Influence of Container Size and Medium Amendment on Post-transplant Growth of Prairie Perennial Seedlings

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ADDITIONAL INDEX WORDS. **hydrogel, hydrophilic polymer, prairie restoration, seedling transplants, wildflower establishment, highway planting**

SUMMARY. **The objective of this study was to determine whether container size or incorporation of water-holding hydrogels in the container medium would affect growth of prairie perennials transplanted on a steep slope. Seedlings of pale-purple coneflower (*Echinacea pallida* Nutt.), rough blazingstar (*Liatris aspera* Michx.), gray-headed coneflower [*Ratibida pinnata* (Venten.) Barnh.], and little bluestem grass [*Schizachyrium scoparium* (Michx.) Nash.], were grown in 3.7-cm (1.46-inch) diameter tubes that were either 13 cm (5.1 inches) or 18 cm (7.1 inches) long containing either standard greenhouse mix or the mix amended with hydrogels Terra-sorb AG or Liqua-Gel, or a nonhydrogel experimental compound, GLK-8924. The seedlings were transplanted to the slope in May 1994, and harvested in June 1995. After two growing seasons, plants of pale-purple coneflower and gray-headed coneflower from the longer containers were larger (dry weight) than those from the shorter containers. The blazingstar and little bluestem were unafffected by container size. Terra-sorb AG and Liqua-Gel did not significantly affect height growth of the prairie perennials. GLK-8924-amended medium resulted in smaller or similar height plants.**

Highway embankments must be vegetated to prevent erosion or damage to the roadway (Trautman and Lohmeyer, 1980). The reestablishment of vegetation on steep slopes is difficult because of numerous problems including severe erosion, poor soil texture, low nutrient availability, and low water availability (Hargett et al., 1982).

Highway planners have used hydroseeding, seeding with herbaceous perennial ground cover species other than grasses, seedling-mat installation, hardwood mulch installation, and installation of limestone rock in attempts to control erosion and prevent weed invasion on steep banks. However, such methods may be ineffective in erosion or weed control, considered aesthetically unappealing, or cost prohibitive (Hargett et al., 1982; Osborne and Gilbert, 1978).

The establishment of prairie perennial transplants on steep embankments may be a cost-effective technique to control erosion, provide aesthetics, and control weeds. Native prairie plants are deep rooted and can survive extended periods of drought (Weaver, 1954). Established prairie communities resist weed invasion if not disturbed, and the installation of prairie species near highways is considered to be a cost-effective and aesthetically pleasing alternative to turf monocultures (Harrington, 1994).

The success of seedling transplants on steep banks on highway rights of way is dependent on many factors including species and environmental conditions following transplanting. Nuzzo (1978) successfully planted seedlings of prairie perennials along Wisconsin roadsides in drought conditions. While Nuzzo did not transplant prairie species on steep slopes, she did determine that survival of prairie seedlings on droughty sites was species dependent (Nuzzo, 1978).

Journal paper 15750 of the Purdue University Office of Agricultural Research Programs. This research was supported by the Indiana Department of Transportation through grant HPR-2075 (029) of the Joint Highway Research Project. The authors also wish to thank Brian Boszor for his technical assistance, and Don Bickel and Dave Sosby of the Indiana Department of Transportation for their advice and assistance. The cost of publishing this paper was defrayed in part by page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

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Researchers have documented the effect of container size on subsequent survival and growth of horticultural crops. Plants grown in small containers often show limited growth after transplanting due to low water availability (Milks et al., 1989). Growth and survival of bell pepper (*Capsicum annuum* L.) and marigold (*Tagetes erecta* L.) seedlings grown in small containers were poor compared with seedlings grown in larger containers and transplanted to the field (Latimer, 1991; NeSmith et al., 1992). One-liter (0.26-gal) plastic bags and 4-cm (1.6-inch) peat containers have been used on a limited scale to grow transplants of prairie perennials for a field study in Iowa, but the effect of transplant container size was not reported (Christiansen, 1967). Deep containers that allow more root growth of deeply rooted prairie species and provide more water holding capacity may increase survival of prairie species on steep slopes.

Hydrophilic or starch-based polymer gels (hydrogels) have been studied as a means of increasing the water-holding capacity of container mixes for vegetables and bedding plants (Gehring and Lewis, 1980; Wang, 1989). Hydrogels in soilless greenhouse mixes used in container production are particularly effective when the seedlings are transplanted to situations where soil fertility and water availability are low (Henderson and Hensley, 1986; Sayed et al., 1991). Since many highway rights of way are characterized by similar conditions, hydrogels used as container-media additives may increase the survival and growth of prairie species by increasing the water-holding capacity of the medium immediately surrounding the roots of newly installed seedlings.

Researchers have not investigated the effect of container size or the addition of hydrogels to the growing medium of container-grown seedlings of native prairie perennials. Prairie species establishment has been studied under harsh conditions on a borrow pit (Conover and Geiger, 1989), but not on a highway embankment.

