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PLANT GROWTH IN SOILS FROM SNOWDRIFT VS. ADJACENT DRIFTLESS MEADOW SITES

ABSTRACT

Soils from snowdrift sites may be leached of nutrients and thus support less plant production than soils from otherwise similar sites. In greenhouse experiments designed to test this hypothesis, biomasses of plants grown in soils from drift sites were 3-5 percent less than plants grown in soils from adjacent normal-pack sites. While the differences were statistically significant, it is unlikely that the large differences in vegetation between drift and driftless sites seen in the field are caused by leaching.

Keywords: Leaching, fertility, snow drift, mountain meadows, *Festuca idahoensis*.

INTRODUCTION

Snow deposits in mountain meadows of the Bangtail Range (Bozeman, MT) range from slight on windswept sites to considerable under large drifts. Vegetation differs relatively little between windswept (<0.5m of snow) and normal (<1m) sites. But vegetation of heavily drifted sites (>2m) is distinct (Weaver 1974): species composition is almost completely different and production is less. Comparable snow effects are reported from Colorado (Webber et al. 1976), Utah (Harper 1981) and Wyoming (Knight 1975).

We consider four factors as possible reasons for snow effects on vegetation. 1) Soil water. While water deposited on drift sites is five or more times greater than on normal sites (Weaver 1974), we expect little difference in community water relations. Water availability on drift sites does not exceed that of driftless sites with similar soils, however, because water storage is determined by the water holding capacity of the profile and excesses run through or off (Buchanan 1972, Weaver and Collins 1977). Differences in flooding are also unlikely, because the soils are loamy and well-drained (Buchanan 1972). 2) Compaction. Soils of drift sites are more compact than those of non-drift sites (Weaver 1974 and Weaver and Collins 1977). Plant growth in compacted soils is significantly reduced, but the effect of compaction is too small to explain the large differences in vegetation observed (McNeal and Weaver 1982). 3) Leaching. Presumably, large flows of melt-water through soils of drift sites are responsible for lowered nutrient levels on long-affected sites (Table 1) (Weaver 1974) and, even, on sites affected for as few as five years (Weaver and Collins 1977). Plant growth in soils of these sites should be contrasted to determine if nutrient reductions are sufficient to account for vegetation differences. 4) Seasonality. Relative to plants on a drift site, plants on a driftless site a) initiate growth earlier and under cooler shorter-day conditions, b) cease growth earlier due to earlier exhaustion of water, and c) have a longer growing season because their water is used under cooler less

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Table 1. *Snowdrift effects on soil density (gm/cc), soil chemistry (ppm) and the nutrient supplying capacity of soils (gm plant/kg soil). Means are given with their standard errors. Depth (Weaver 1974), density (McNeal and Weaver 1982), and chemistry (Weaver 1974 and Weaver and Collins 1977) are summarized from earlier work. The phytometer analysis (gm/kg) is new.*

		Control	Drift
Snow depth (dm)		<2	>24
Soil density (gm/cc)		0.9 ± 0.2	1.27 ± 0.2
Soil chemistry/physics			
pH	natural drift	5.8	5.3
	snowfence	6.2 ± 0.1	6.0 ± 0.0
Conductivity (mmhos)	natural drift	0.6 ± 0.1	0.5 ± 0.1
	snowfence	0.4 ± 0.1	0.2 ± 0.0
Mg (ppm)	natural drift	878 ± 69	617 ± 43
	snowfence	461 ± 20	434 ± 8
K (ppm)	natural drift	875 ± 94	892 ± 30
	snowfence	553 ± 20	435 ± 9
Na (ppm)	natural drift	100 ± 7	98 ± 9
	snowfence	76 ± 4	64 ± 4
NO_3 (ppm)	natural drift	0.7 ± 1	0.5 ± 1
	snowfence	1.7 ± 0.2	2.1 ± 0.1
NH_4 (ppm)	snowfence	29 ± 25	26 ± 7
OM (%)	natural drift	4.8 ± 0.2	4.7 ± 0.0
	snowfence	6.0 ± 0.2	5.7 ± 0.1
P (ppm)	natural drift	54 ± 7	84 ± 7
	snowfence	16 ± 1	21 ± 2
Resource supplying capacity			
Wheat (gm/kg[1])	natural drift	50 ± 2	47 ± 0
	snowfence	52 ± 2	51 ± 1
Corn (gm/kg[1])	natural drift	52 ± 2	51 ± 1
	snowfence	53 ± 2	50 ± 1

[1] Gm plant/kg soil. The actual measurement, based on 489 gm soil, was multiplied by 2.045 to give gm/kg.

evaporative conditions (Weaver and Collins 1977). Such differences could select for different species on drift and non-drift sites.

