

EFFECTS OF FERTILIZER ON ROOT STRENGTH OF SHERMAN BIG BLUEGRASS (*Poa ampla* Merr.)¹

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ABSTRACT

Pulling of plants by grazing animals has been a common problem on 'Sherman' big bluegrass (*Poa ampla* Merr.) pastures in Colorado. Fertilizers were applied to individual plants in a greenhouse study to evaluate their influence on plant resistance to pullup. The fertilizer treatments were 56 kg/ha N, 56 kg/ha P, or 56 kg/ha of each element as an N+P combination. Fertilizer treatments were applied to vernalized and nonvernalized plants grown in two soils.

Tensions required for pullup in the greenhouse were correlated with total root weight ($r = .75^{**}$) and significantly increased with N fertilization. Plants fertilized with N produced more vegetative and reproductive shoots, tillers, foliage weight, and root system weight and length. Phosphorus fertilization produced a significant increase in vegetative and reproductive shoots, and a significant interaction between N and P was found for root system size and the amount of roots that were pulled from the soil with the plants.

Additional index words: N, P, and N+P fertilization, Total plant yield, Root and top development.

'SHERMAN' big bluegrass (*Poa ampla* Merr.), a long-lived native bunchgrass of the Pacific Northwest, is well adapted to the Rocky Mountain and Intermountain regions and is a valuable forage grass for supplementing native range in fall and winter. In Colorado this species retains green leaf tissue during the winter and provides green herbage when other plants are dormant. Unfortunately, big bluegrass pasture productivity and value are often reduced when plants are pulled up by grazing animals.

The phenomenon of pullup has been reported by several authors from various geographic locations in the United States (1, 3, 4). The period for pullup and the number of years that pullup persists varies by location. At the Manitou Experimental Forest, Colo., cattle pulled up big bluegrass for more than 5 years after pastures were seeded, but in Oregon, pullup lasted about 2 years after seeding. Preliminary field investigations in Colorado have shown pullup of big bluegrass can be decreased substantially by the addition of commercial fertilizers.³

The objective of this study was to investigate whether soil fertilization under greenhouse conditions affects root and foliage growth and, thereby alters resistance to pullup.

MATERIALS AND METHODS

The study was conducted under greenhouse conditions at Fort Collins, Colo., with soils and plants collected from 2-year-

old pastures of Sherman big bluegrass at the Manitou Experimental Forest. The Forest is located 45.1 km northwest of Colorado Springs, Colo., at an elevation of 2,400 m. Soils in the area were formed on alluvial deposits derived from Pikes Peak granite.

Soil was collected 18 months before the greenhouse work started, and again in 1967 just prior to planting. All soil was air-dried and screened. Due to changes that may have occurred in storage, a check on the soil used was designed into the study and data were analyzed accordingly. A mixture of soil from that stored in 1966 and the nonstored 1967 soil collection was uniformly packed in two separate compartments of 24 glass-faced wooden boxes. The mixture was referred to as stored soil in the results. Nonstored soil was uniformly packed into both compartments of the remaining 24 boxes.

One group of 2-year-old plants, collected before onset of frost in the fall, was transplanted into containers taken directly to the greenhouse, where they were kept for 109 days; another group of plants was placed in containers and left outside to be vernalized. The vernalized plants were subjected to an average high of +23.5 C and an average low of -5.5 C for the 109-day period. Growth was not recorded until the plants were transplanted to the boxes. The diurnal temperature regime of the greenhouse was 16 hours at 21 C and 8 hours at 4.5 C. Relative humidity was increased to approximately 80% at night by spraying water on the greenhouse floor. Equal amounts of water were added to each compartment of a box as the surface soil began to dry.

Prior to planting in the boxes, whole plants from each group were broken into plant segments that measured approximately 3 cm in diameter at the crown. Foliage and roots of each plant segment were uniformly clipped to 5- and 10-cm lengths, respectively. One segment from each group was then randomly planted in each box.

Four treatments were applied to the vernalized and nonvernalized plants in the boxes: Control (no N or P), 56 kg/ha N, 56 kg/ha P, and both N+P, each at the 56 kg/ha rate. We applied the fertilizers as water solutions of ammonium nitrate (33.5 - 0 - 0) and suspensions of treble superphosphate (0 - 46 - 0).

The experimental design was a $2 \times 4 \times 2$ factorial experiment in a split plot with six replications. Measurements shown in Table 1 were analyzed statistically. Tillers were counted three times, and all other measurements were made once. All reference to time was with respect to days from the beginning of the study.

Tension required to pull plants was measured with a dynamometer, an instrument used to measure power (Fig. 1), when most root systems had reached the bottom of the box compartments. A tripod was set so the dynamometer was suspended directly above the plant being pulled. A wooden clamp-type pants hanger was clamped to the foliage 5 cm above the crown. A C-clamp was used to further tighten the hanger's wooden slats to prevent slippage. An even pulling force was then exerted. The force required to lift the plants was registered on the maximum tension needle of the dynamometer. All tension measurements were made when soil moisture was near field capacity.

The root system of each pulled plant was placed on a screen and washed free of rocks and soil. Roots still attached to the crown were clipped at their base and kept separate from those remaining in the planter box.

Root system lengths were estimated on three replications of plants by the method described by Newman (5). From the root length estimates and root weight measurements, a regression equation was derived to estimate root lengths from the root weights of the three remaining replications. Root length estimates were then analyzed by automatic data processing.

