Bjugstad, Ardell J.; Whitman, Warren C. Perennial forbs for wildlife habitat restoration on mined lands in the northern Great Plains, In: Proceedings of the Annual Conference of the Western Association of Fish and Wildlife Agencies. July 18-22, 1982, Las Vegas, Nevada: 622 p.

PERENNIAL FORBS FOR WILDLIFE HABITAT RESTORATION ON MINED LANDS IN THE NORTHERN GREAT PLAINS

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Abstract - Research was designed to assess the establishment and growth potential of 30 perennial forbs by seeding and/or transplanting them on coal mine spoil materials over a 2-year period. Five species showed exceptional emergence and vigorous growth from direct seeding. Six species showed vigorous growth with the use of transplanted plants. Seeding resulted in successful stands of most forbs on coal mine spoil material.

Introduction

Plans for reclamation of strip-mined land may require that the native vegetation be restored for purposes of controlling erosion, enhancing rangeland and wildlife values, increasing recreational opportunities, or for fulfilling the needs of proposed future land use plans, especially those related to livestock grazing operations. In North Dakota and elsewhere in the northern Great Plains, attention has been given to the restoration of mine spoils with native grasses, but little or no attention has been directed to the restoration of the forbs. Forbs (native broad-leaved herbaceous plants) are an integral part of the grassland of the northern Great Plains, usually making up 10 percent or more of the total production on vegetation types subjected to normal grazing use (Whitman and Hanson, 1939). Grassland forbs are important for furnishing dietary variety, cover, and seeds for granivorous animals.

In previous revegetation studies the forb component of grasslands was not readily established (Ferguson and Monsen, 1974). Furthermore, it was found that sources of forb seeds or forb seedlings for use in revegetating mined land was very limited or nonexistent. In addition it was apparent that the problems of the development of cultural practices and site conditions conducive to the establishment of native forbs on mine spoil materials had not been studied.

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The objectives of this study, conducted at the Dickinson Experiment Station in southwestern North Dakota, were to (1) collect seeds of native forbs that might be useful in the reclamation of mined lands; (2) determine how to propagate these species; and (3) test the adaptation of these forbs to mined land under actual field conditions. Seedling germination, establishment of field-sown seed, and growth of containerized seedlings of forb species for transplanting to mine spoil material were tested.

It was hypothesized that forb species which normally grow on clay buttes or scoria-capped buttes in the Badlands area of western North Dakota may display adaptive characteristics suitable for planting on clayey mine spoil materials. The vegetation found on these steep slopes includes relatively drought-resistant species and is rich in perennial forbs (Whitman and Hanson, 1939). Flesland (1964), Dodd (1970), Sanford (1970), and Hladek (1971) have reported the species composition of vegetation types on these sites, and forbs were selected from these reports for use in this study.

Seed Germination Studies

Blake (1935) collected seed of 27 forbs from native tall grass prairie near Lincoln, Nebr.. The germination of most forb seeds kept in dry storage was below 15%, but stratification of seeds through the winter months resulted in marked improvement in germination for many of the forbs. Griswold (1937) reported that the effects of alternate wetting and drying on germination of forb seeds in Utah varied with individual species.

Tolstead (1941) collected seed of native Nebraska Sand Hill plants, and found that some forb species would not germinate without low-temperature treatments. Another group of species germinated without this treatment, but germination was usually accelerated when the seeds were previously subjected to winter temperatures. Wright (1967) concluded that a 5 C treatment breaks the dormancy of most forb seeds.

Plummer et al. (1968) suggested transplanting root sections of forbs in Utah when satisfactory seed supplies could not be obtained. Mixtures including seeds of shrubs, forbs, and grasses were recommended for game range seeding. McDonough (1969) collected seeds of nine perennial and one biennial forb from forb-grass and aspen types at an elevation of 2300-3600 m in the Uinta and Dixie National Forests and grew seedlings under controlled alternating temperatures. Day temperatures were 20 C, but nighttime temperatures were alternated. Only two species showed significantly greater growth at the 15 C night temperature than at other temperatures. The other species showed no single optimum night temperature.