The following experiments were designed to determine whether differences in soils of driftless and drift sites might be responsible for the differences in vegetation observed on them. While we hypothesize effects due to leaching of nutrients, it is not our object to distinguish leaching effects from other snow induced developmental changes, such as clay movement leading to changes in texture and classification.

METHODS

We conducted two experiments designed to determine if differences in soil qualities might account for differences in plant production that might, in turn, explain differences in vegetation between snow drift and driftless sites. Our general strategy, elaborated below, was to collect soils from drift and driftless sites, grow plants in them, and compare yields (gm plant/kg soil). Soil qualities were tested with plants, phytometers, (Weaver and Clements 1938) because plants integrate influences across nutrients better than previously made chemical analyses and may incorporate influences not measured in standard soil tests. The test plants were wheat (*Triticum aestivum* var pondera) and corn (*Zea mays* var Pioneer hybrid 3540). They were chosen because they were easily available, grow rapidly, are well adapted to greenhouse conditions, and, as grasses, may represent the dominants of the meadow flora.

The meadow sites studied were both located near the Bangtail Station, Bangtail Range, Bozeman, Montana (T1S, R6E,Sec 6). The first experiment focused on a line of trees that created a natural snowfence (Billings 1969) approximately 2 km south of the station. Drifting and leaching differences have occurred upwind and downwind from the tree line for over 100 years and, thus soil conditions may be approaching equilibrium. Along this natural snow fence site, six pairs of samples were collected with one unit taken in the drift and one upwind of it. Each sample consisted of dozens of rectangular cores, approximately 3 cm x 15 cm x 15 cm deep, taken at 1 m intervals on lines parallel to the fence. The total volume of each sample exceeded 20 liters.

The second experiment was started in 1969, when five snowfences (30 m x 2.5 m) were installed parallel to each other and perpendicular to the prevailing wind to create a 30 x 30 m drift (Weaver and Collins 1977). In comparison with the natural drift (Experiment I), the soil development (leaching) period in Experiment II was shorter (27 years). Thus, soil differences were less (Table 1) (Weaver 1974, McNeal and Weaver 1982), and conditions were likely non-equilibrium. Soils under the 30 m drift were collected on lines parallel to and between fences. Soils that were comparable, but not influenced by the drift, were collected on lateral extensions of the transects in locations to the side of the drifted area.

Soils from the natural drift, 'equilibrium', site were used to compare soils from long established drift and driftless areas. Details of the analysis follow: 1) Soils from the first site (Expt Ia) were dried and sieved immediately after collection. 2) Thirty-six 10 cm pots were filled with soil, half (6 samples x 3 pseudo-replications) from the drifted area and half from the driftless area. Because nutrient supply is proportional to soil weight, a uniform quantity (489 gm) of soil was put in each pot. 3) Wheat was planted in each pot. A template with 3 cm prongs created four identical holes in moistened soils. Two seeds were planted in each hole and, on germination, the weaker seedling was cut. 4) Pots were arranged in a 12 x 3 matrix on the bench. The first row contained alternating samples from drift and driftless subsites, starting with a driftless sample. The third row was identically arranged, the second row differed in starting with a drift sample. 5) Plants were grown under warm well-watered greenhouse conditions to eliminate differences in environmental conditions other than those due to soil. 6) They were harvested after flowering, fruiting, and partial drying. The wheat grew 130 days (18 Jan-8 May 1997). They were then pressed, dried, and weighed. Each of the 12 samples included twelve plants: four per pot over three replicate pots. The first pooling guaranteed that

nutrient extraction from each pot was maximized and that use was averaged among plants. The second maximized uniformity of environment while avoiding pseudo-replication.
7) Treatments were contrasted with a t-test on the advice of the MSU Statistician, W Quimby.

The first experiment was repeated with a second species, field corn (Expt 1b, 2 treatments x 6 reps x 3 pseudo-reps). This experiment was identical except for species, location of pots on the bench, and the growth period. The growth period was 95 days (13 Feb-18 May 1997). Because of these differences, we compared performance in the two soils with a second t-test.