Table 1. Criteria used to evaluate characteristics of big bluegrass plants in planter boxes under different soil, vernalization, and fertilizer treatments.

Item and units	Sampling period, days	Criteria
Tension, kg.	98	Severance from soil column
Reproductive shoots, no.	98	Evidence of internode elongation
Vegetative and reproductive shoots, no.	98	Shoots over 5 cm long
Tillers, no.	4-37-98	New tillers counted, those not clipped
		Initially and with no internode elongation
Foliage weight, g	98	Oven dried, 100-105° C, 24 hours
Root weight, g	98	Oven dried, 100-105° C, 24 hours

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Fig. 1. Apparatus for measuring tension required to pull big bluegrass.

RESULTS AND DISCUSSION

Tensions required to break root systems were positively correlated ($r = 0.75^{**}$) with weight of roots. Also, root weight was correlated ($r = 0.63^{**}$) with number of shoots.

Tensions required for pullup were significantly increased by N fertilization (Table 2). A significant interaction between N and P was found for the weight of roots attached to the plants when pulled from the soil (Table 2). Phosphorus alone did not change the amount of roots pulled compared to the check plants, but N+P resulted in more roots attached to pulled plants than when N alone was applied. Roots on plants that received both N and P seemed stronger near the base of the plant than check plants, although apparently no larger.

Proportion of reproductive shoots was not closely correlated with tensions required to pull plants. Plants in the field in Oregon (2) usually produced a larger proportion of reproductive shoots than did our plants in the greenhouse. The smaller proportion of reproductive shoots in our greenhouse study were possibly produced by the cold treatment or the root pruning and may have affected the lack of relationship between the two studies.

Tensions required to pull unfertilized plants in the field averaged 14.8 kg, which was 4 kg lower than the tension value measured in the greenhouse.³ Possibly differences in environmental conditions, fertilizer or other factors favored the greenhouse plants over the field plants. The fact that the tensions varied for the unfertilized plants suggest an interaction of factors not explainable with the present data. The number of tillers and shoots and total foliage weights was increased by N fertilization (Table 2). A significant interaction between N and P was found for root system weights and total lengths. In the greenhouse the added boost to root production provided by the N and P, compared to those elements alone, did not significantly increase the tensions required to pull those plants compared to those treated by N alone. In field trials, however, an N-P interaction was found that

Table 2. Effects of N, P, and NP interaction, vernalization, and soil storage on growth and development characteristics of greenhouse-grown big bluegrass plants.

Characteristics	Fertilizers				Vernalization		Soils	
	Control	Main effect		Inter-action	Control	Main effect	Control	Main effect
		None	N+			Vernalized		Stored
Pull-up tension (greenhouse), kg	18.8	3.6†	1.6	0.9	19.4	3.2†	20.1	1.8
Vegetative & reproductive shoots	74	19**	5†	5	72	16**	75	16*
No. tillers	58	15*	3	4	60	10*	58	14**
No. reproductive shoots	3	1	0	0	2	3**	3	1
Reproductive shoots in relation to total shoots, %	4.1	0.5	-0.5	0.45	2.1	3.4*	3.7	0.2
Foliage weight, g	11.8	1.4†	0.6	1.4	9.9	4.3*	11.3	1.5*
Root weight, g	2.7	0.6†	0.3	0.3	2.7	0.6*	3.0	0.0
Foliage weight-root weight ratio	4.6	-0.2	-0.4	0.0	4.2	0.2	4.1	0.4
Pulled root weight, g	0.7	0.1	0.0	0.1*	0.7	0.1	0.7	0.0
Total root system length, m	604.7	74.8†	34.1	39.3†	604.0	71.1*	643.8	-8.5

Significant increases: .01**, .05*, and .10† levels respectively. Significant levels based on breakdown of pooled error mean square for respective treatment.

+ $(N_1P_0 + N_0P_1) - (N_0P_0 + N_0P_0)$ ++ $(N_0P_1 + N_1P_1) - (N_0P_0 + N_0P_0)$

+++ $(N_0P_2 + N_1P_1) - (N_0P_0 + N_0P_1)$

increased tension 5.0 kg over those recorded for the single fertilizer applications.³

Foliage characteristics, that is, proportion of reproductive shoots, number of shoots and tillers, foliage weight, and basal area, were all significantly increased by the vernalization treatment (Table 2). The foliage weight:root weight ratio was the only characteristic where the difference was not significant. Also, there was a significant interaction between nitrogen and vernalization for some characteristics. Number and proportion of reproductive shoots, total number of shoots and tillers, foliage weight, pulled root weight, and total root system length, all showed a greater response to N for plants which had been vernalized. These results suggest that cold stratification is probably needed annually for the highest yields in the presence of fertilizer. They also confirmed the suggestion of Hyder and Sneva (2) that big bluegrass needs cold stratification for initiating reproductive shoots.

The two soils effects were analyzed because bacterial action may have changed the chemical composition during the storage period. The data indicated storage of soil did have an effect on plant growth and the development response to treatments (Table 2). Foliage weights, total number of shoots, and tillers on plants were significantly greater when grown in boxes containing stored soil. We also found a significant N-soil interaction for number and proportion of reproductive shoots, number of tillers, and basal area. In each case, N addition produced the largest response on the new soil. Soil storage did appear to change the nutrient status of the soil.

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