McDonough (1970) determined dormancy mechanisms or specialized temperature requirements for germination in forb and grass species from high elevation ranges in Utah. Fifteen species of forbs were included in his trials, and he concluded that the severe climatic conditions of the high altitude ranges did not result in a greater incidence of seed dormancy nor in specialized temperature requirements for germination, as compared to the germination responses of species from lower elevations. Florez and McDonough (1974), in a study of western coneflower (Rudbeckia occidentalis), found alternating temperature ranges with an 8-hour photoperiod favored germination, as did cold temperature stratification for two months.

Hull (1973a) seeded 37 species on mountain rangelands in Utah. While most of these were grasses and legumes, six species were range forbs. Seeds were sown by hand on terraced slopes in spring, early fall, and late fall. Stand ratings were made 3-5 years after the seeding and again about 30 years later. Five of the six forbs showed fairly good stands at 3-5 years after seeding, but 30 years later both the forbs and the legumes were nearly gone from the seeded plots. In another trial on mountain rangelands, Hull (1973b) found that seedling emergence was generally good for grasses and forbs, but high seedling mortality resulted from summer drought, from frost heaving in spring and fall, from other plant competition and from pocket gopher action. The legumes and forbs that showed promise were birdsfoot trefoil (Lotus americanus), crownvetch (Vicia sativa), bardvetch (Vicia monantha), alfalfa (Medicago sativa), and horsemint (Monarda sp).

Hull (1974) found that range forb seeds stored for relatively long periods of time (23-41 years) lost their germinability. Of 21 lots of forb seeds stored for this period, only alfileria (Erodium cicutarium) produced seedlings.

McDonough (1974), in 1972, tested seeds of trees, grasses, and 18 forb species collected from mountain ranges in 1928-31 at the Great Basin Experiment Station, Ephraim Canyon, Utah. Four forb species showed viability with the tetrazolium test, and low to intermediate germination percentages. Survival of seedlings transplanted to the. greenhouse was generally good.

Sorensen and Holden (1974) collected seed of native forbs associated with tall grass prairie near Brookings, S. Dak. Of the 23 species tested, 69.5% germinated under normal conditions, 21.7% required moist-cold treatment, 4.4% required scarification, and 4.4% did not germinate. Chemical induction of germination with gibberellic acid was beneficial only to downy gentian (Gentiana puberulenta). Seed of prairie coneflower (Ratibida columnifera) required puncture of the membrane around the embryo before viability or germination would be exhibited.

In general most of the native grassland forbs can produce viable seed, although seed set may not always be satisfactory. Germination of the seed of most forbs will be benefited by cold treatment. Most forb seeds can be expected to retain their viability for 4-5 years.

Special treatments to stimulate germination were needed for only a few species; scarification for native legume seeds was the major required treatment. The survival of planted forb seedlings in the field apparently has been tested in only a few cases.

Containerized Seedling Studies

Most work on the growth and transplanting of containerized seedlings has concentrated on tree seedlings; the techniques involved have been extensively documented by Tinus et al. (1974). A limited amount of work has been done using containerized seedling of shrubs, forbs, and grasses for transplants in revegetation work on difficult soil areas (Aldon 1970; Bjugstad et. al. 1981; Dietz et al. 1980; Bjugstad 1977, 1979; and Orr 1977).

Aldon (1970) grew fourwing saltbush in containers for transplanting to mine spoils, and containerized seedlings of western wheatgrass (*Agropyron smithii*) for transplanting in a similar disturbed situations (Alson et al. 1973). Ferguson and Monsen (1974) used containerized seedlings of shrubs and forbs in attempts to revegetate deer winter range in I&ho. They concluded that the use of containerized seedlings for revegetatfon of disturbed areas offers considerable promise, but the technique probably cannot overcome extremely adverse climatic or soil factors.

Techniques of growing containerized seedlings for use in the northern Great Plains have been discussed by George (1974), Hite (1974), Tinus (1974), and the discussion of techniques by Ferguson and Monsen (1974) seems to have particular value relative to this study. Procedures used in growing containerized shrub seedlings on mine spoils are discussed by SEAM (1975). Davidson and Sowa (1974) suggest that containers made from compressed peat have some advantages on mine spoils. The Walters bullet container appears to have some limitations for potential use with forbs (Ferguson and Monsen, 1974).

Methods and Materials

Seed Collection

Seed collection began in late June of 1976 and 1977 and continued until late October of each year. Seeds were collected in the Badlands area south of Medora, N. Dak., near Dickinson Experiment Station, from species that normally grow in the raw clay material on the sides or tops of the hills and buttes of the area, and were thus considered to have good potential for growth on clayey mine spoil materials (Table 1).

