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Trampling increases soil compaction; soil compaction depresses vigor of *Andropogon gerardii*

PATRICK MCNEARNEY, JUSTIN RILEY, and ALAN WENNERSTEN
Biology Department, Grinnell College, Grinnell, IA 50112, USA

Abstract
The soil of the prairie is never static; it is constantly affected by and affecting its inhabitant flora and fauna. Many interactions, including the scientific observer's movement on the prairie, have an impact on the quality of the soil. This study examines the compaction that comes about from human foot traffic and the effect of soil compaction on the germination and vigor of Andropogon gerardi*i. We predicted that repeated footfalls would significantly increase soil compaction in the field and that this greater soil density would retard germination and stunt growth. Our findings confirmed that foot traffic increased soil compaction and that greater soil compaction depressed the growth of* A. gerardi*i but not its germination rate.*

Introduction

Despite the many important works that have contributed to a greater understanding of prairie community dynamics, the effects of prairie observation itself during the course of scientific study have been largely overlooked. Many human interactions with the prairie have some impact upon an area through soil compaction and the trampling of flora. Trampling occurring during research could potentially introduce variability to results and affect vegetation growth. Wild game trails, the use of heavy machinery, bison wallows, and pre-existing soil conditions also influence soil compaction (Weaver 1978). Seasonal freeze and thaw cycles in Iowa prairies, as well as those in similar climates, act to loosen the soil over time (Reichman 1987), but even within a single year, certain patterns of movement are established, creating localized changes in soil compression (Burden 1972). Previous studies have quantified the effect of soil compression on cultivated cereals (eg. wheat and oats) and show a strong correlation between soil compaction and poor plant development with regard to depressed seed germination (Hegarty 1978), growth (Atwell 1990), and overall biomass (Gupta 1933). We address in our study whether or not this applies to prairie.

Minimizing human effects on the prairie requires an understanding of the effects of human presence on plant life. Our research was twofold: we measured the effect of weight on soil compaction on an area of restored prairie at Conard Environmental Research Area (CERA), and we conducted a greenhouse experiment in which we quantified germination, growth rate, and final biomass of *Andropogon gerardii* (big bluestem) grown in soil of different compaction levels. The response of *A. gerardii* to soil conditions is especially significant, as it is the dominant and distinguishing plant of most tall-grass prairies (Reichman 1987). We hypothesize that repeated footfalls on prairie soil increases its compaction. In addition, we hypothesize that higher soil compaction will inhibit germination, aboveground growth, and belowground growth of *A. gerardii*.

Methods

Greenhouse Study

The greenhouse experiment isolated the effects of soil compaction on plant growth, germination, and root structure. We collected soil from a level, uniform plot of prairie at Connard Environmental Research Area (CERA) located near Kellog, Iowa, and then sterilized it before planting to eliminate seeds, fungi, arthropods, and microorganisms that could affect plant growth. Next, we plated Big Bluestem (*Andropogon gerardii*) seeds, which were collected the previous summer at CERA. We used four plant flats, each divided into 24 pots each (4 pots x 6 pots), for a total of 96 independent pots (measuring 8.5 x 6.0 x 7.0cm). Each pot held five equidistantly planted seeds (in the expectation of 70% germination rate of *A. gerardii* (Henning 1993)). Four different levels of soil compaction were assigned randomly to each pot, measuring 0.5, 1, 2, and 3 Mega pascals (Mpa: tons/ft^2) to span compaction levels that we found to be common in preliminary testing at CERA (1 and 2 Mpa) and two extremes that we found (0.5 and 3 Mpa). For each compaction level, we compressed a previously determined mass of soil into a constant volume. To limit the effect of variables such as light, temperature, and moisture, the pot flats were rotated clockwise every 3 days. All plants were watered equally and exposed to 16hrs of light per day. The air temperature remained a steady 21°C throughout the experiment. We measured plant growth three times per week every 3rd, 5th, and 7th day of the week for the first 19d after planting. At this point, all plants except the centermost individual in each pot were harvested to eliminate the variable of competition among plants, noting aboveground biomass of harvested plants after oven drying at 60°C for 48hrs. After four weeks (Oct 18th-Nov 15th) of growth we measured dry weight and length of both the shoots and roots of the remaining plants. We grouped the plants together according to soil density then oven dried them at 60°C for 48hrs, then we weighed the shoots and roots separately. We used the t-test to compare means of the different levels of compaction for our statistical analysis.

Field Study

We conducted the field portion of our research on various plots at CERA that contain distinct paths that had been consistently compacted by foot and vehicle travel (Adams, 1982). At these areas, we measured the soil compaction using a penetrometer at a randomly determined point on the trampled paths, and then of a visibly untrampled area nearby (within a meter) to keep other variables such as soil type, typography, moisture, etc. consistent.