The purpose of this study was to answer two questions. First, does the size of the production container affect the survival and growth of prairie perennials transplanted to a steep slope? Second, do water-holding hydrogels in the container affect survival and growth of the transplanted seedlings?

Materials and methods

Three native forb species, pale-purple coneflower, rough blazingstar, and gray-headed coneflower, and one native grass, little bluestem, were used in this study. The forb species were selected to gain a representative sample of prairie species with different transplant survival characteristics (Schulenberg, 1972). The prairie grass was chosen because it is tolerant of drought and provided a forb-grass comparison.

The hydrogel media amendments used in this study were 1)Terra-sorb AG, a superabsorbant acrylamide copolymer (Industrial Services International, Bradenton, Fla.) and 2) Liqua-Gel, a starch-based product (Miller Chemical and Fertilizer, Hanover, Pa.). In addition, GLK-8924 (Great Lakes Chemical Corporation, West Lafayette, Ind.), an experimental low-level stress inducing substance was included in the treatment array. While not a hydrogel, GLK-8924 had been shown in proprietary experimentation to confer on treated seedlings an increased tolerance of drought. GLK-8924 is a simple carbohydrate molecule (R.J. Joly, personal communication).

In October 1993, forb seed was obtained from Prairie Ridge Nursery (Mt. Horeb, Wis.) and little bluestem seed was obtained from Sharp Brothers, Inc. (Clinton, Mo.). All seed was stored at 4 °C (40 °F). In Jan. 1994, we filled seedling trays with a steam-pasteurized (80 °C) (176°F) mix containing 2:2:1 (v/v/v) ratio of perlite, sphagnum peat moss and soil amended with 890 g (1.96 lb) $Ca(H_2PO4)_2$, 593 g (1.30 lb) KNO_3, 593 g (1.30 lb) $MgSO_4$, 4.75 kg (10.47 lb) ground limestone and 74.2 g (0.16 lb) Peters fritted trace elements No. 555 (W. R. Grace & Co. , Fogelsville, Pa.), all per cubic meter (1.3 $yard^3$) of mix.

We placed the forb and grass seed on top of the medium in the seedling trays and placed the trays under intermittent mist for 10 d until the seeds germinated. The seedling trays containing the emerging seedlings were then transferred to a greenhouse bench where they were watered daily. The plants were fertilized at each watering with 201 $mg\cdot L^{-1}$ (ppm) N; this was supplied from KNO_3, $Ca(NO_3)_2$, and NH_4NO_3 at concentrations of 71, 65 and 65 $mg\cdot L^{-1}$, respectively, plus 200 $mg\cdot L^{-1}$ K from KNO_3 and 46 $mg\cdot L^{-1}$ P from technical grade H_3PO_4 via the irrigation system.

The containers used in this study were Ray Leach Cone-tainers (Stuewe & Sons, Inc., Corvallis, Ore.), which were 3.7 cm (1.46 inch) in diameter and either 13 cm (Super Stubby cell) or 18 cm (Super cell) long. After 2 weeks, 15 uniform seedlings of each species were transferred from the seedling flats to each the following container systems/treatments:

Treatment 1. 13-cm-long cells filled with the steam pasteurized mix described above.

Treatment 2. 18-cm-long cells filled with the same medium as Treatment 1.

Treatment 3. 13-cm-long cells filled with the steam pasteurized mix to which 2240 $g\cdot m^{-3}$ (3.78 lb/$yard^3$) of Terra-sorb AG was added.

Treatment 4. 18-cm-long cells filled with the same medium as Treatment 3.

Treatment 5. 13-cm-long cells filled with the steam pasteurized mix to which 2240 $g\cdot m^{-3}$ of Liqua-Gel was added.

Treatment 6. 18-cm-long cells filled with the same medium as Treatment 5.

Treatment 7. 13-cm-long cells filled with the steam pasteurized mix to which 20 mL (0.68 fl oz) of a 4% solution of compound GLK-8924 was added 24 h before transplanting to the field.

Treatment 8. 18-cm-long cells filled with the same medium as Treatment 7.

A 75% manufacturer's recommended rate of Terra-sorb AG or Liqua-Gel to steam pasteurized mix (Treatments 3 to 6) was used because the full rate resulted in a heavy mixture that stuck to the sides of the cells. The mixture stickiness made it impossible to remove the transplants from the containers without damaging the root systems of the transplants. Due to a shortage of material, only pale-purple coneflower and gray-headed coneflower seedlings received Treatments 7 and 8.

The seedlings remained in the greenhouse 4 weeks following transplanting. They were then moved to a clear polyethylene film-covered cold frame to harden off after visual inspection of the seedlings confirmed that the roots had filled the container. In May 1994, the polyethylene film was removed from the cold frame. The seedlings were exposed to ambient conditions until they were transplanted to the field plot.

Table 1. The effect of production medium amendments on height of prairie perennial seedlings of four species transplanted to a steep cut-slope embankment.