The forb seeds were stored at room temperature during the summer and threshed-out as time permitted. For the most part the seeds threshed and cleaned satisfactorily. However, in some cases floral or fruit parts remained combined with the seed, and it was necessary to conduct the germination trials, container plantings, and plot seedings using seed to which appendages or portions of appendages were still attached.

Species especially prone to retaining appendages included yarrow (Achillea lanulosa), sagewort wormwood (Artemisia caudata), white upland aster (Aster ptarmicoides), wild buckwheat (Eriogonum multiceps), butterfly weed (Gaura coccinea), skeleton weed (Lygodesmia juncea), golden aster (Chrysopsis villosa), all the goldenrods (Solidago spp.), and goatsbeard (Tragopogon dubius).[2]

Container Grown Seedling

Seedlings were grown in containers in the greenhouse during 1977 and 1978. Styrofoam block type containers, each holding numerous plugs, were used in 1977. Each plug was approximately 2.2 cm (7/8 inch) in diameter and 10.2 cm (4 inches) deep. Seeds subjected to a short, dry, cold period were planted the first week in December, and the container-grown seedlings were transplanted to the spoil plots during the first week in June.

Seed of 30 species (Table I) were planted in 7.5-cm (3-inch) peat pots in the greenhouse in February 1978. Ten pots of each species were planted using commercial potting soil as the planting medium. All pots were kept well-watered, and after emergence seedlings were thinned to 2-3 per pot. Ten pots of each species except bluebell (Campanula rotundifolia) and Indian breadroot (Psoralea esculenta) were available for planting by the end of May.

Construction of Spoil Piles

During May 1977, 46 m^3 (60 cubic yards) of raw coal spoil material was hauled to the Dickinson Station from North American Coal Corporation's Indianhead Mine near Zap, N. Dak.. This material was taken from a depth of 9-12 m (30-40 feet); it had a somewhat yellowish tinge and a sandy clay loam texture. The material had been exposed for about 5 months prior to being moved to Dickinson.

This spoil material was assembled into two piles about 8.9 m (96 feet) long, 2.4 m (8 feet) wide, and 30.5 cm (14 inches) deep; these were held in place by a framework of heavy timber. The surface of these areas was rototilled before any seeds or seedlings were introduced.

Seeding and Planting of Spoils

Each spoil pile was divided into plots 1.2 x 1.2 m (4 x 4 feet) in size. The plantings of container-grown seedling and the seedings were made in two replications per treatment for each species in each of 2 years. Seed was broadcast by hand and raked; it was applied at what was considered to be heavy rates when compared to seeds of similar size of tested seeding rates. Seeding and planting was done the first week of June. After the completion of the transplanting and seeding of the plots, all plots were watered with a fine-spray to keep the surface damp.

[2] Plant names are according to Stevens (1963).

Results and Discussion

Plot Seedings

Narrow-leaved beardtongue (*Penstemon angustifolius*) and Lewis wild flax (*Linum lewisii*) did not produce seedlings for measurement during the 1977 season. Thirty species were seeded in the 1978 season, of which the following seven did not produce any seedlings by the end of the observation period: seablite (*Suaeda fruticosa*), narrow-leave beardtongue, bluebell, Indian breadroot, stiff sunflower (*Helianthus rigida*), skeleton weed (*Lygodesmia juncea*), and stiff goldenrod (*Solidago rigida*).

Seedling growth was quite comparable between the 2 years (Table 2). Seablite, stiff goldenrod, and stiff sunflower produced seedlings on the plots in the 1977 season; although as stated earlier, no seedlings of these species were produced on the plots seeded in 1978.

Several species showed exceptionally good emergence of seedlings and subsequent vigorous growth in both years: white prairie clover (*Petalostemum candidum*), wild licorice (*Glycyrrhiza lepidota*), prairie coneflower (*Ratibida columnifera*), blazing star (*Liatris punctata*), and long-leaved milkvetch (*Astragalus ceramicus*). Species that were seeded in both years, but that did well in 1977 included white upland aster (*Aster ptarmicoides*), purple coneflower (*Echinacea angustifolia*), and early goldenrod (*Solidago missouriensis*). Green milkvetch (*Astragalus strfatus*), purple prairie-clover (*Petalostemum purpureum*), and evening star (*Mentzelia decapetala*) were seeded in both years, but showed especially good emergence and early growth only in the 1978 season. Golden aster and goatsbeard were seeded only in the 1978 season, with both species producing numerous seedlings showing vigorous early growth.