We also examined the immediate effects of trampling. We randomly selected five points across an undisturbed reconstructed prairie for manipulation and measurement. At these $0.2m^2$ areas we removed the aboveground biomass and then placed a brick with a surface area of $200cm^2$ on the cleared area. 79.4kg (a researcher's bodyweight) was placed on the brick for durations of 1sec, 5sec, 30sec, 1min, and 5min, and the compaction measured after each interval. We analyzed our compaction data using the t-test.

Results

Aboveground Biomass and Shoot Height

Vigor of aboveground biomass of *A. gerardii* decreased significantly as soil compaction increased. According to T-tests, the mean shoot height was significantly greater at 0.5Mpa than 3Mpa ($T = 2.046$; $P = 0.0459$; $n=24$) from four weeks of growth onward (Fig. 1). We took the aboveground biomass measurements of our *A. gerardii* in aggregates, rendering statistical comparison impossible. However, this data fit the trend set by all other data collected that *A. Gerardii* grown in soils of low compaction levels show a greater combined mass than that grown in high compaction levels (0.5Mpa = 0.1765g, 1Mpa = 0.1737g, 2Mpa =

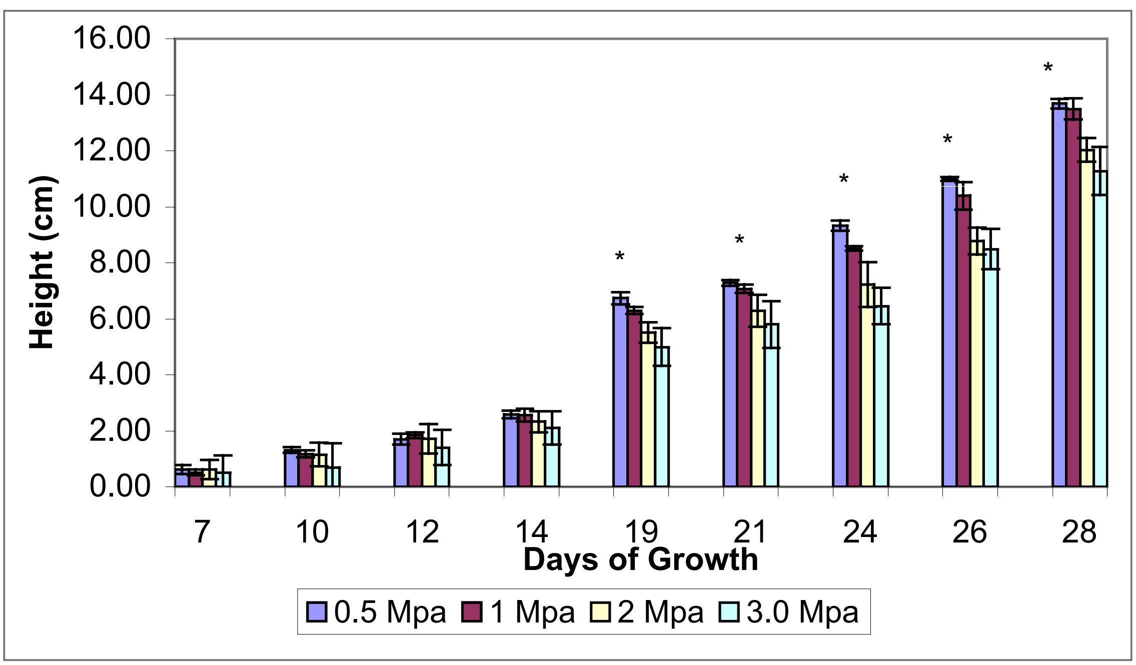

Figure 1. Mean height of *A. gerardii* (± S.E.) for 4 different compaction treatments over 4 weeks (n=24). *p<0.05 between 0.5Mpa and 3Mpa.

0.144g and 3Mpa = 0.1135g; n=1). The mass of plants taken from the 0.5Mpa level was 55% greater than the mass from the 3Mpa level.

Belowground Biomass

We found that higher soil compaction levels resulted in depressed root length, structure, and dry-weight in four week old *A. gerardii*. Root systems in the lower compaction levels were significantly longer and more extensive than those grown in more highly compacted soil, with the exception of a negligible difference between 0.5Mpa and 1Mpa (between 0.5Mpa and 3Mpa: T=6.0554; P=0.000002; n=24) (Fig. 2). We observed that the root structures followed a similar trend: the higher the compaction, the more localized the roots and the less soil volume the roots had accessed. Again, taken in aggregate, the dry-weight of plants grown in low soil compaction after four weeks was greater than that of those grown in high soil compaction; 0.5Mpa soil having 524% more dry-weight than 3Mpa (0.5Mpa=0.0645g, 1Mpa=0.0444g, 2Mpa=0.0178g, 3Mpa=0.0123g).

