1989

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Abstract. Propagating and developing plants for successful transplanting will be important for the recovery of Nebraska's only endangered plant species, blowout penstemon (*Penstemon haydenii* S. Wats.). Therefore, the effect of various cultural treatments on seedling growth was examined in a greenhouse study. Young blowout penstemon seedlings, fertilized with both nitrogen and phosphorus, exhibited significantly greater weekly growth rates than seedlings fertilized with one or no nutrient. After removal of the upper part of the shoot to the third pair of true leaves, only those seedlings fertilized with both nutrients exhibited a temporary increase in weekly growth rate and more axillary shoots.

Key Words. blowout penstemon, *Penstemon haydenii*, endangered, propagation, fertilization, growth rate, Sandhills, Nebraska

INTRODUCTION

Blowout penstemon (*Penstemon haydenii* S. Wats.) is Nebraska's only officially endangered plant species (Nebraska Game and Parks Commission 1986). This perennial, multistemmed forb occurs naturally in only a few blowouts in the Nebraska Sandhills (Weedon *et al.* 1982a). Blowout penstemon is successional in nature, colonizing the blowout just after the sand has physically stabilized and declining when vegetation has become well established (Weedon *et al.* 1982b).

Blowout penstemon was once a common plant in blowouts (Pool 1914). However it was thought to be extinct from 1940 until it was rediscovered in 1968 (Stubbendieck *et al.* 1983). Since that time, extensive searching has led to the rediscovery of fewer than 4250 plants. The reasons for its decline from being a common plant in the early 1900's to its current population are unknown. With wildfire control and improved range management practices, the amount of Sandhills blowout habitat has greatly decreased (Stubbendieck *et al.* 1982b). Also, the drought of the 1930's severely reduced or influenced numerous prairie plant species (Weaver 1954), and it may also have had a negative influence on blowout penstemon (Stubbendieck 1986).

Even though blowout penstemon is protected by law (Fish and Wildlife Service 1987), its continued existence is not assured. Large fluctuations in plant numbers have been noted from one year to the next (Stubbendieck and Weedon 1984).

Blowout penstemon primarily reproduces by rhizomes, and naturally occurring seedlings are relatively rare (Stubbendieck *et al.* 1983, Stubbendieck and Weedon 1984). The supply of blowout penstemon seed is limited, and germination rates are also low (Weedon *et al.* 1982a, Stubbendieck *et al.* 1982a, 1982b; Stubbendieck *et al.* 1983, Stubbendieck and Weedon 1984). Researchers have been able to increase germination to over 90% through a combination of scarification and removal of soluble inhibitors (Stubbendieck *et al.* 1982a, Stubbendieck *et al.* 1983, Stubbendieck and Weedon 1984). Once hand-scarification techniques were found to enhance germination, efforts were made to determine proper methods of producing healthy transplants (Stubbendieck *et al.* 1982a, Stubbendieck *et al.* 1983, Stubbendieck and Weedon 1984). These researchers have shown it was best to grow seedlings in seedling tubes in the greenhouse and to transplant them outside in mid-May. Seedlings also did not tolerate heavy watering and were initially subject to damping-off, a fungal disease. Therefore, the effect of various cultural treatments on the growth of blowout penstemon seedlings was examined in a greenhouse study.

METHODS

Blowout penstemon seeds were collected in August 1986 from plants growing in Garden County, Nebraska. Seeds were separated from fruiting stalks, separated in an air column into heavy and light fractions, and stored at 3-4 C in plastic vials. Only heavy seeds were used in this study, within six months after harvest.

In January 1987, blowout penstemon seeds were soaked in a nylon bag under running tap water for 24 hours to remove soluble germination inhibitors (Stubbendieck *et al.* 1982a). Seeds were then hand-scarified by removing the seed coat at the root end of the seed using a razor blade with the help of a dissecting microscope. Hand-scarified seeds were immediately planted at a depth of 1 cm in seedling tubes (four per tube) containing pure, steamed (120 C, 120 min) river sand. Seedlings which emerged within one to two weeks received 14 hours of continuous supplemental light daily. Greenhouse temperatures ranged between 20-30 C. Seedlings were watered as needed and sprayed with a combination fungicide/insecticide weekly.