There was an abundant emergence in 1978 of seedlings from the plots seeded in the 1977 season. In a number of cases only a few plants of the seeded species developed in the 1977 season, so an ample supply of ungerminated seed was carried over into the 1978 season. New seedlings were especially abundant in 1978 for evening star, sagewort wormwood, narrow-leaved beardtongue, and stiff goldenrod, which were seeded in 1977 (Table 3).

Overwintering under natural conditions promoted germination of seed and emergence of seedlings from previously dormant seed of some of the forb species. Good rains were received at Dickinson in the fall of 1977, so the conditions that prevailed on the plots in the 1977-78 winter could be described as providing a wet-cold treatment. Many of the new seedlings did not survive the intense competition from the other seedlings and from the larger plants that became established in the 1977 season and that continued vigorous growth through the summer of 1978.

Transplant Trials

The greenhouse container plantings produced a plentiful supply of seedlings of white upland aster, bluebells, wild licorice, stiff sunflower, blazing star, white prairie clover, prairie coneflower, stiff goldenrod, and golden pea. Other species that produced only a few seedlings were as follows: wild buckwheat, purple prairie clover, green milkvetch, narrow-leaved beardtongue, evening star, and purple coneflower.

Transplant survival was nearly 100% for most species in both years. The only species that did not show nearly complete survival of transplants were skeleton weed (1978 only), stiff sunflower (both seasons), bluebells (both seasons), and seablite (transplanted in 1978 only, with all plants dying by mid-season). A few transplants of Indian breadroot were grown in both seasons, but none of the transplants of this species survived more than a short time on the spoil material. This species is not listed in the table.

Growth of the transplants was generally better in the 1978 season than in the 1977 season (Table 4), apparently because of the differences in the containers in which the transplants were grown. Species that showed exceptionally vigorous growth as transplants in both seasons included white prairie clover, prairie coneflower, wild licorice, stiff sunflower, purple prairie clover, and white upland aster. In addition to making vigorous height growth, these species also developed substantially more cover on the plots than did most of the other species. Golden aster and butterfly weed, grown only in the 1978 season, both showed good vigor and cover characteristics.

Flowering occurred in many of the transplanted plants toward the end of the growing season in both 1977 and 1978. In the 1977 season flowering was-most abundant in the transplants of white prairie clover, purple prairie clover, prairie coneflower, and stiff sunflower. In the 1978 season the transplants of 12 species flowered. Included in this group were prairie coneflower, golden aster, white prairie clover, purple prairie clover, butterfly weed, buckwheat, scarlet globemallow, stiff sunflower, golden pea, slender milkvetch, green milkvetch, and the biennial goatsbeard.

Summary and Conclusions

From the results of the seeding trials it was concluded that most of the forb species could be established from seed on the spoil material, but the use of the container-grown transplants produced more vigorous first-year plants with a greater chance of survival than the seedlings. With most species the relatively late emergence and slow development of plants from seed would place the seedlings at a competitive disadvantage as compared to the transplants. The use of containerized transplants apparently could be helpful in introducing a forb component into developing stands of native vegetation.

Height growth and cover, while important in terms of potential suitability of a species for use in mine spoil revegetation, are not the only criteria for selection. A number of species showed excellent establishment characteristics, even, though they did not make outstanding height growth or provide exceptionally good cover. Included in this group would be such species as evening star, green milkvetch, slender milkvetch, Lewis wild flax; wild buckwheat, scarlet globemallow, blazing star, purple coneflower, soft goldenrod, and early goldenrod.

The following conclusions were made:

1. Both planting with container-grown seedlings and direct seeding resulted in the production of successful stands of most forbs tested on mine spoil material.

2. Establishment of many of these native forbs was accomplished on spoil material without topsoil and/or amendments.

3. Growth of container-grown forbs on the mine spoil material was more rapid and more vigorous than growth of plants from direct seedings in both seasons.

4. The relatively late emergence and slow development of plants from seedings placed these plants at a competitive disadvantage as compared to the container-grown transplants.