Soils from the non-equilibrium snowfence site (Expt 2) were used to compare soils from drift and driftless areas established for only 27 years. In this analysis (Expt 2a), wheat phytometers were used to contrast the soils with procedures very similar to those described above. A different field site was sampled. Four, rather than six, samples were taken in each treatment area, 2 treatments x 4 reps x 3 pseudo-reps. A different bench site was used. The same time period of 130 days was used (18 Jan-8May 1997). Processing and analysis were identical.

The preceding experiment was repeated with a second species, corn (Expt 2b). Thus, it was identical to experiment 2a (2 treatments x 4 reps x 3 pseudo-reps), except for species, bench location, and duration of growth, 95 days, (13 Feb-18 May 1997).

Chemical analyses of these soils were made by the MSU Soil Testing Lab and published earlier (Weaver 1974, Weaver and Collins 1977). The data are repeated in Table 1 to provide a context for our evaluation of the differences measured with phytometers (Weaver and Clements 1938).

RESULTS AND DISCUSSION

Soils from drift sites have lower nutrient concentrations than those from sites with normal packs (Table 1), presumably due to leaching. This is true whether the drift is ancient (Weaver 1974) or only five years old (Weaver and Collins 1977). Integrative indicators (pH and conductivity) and most individual ions (Mg, K, Na, NH_4) decline with the presumptive leaching and decline more on sites leached for more years. That the transport is not entirely simple is shown by phosphorous: instead of falling, its concentration rises on drift sites, probably because phosphorus is imported on blowing clays or organic matter.

We hypothesized correctly that plants grown in soils from 'low nutrient' drift sites will produce less than those grown in soils from driftless, unleached, sites. On the 'equilibrium' site, wheat plants growing on the leached portion weighed 4.5 percent less than those growing on the driftless portion (p<5 percent) And corn plants growing on the leached portion were 1.8 percent lighter (p<5 percent). A similar pattern was observed on the 'artificial' site snowfenced for 27 years. Wheat plants growing on the leached portion were 3.3 percent lighter than those growing on the normal portion (p> 5 percent). And corn plants growing on the leached portion were 5.4 percent lighter (p< 5 percent).

Our test was made with wheat and corn rather than the native grasses which decline (*Festuca idahoensis* and *Danthonia intermedia*) or increase (*Bromus ciliatus* and *Agropyron caninum*) on drift sites (Weaver 1974, Weaver and Collins 1977). While the natives might have been more appropriate subjects, we used exotics because we expected them to give a more rapid, certain, and robust response. The responses of grasses were parallel, wheat produced 6.2 percent less than corn on drift sites (p<5 percent) and 5.4 percent less than corn on driftless sites (p<5 percent). The fact that these very different grasses behaved similarly suggests that the responses of native grasses to nutrient differences would also be similar.

Despite the phytometer response, it seems unlikely that the large differences in vegetation on normal and drift sites (Weaver 1974) are due to lack of nutrients on drift sites. There are consistent differences in nutrient availability, estimated by chemical tests, but these differences are small (Table 1) (Weaver 1974, Weaver and Collins 1977). Plant responses correlated with such nutrient differences are statistically significant, but small. Thus, leaching cannot be the primary cause because the yield deficiency of drift site soils, as observed in experiments isolating the fertility factor, is small (Table 1), compared with yield deficiencies observed on natural drift sites greater than 60 percent (Weaver 1974).

Interaction of nutrient differences and another edaphic factor with small significant effects (compaction, McNeal and Weaver 1982), doesn't explain the observed yield differences, but it may contribute to differences in community composition on drift and non-drift sites. Consider two models. First, if roots of a grass penetrate compacted soils poorly (McNeal and Weaver 1982), compaction is expected to reduce access to nutrients and reduce yields. Second, if roots of another species penetrate compacted and uncompacted soils to equal depths, compaction by 20 percent (McNeal and Weaver 1982) will provide access to 20 percent more nutrients and 20 percent more production. Thus, compaction might increase or decrease yields, but in neither case to the extent seen on natural sites, >60 percent, (Weaver 1974). On the other hand, differences in vegetation composition on drift and driftless sites not described here (Weaver 1974, Weaver and Collins 1977) may be determined partially by compaction influenced competition for nutrients.

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