Blowout penstemon seedlings having two pairs of true leaves were given 0, 75, or 150 ppm of nitrogen and/or phosphorus weekly (Table 1). Those plants fertilized with both nitrogen and phosphorus received 10 ml of 0.26 molar or 0.52 molar $Ca(NO_3)_2$ solution and 10 ml of 0.24 or 0.48 molar NaH_2PO_4 solution. Seedlings fertilized with only one nutrient received an additional 10 ml of distilled water. Those plants not fertilized received 20 ml of distilled water only. Thus, all seedlings received an equal amount of solution (fertilizer and/or distilled water) at each fertilization to eliminate the effect of additional moisture on growth. One-half of these seedlings were pinched back to the third pair of true leaves using a razor blade, after the ninth week of the study had passed. Pinching was done to stimulate growth and number of axillary breaks, or shoots, emerging from the axils of leaves.

Table 1. Amount of phosphorus and/or nitrogen (ppm) applied per treatment.

Treatment	*Phosphorus*	*Nitrogen*
	---------- ppm ----------	
1	0	0
2	75	0
3	150	0
4	0	75
5	0	150
6	75	75
7	150	75
8	75	150
9	150	150

Each of the 18 treatments was replicated five times in a randomized complete block design. The experimental unit consisted of a group of three blowout penstemon seedlings of similar height and two pairs of true leaves.

Plant height was measured weekly from the cotyledonary node to the tip of the longest leaf. After the pinching date, the height of pinched plants was measured from the "pinching point" to the tip of the longest leaf of a shoot emerging from an axil just below this point. Height data were used to calculate growth rate, in cm per week. The average weekly growth rate per treatment was computed as the mean of 15 (five replications with three plants per replication) weekly growth rates. The number of new axillary breaks per plant was recorded weekly after the pinching date. The study was terminated after its 14th week.

Repeated measures analysis of variance was used to detect overall differences among treatments, and over weeks, for weekly growth rate. Treatment differences over weeks were evaluated using Wilks' criterion test statistic. Preplanned contrasts were used to compare individual treatment means (Steel and Torrie 1980). Univariate analysis of variance (ANOVA) on final number of new axillary breaks was performed to partition the variance into main effects and interactions between the factors (Steel and Torrie 1980).

DISCUSSION

Before pinching, average weekly growth rates of nonpinched and "to-be-pinched" young blowout penstemon seedlings were not significantly different ($p = 0.45$). Thus, these "before pinching" growth rates were pooled for further statistical analysis.

Generally, before pinching, average weekly growth rates of blowout penstemon seedlings increased to a point and then declined (Figure 1). Also, the seedlings fell into two distinct groups. The group of seedlings exhibiting higher weekly growth rates were fertilized with both nitrogen and phosphorus. These seedlings exhibited the highest average weekly growth rates in weeks 4 and 5 (Figure 1). The second group of seedlings were fertilized with one nutrient only, or no nutrient. These seedlings exhibited low, stable weekly growth rates (Figure 1).

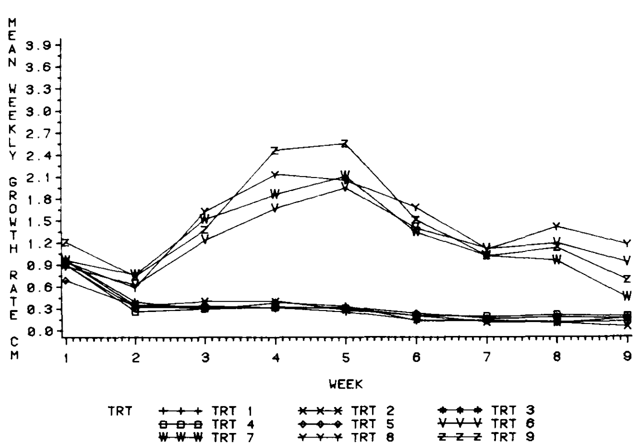

FIG. 1. Effect of treatment on average weekly growth rate of blowout penstemon seedlings before pinching. Treatments 6 through 9 involved the application of both nitrogen and phosphorus; treatments 1 through 5 involved the application of either nutrient, or no nutrient.

Thus, before pinching, nitrogen and phosphorus fertilization interacted to enhance the growth rate of blowout penstemon seedlings, although the nature of this interaction differed weekly ($p < 0.01$). Treatments involving the application of both nutrients enhanced the weekly growth rate to a greater degree than those treatments which involved the application of one or no nutrient ($p < 0.01$).