5. Forb species that showed exceptionally vigorous growth as transplants in both seasons included white prairie clover (*Petalostemum candidum*), prairie coneflower (*Ratibida columnifera*), wild licorice (*Glycyrrhiza lepidota*), stiff goldenrod (*Solidago rigida*), purple prairie clover (*Petalostemum purpureum*), and white upland aster (*Aster ptarmicoides*).

6. Species that showed exceptionally good emergence from direct seeding and subsequent vigorous growth included white prairie clover, wild licorice, prairie coneflower, blazing star (*Liatris punctata*), and long-leaved milkvetch (*Astragalus ceramicus*).

7. Only a few species of those tested appeared to show little promise because of low germination and/or survival for use in revegetation trials on spoil bank material. These were skeleton weed, Lewis wild flax, Indian breadroot, and possibly gaillardia.

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Table 1. List of species* collected near Dickinson, N. Dak., in 1976 and 1977 used in experiments on forb establishment on coal mine spoil material.

Commonname	Scientific name	Years collected 1976	1977
Blazing star	Liatris punctata	X	X
Bluebells	Campanula rotundifolia	X	X
Butterfly weed	Gaura coccinea		X
Early goldenrod	solidago missouriensis	X	X
Evening star	Mentzelia decapetala	X	X
Gaillardia	Gaillardia aristata	X	X
Goatsbeard	Tragopogon dubius		x
Golden aster	Chrysopsis villosa	X	X
Golden pea	Thermopsis rhombifolia	X	X
Green milkvetch	Astragalus striatus	X	X
Indian breadroot	Psoralea esculenta	X	x
Lewis wild flax	Linum lewisii	X	X
Long-leaved milkvetch	Astragalus ceramicus	X	X
Narrow-leaved beardtongue	Penstemon angustifolius	X	X
Prairie coneflower	Ratibida columnifera	X	X
Purple coneflower	Echinacea angustifolia	X	X
Purple prairie clover	Petaldstemum purpureum	X	X
Sagewort wormwood	Artemisia caudata	X	X
Scarlet globemallow	Sphaeralcea coccinea		X
Seablite	Suaeda fruticosa	X	X
Skeleton weed	Lygodesmia juncea		X
Slender milkvetch	Astragalus flexuosus		X
Soft goldenrod	Solidago mollis		X
Stiff goldenrod	Solidago rigida	X	X
Stiff sunflower	Helianthus rigidus	X	X
White prairie clover	Petalostemum candidum	X	X
White upland aster	Aster ptarmicoides	X	X
Wild buckwheat	Eriogonum multiceps	X	X
Wild licorice	Glycyrrhiza lepidota	X	X
Yarrow	Achillea lanulosa		X

*According to Stevens (1963).

Table 2. Heights of plants on seeded plots of mine spoil material at the Dickinson Station in 1977 and 1978 and listed according to greatest height in 1978.

Species	Average height (cm)* 8/30/77	8/31/78
Tragopogon dubius	- - -†	16.5 ± 0.8
Glycyrrhiza lepidota	17.1 ± 0.6	15.3 ± 1.5
Astragalus ceramicus	16.5 ± 3.8	12.7 ± 1.4
Petalostemum candidum	10.2 ± 2.6	12.7 ± 0.0
Astragalus striatus	4.6 ± 0.6	7.6 ± 0.0
Petalostemum purpureum	8.9 ± 3.8	7.6 ± 0.0
Astragalus flexuosus		5.1 ± 1.5
Thermopsis rhombifolia	4.6 ± 0.0	5.1 ± 0.0
Liatris punctata	5.1 ± 0.0	5.1 ± 0.0
Ratibida columnifera	3.8 ± 0.0	5.1 ± 1.5
Sphaeralcea coccinea	- - -	4.5 ± 1.1
Mentzelia decapetala	5.7 ± 1.9	3.8 ± 0.8
Gaura coccinea	- - -	3.8 ± 0.8
Linum lewisii	- - -	3.2 ± 0.4
Gaillardia aristata		2.5 ± 0.0
Aster ptarmicoides	3.8 ± 0.0	2.0‡
Echinacea angustifolia	5.1 ± 0.0	1.9 ± 0.3
Artemisia caudata	6.4‡	1.3 ± 0.0
Eriogonum multiceps	2.5 ± 0.0	1.3‡
Solidago mollis	- - -	1.3 ± 0
Chrysopsis villosa	- - -	1.3 ± 0.0
Achillea lanulosa	- - -	1.3 ± 0.0
Solidago missouriensis	1.3 ± 0.0	1.0‡
Suaeda fruticosa	19.1 ± 1.3	- - -
Solidago rigida	2.5 ± 0.0	- - -
Helianthus rididus	1.3 ± 0.0	- - -

†No seeding in 1977.