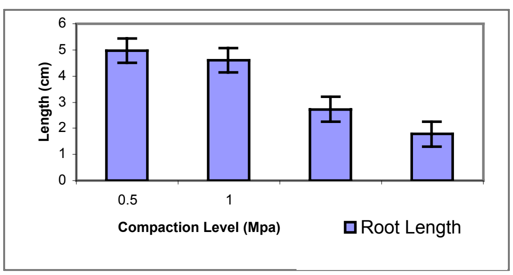

Figure 2. Mean root length (± S.E.) of *A gerardii* for 4 different compaction levels after 28 days of growth (n=24).

Germination

We found an inverse relationship between soil compaction and germination rate. Seven days after planting, 11.7%, 7.5%, 4.2%, and 3.3% (for compactions .5Mpa, 1Mpa, 2Mpa, and 3Mpa respectively) of the plants that would eventually germinate had done so. The overall germination (60.2%) was unaffected by soil compaction (Fig. 3).

The Effects of Trampling on Soil Compaction

In our field research we discovered that trampling increases the immediate soil compaction, and that the longer a specific plot of ground was trampled upon, the more intense the effect. The application of 175 lbs/200cm^2 for 1 second was not statistically significant, but longer periods ranging between 5 seconds and 5 minutes yielded increased soil compaction between 144% and 201% (P=0.054: 0s-1s; P=0.02: 0s-5s; P=0.0000217: 0s-5m; n=5) (Fig. 4).

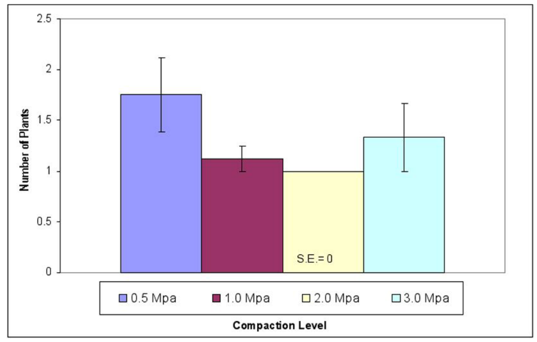

Figure 3. Mean number of *A. gerardii* germinated in the greenhouse (± S.E.) after 7 days of growth for 4 different compaction levels (n=24).

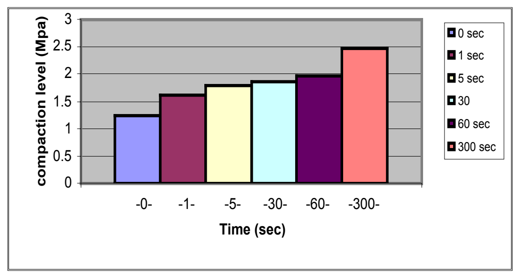

Figure 4. Mean soil compaction of prairie soil in Mpa (± S.E.) after application of 175 lbs/200cm^2 for 6 different in-creasing amounts of time (n=5). *$p<0.05$ between 0s and *s.

Discussion

As hypothesized, we found that increased soil compaction depresses plant vigor both aboveground and belowground. We attribute the height differential to the difficulty root structures have in penetrating the compact soil (Atwell 1990a), thereby decreasing the volume of soil to which the plant has access, and limiting water and nutrient uptake (Atwell 1990b). Denser soils also withhold moisture better, making it more difficult for roots to draw moisture out of the soil (Reichman 1987; Atwell 1990c). Furthermore, denser soil slows germination by impeding the growth of inaugural roots, which are crucial for acquiring the moisture and nutrients needed during early development (Hegarty 1978).

We were unable to perform any statistical tests on the biomass data we collected due to the lack of replication, a consequence of the extremely small masses of our experimental units. However, aboveground, and especially belowground biomass, as suggested by shoot and root length, decreased markedly as the compaction level increased.

The results of our fieldwork show a direct correlation between soil compaction and the duration of an applied static weight. While the dynamics of actual trampling are different than our experimental method (e.g. irregularities on the sole of a shoe, kinesthetic variables, brief impacts of each footfall rather than sustained weight), we believe our method best replicates the effects of the trampling process that usually occurs over a long period of time and includes many variables (Burden 1972).

More comprehensive long-term field and greenhouse experiments would strengthen our findings and better consider the total effects of trampling. A field study of a trampled prairie's recovery could consider factors such as increased dead ground cover, the recovery of pre-established flora, the effects in relation to topography, and the time needed for recovery (Weaver 1978). Harvesting the greenhouse plants when fully grown would more accurately demonstrate the total effects of increased soil compaction and assure that they are indeed substantial and not just slowed as with plant germination. We believe that our results, and the results of future research on this topic, should be considered anytime research or entertainment involves trampling.

Acknowledgments

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