table 10. Soil water potential at 25 cm depth in the vicinity of the ant mounds, 1978. All data are in negative bars. Each value is the mean of seven replications. Standard errors greater than three bars are indicated with an asterisk (*).

DATE	DISTANCE FROM MOUND CENTER (cm)			
	25	90	155	300
22 May	0	7*	7*	1
5 June	0	0	0	0
13 June	0	0	0	0
20 June	0	0	0	0
28 June	0	0	0	0
6 July	0	1	0	0
12 July	0	1	0	0
21 July	0	2	0	0
26 July	0	4	1	0
1 August	1	7	2	3
7 August	2	8	6	6

Table 11. Soil water potential at 75 cm depth in the vicinity of the ant mounds, 1978. All data are in negative bars. Each value is the mean of seven replications. Standard errors greater than three bars are indicated with an asterisk (*).



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Birkby, J. L.
Interaction of western
Harvester Ants with
southeastern Montana
soils and vegetation

[illegible]