*Plus or minus (±) standard error.

‡Mean per plot, no replications.

Table 3. Estimated number of seedlings per square meter produced in the 1978 season on mine spoil plots seeded in the 1977 and 1978 seasons (Estimates made in August 1978 and listed according to highest number per square meter in 1978).

Species	No. seedlings/m^2 - 1978 season	
	Plots seeded 1977	Plots seeded 1978
Astragalus striatus	0	356
Petalostemum candidum	21	335
Mentzelia decapetala	624	302
Tragopogon dubius	--*	280
Glycyrrhiza lepidota	129	248
Liatris punctata	0	204
Astragalus ceramicus	11	140
Petalostemum purpureum	43	140
Chrysopsis villosa	0	97
Linum lewisii	65	43
Echinacea angustifolia	140	32
Astragalus flexuosus	--	21
Solidago mollis	--	21
Sphaeralcea coccinea	--	21
Thermopsis rhombifolia	118	11
Ratibida columnifera	0	11
Aster ptarmicoides	32	11
Eriogonum multiceps	97	11
Achillea lanulosa	0	T†
Artemisia caudata	269	T
Solidago missouriensis	32	T
Gaillardia aristata	--	T
Gaura coccinea	--	T
Penstemon angustifolius	409	0
Solidago rigida	269	0
Helianthus rigidus	151	0
Campanula rotundifolia	0	0
Suaeda fruticosa	0	0
Lygodesmia funcea	--	0

* Species not seeded in the 1977 season.

† T= Seedlings present but averaging less than $1/m^2$.

Table 4. Heights of container-grown transplants in mine spoil material at the Dickinson Station in 1977 and 1978.

Species	Average height (cm)[*] 8/30/77	Average height (cm)[*] 8/31/78
Ratibida columnifera	25.4 ± 3.9	39.0 ± 1.4
Petalostemun candidum	33.7 ± 1.2	30.9 ± 4.1
Tragopogon dubius	- - -[†]	30.1 ± 4.4
Linum lewisii	- - -	27.9 ± 2.6
Glycyrrhiza lepidota	14.6 ± 2.4	27.9 ± 2.5
Lygodesmia juncea	- - -	27.9 ± 2.5
Astragalus ceramicus	- - -	27.3 ± 3.3
Mentzelia decapetala	9.3 ± 1.7	25.4 ± 7.8
Astragalus flexuosus	- - -	25.2 ± 3.2
Chrysopsis villosa	- - -	25.2 ± 2.5
Gaura coccinea	- - -	24.6 ± 2.1
Solidago rigida	11.1 ± 1.0	22.0 ± 0.5
Petalostemum purpureum	12.3 ± 6.6	18.6 ± 2.2
Astragalus striatus	5.9 ± 1.7	18.2 ± 2.2
Eriogonum multiceps	- - -	16.1 ± 1.3
Aster ptarmicoides	10.8 ± 0.6	14.6 ± 0.9
Artemisia caudata	- - -	14.4 ± 0.9
Thermopsis rhombifolia	7.4 ± 1.7	14.4 ± 1.2
Sphaeralcea coccinea	- - -	11.0 ± 3.1
Gaillardia aristata	- - -	10.4 ± 0.7
Achillea lanulosa	- - -	10.0 ± 1.0
Solidago missouriensis	- - -	9.1 ± 1.0
Liatris punctata	3.1 ± 0.3	8.7 ± 0.7
Solidago mollis	- - -	7.8 ± 0.6
Penstemon angustifolius	2.5 ± 0.9	7.2 ± 1.0
Echinacea angustifolia	6.8 ± 5.1	5.1 0.3
Helianthus rigidus	12.4 ± 4.0	72.4[**]
Campanula rotundifolia	3.8 ± 1.6	20.3[**] ± 0.8
Suaeda fruticosa	- - -	(plants dead)

[*] Plus or minus (±) standard error.

[†] No planting in 1977.

[**] Measurements on two surviving transplants only.