After the pinching date, average weekly growth rates of nonpinched plants were low and did not change over time (Figure 2). Also, the seedlings did not fall into two distinct groups. However, average weekly growth rates of pinched plants were similar to those exhibited before the pinching date (Figure 3). Weekly growth rates of pinched plants generally increased to a point and then declined, and the pinched seedlings fell into two distinct groups. Pinched seedlings fertilized with both nutrients exhibited the highest weekly growth rates in week 12 and the lowest in week 10, just after pinching (Figure 3). Pinched seedlings not fertilized or fertilized with one nutrient exhibited low, stable weekly growth rates (Figure 3).

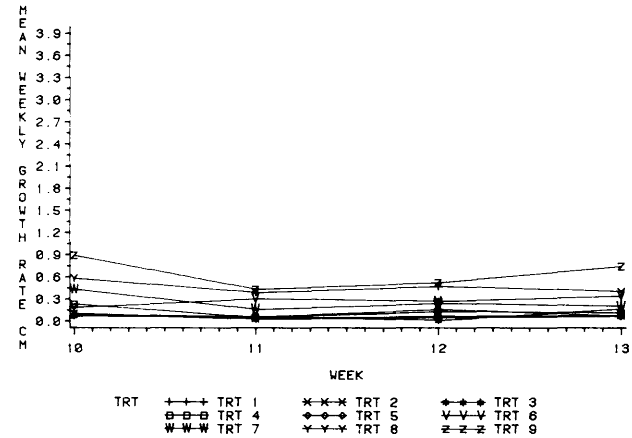

FIG. 2. Effect of treatment on average weekly growth rate of nonpinched blowout penstemon seedlings. Treatments 6 through 9 involved the application of both nitrogen and phosphorus; treatments 1 through 5 involved the application of either nutrient, or no nutrient.

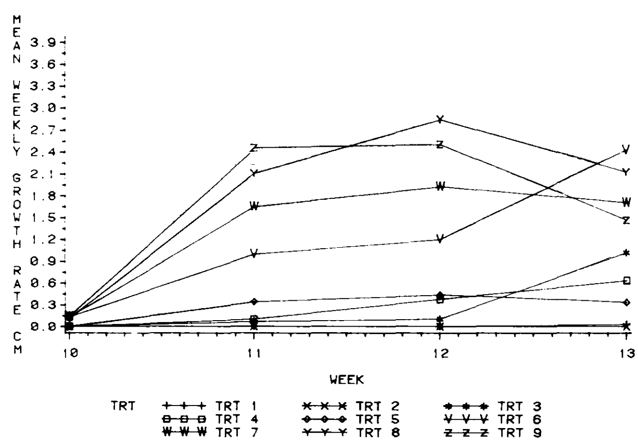

FIG. 3. Effect of treatment on average weekly growth rate of pinched blowout penstemon seedlings. Treatments 6 through 9 involved the application of both nitrogen and phosphorus; treatments 1 through 5 involved the application of either nutrient, or no nutrient.

Thus, after pinching, nitrogen and phosphorus fertilization increased weekly growth rates of pinched plants only ($p = 0.02$), although this increase was short-lived. Treatments involving the application of both nutrients enhanced weekly growth rates of pinched plants to a greater degree than those involving the application of one or no nutrient ($p < 0.01$).

Pinching had no effect on number of axillary breaks produced, over all levels of nitrogen and phosphorus fertilization ($p = 0.38$)

(Table 2). Those plants fertilized with both nutrients produced more breaks than those fertilized with one or no nutrient (p= 0.11). Perhaps the age of the seedling as well as its nutrient status primarily determined the total number of axillary breaks produced, rather than a pinching treatment.

Table 2. Effect of pinching and level of nitrogen and phosphorus fertilization on mean total number of axillary breaks per seedling formed after the pinching date.

Fertilization Level	*Nonpinched*	*Pinched*
	number of axillary ------------ breaks/seedling ------------	
None	1.1	1.3
One nutrient, N or P	1.9	1.8
Both N and P	3.3	3.7
OVERALL	2.1	2.3

CONCLUSIONS

Nitrogen and phosphorus fertilization may be used to produce vigorous blowout penstemon seedlings in the greenhouse, when seedlings are grown on river sand. Pinching fertilized plants just prior to transplanting outside may be desirable to stimulate growth. These production methods could be used in the recovery and reestablishment of blowout penstemon, Nebraska's only endangered plant species.

ACKNOWLEDGEMENTS

Appreciation is expressed to the Nebraska Game and Parks Commission for financial support of the research on blowout penstemon. Journal Series Number 8412, Agricultural Research Division, University of Nebraska.

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