Amendment treatment	Ht (cm)[z]							
	Little bluestem		Gray-headed coneflower		Rough blazingstar		Pale-purple coneflower	
	1994	1995	1994	1995	1994	1995	1994	1995
Liqua-Gel	16.9b[y]	31.7a	21.8a	50.1ab	5.0a	27.9a	14.6b	45.7a
Terra-sorb AG	20.6ab	31.3a	22.4a	55.5a	4.4a	26.6a	17.2a	45.0a
GLK-8924	---	---	21.1a	41.1b	---	---	13.1b	31.6b
Control	26.0a	29.4a	21.6a	54.9a	6.1a	23.4a	14.5b	44.7a
Protected LSD$_{(P < 0.05)}$	8.7	5.7	1.9	9.7	2.4	8.7	2.4	11.4

[z]In 1995, plant height was measured to top of inflorescence; 2.54 cm = 1.0 inch.
[y]Mean separation in columns by Fisher's protected test. Items with the same letter are not significantly different from each other. Values represent means of 30 replicates averaged across container depth as amendment × container size interaction was not significant.

The field plot was located 8 km (5 miles) north of Lafayette, Ind., in Tippecanoe County, on a steep, southwest-facing cut-slope embankment on Interstate 65. The original soil reported to have been found on the site prior to highway construction was a Hennepin Loam (fine loamy, mixed mesic, typic Entrochrept) with a 20% to 50% slope (Ulrich and Barnes, 1959). The existing soil at the time of the study was light colored, with a pH of 7.5 and a heavy clay texture, suggesting that only a B-horizon subsoil was present.

The 15 seedlings/treatment were transplanted on 10 May 1994, in a completely randomized design using planting dibbles manufactured to match the shape of the production containers (Stuewe and Sons, Inc., Corvallis, Ore.). The soil at the site was moist due to rain the previous week. Two days after we installed the transplants, 4.5 cm (1.77 inches) of rain fell on the site. In August 1994, the number of vegetative shoots per plant, plant height and survival were recorded. In June 1995, flowering shoots per plant, plant height to the top of the inflorescences and survival were recorded. Data in 1995 were recorded as each species reached anthesis. The aboveground portion of each plant was excised at the soil line and dried for 48 h at 80 °C (176 °F), then weighed. Flower shoot number and height were recorded only in 1995 because the plants did not flower in 1994. Height, flowering and dry weight data were subjected to ANOVA using SuperAnova (Abacus Concepts, Berkeley, Calif.). Means were compared using Fisher's protected test. The experimental design did not allow for statistical analysis of survival data.

Total precipitation observed at a weather station 4.5 km (2.7 miles) from the plot site over the entire experimental period nearly matched average levels. However, rainfall was above average during Summer 1994. Monthly values (expected: actual) for that period were: June [10:15 cm (3.9:5.9 inches)], July [10:14 cm (3.9:5.5 inches)], August [10:12 cm (3.9:4.7 inches)] (J.R. Mcintyre, personal communication).

Results

Year 1–August 1994

SHOOTS PER PLANT. No significant differences were observed (data not presented).

PLANT HEIGHT. Little bluestem plant height was reduced by amending with Liqua-Gel compared to the control ($P < 0.01$) . Seedlings of pale-purple coneflower were taller in the Terra-sorb AG treatment compared to the seedlings in the other medium amendment treatments ($P < 0.05$) (Table 1).

SURVIVAL (DATA NOT PRESENTED). 87% of all seedlings survived 3 months after planting. All gray-headed coneflower seedlings survived, 98% of pale-purple coneflower and 82% of little bluestem seedlings survived, but only 62% of the rough blazingstar survived. Little bluestem seedlings amended with hydrogels survived at 97% (Terra-sorb AG) and 86% (Liqua-Gel) while control plants survived at 75%. Survival of GLK-8924-treated gray-headed coneflower and pale-purple coneflower plants was 100% and 95%, respectively, while control values were both were 100%. Also, rough blazingstar seedlings grown in larger containers survived at 67% compared to 56% for smaller container seedlings.

Year 2–June 1995

FLOWERING SHOOTS PER PLANT (DATA NOT PRESENTED). Gray-headed coneflower seedlings developed significantly fewer ($P < 0.05$) flowering shoots-per-plant when GLK-8924 was used as an

Table 2. The effect of container size on shoot dry weight of prairie perennial seedlings transplanted to a steep cut-slope embankment.

Container size	Shoot dry wt (g)[z]			
	Little bluestem	Gray-headed coneflower	Rough blazingstar	Pale-purple coneflower
13cm	7.2a[y]	3.3b	1.6a	4.9b
18cm	7.9a	5.0a	1.7a	8.7a
Protected LSD$_{(P < 0.05)}$	2.5	0.8	0.9	2.0

[z]Plants planted in May 1994 and harvested June 1995; 28.35 g = 1.0 oz.
[y]Mean separation in columns by Fisher's protected test. Items with the same letter are not significantly different from each other. Values represent means of 60 replicates averaged across medium amendment treatments as amendment × container size interaction was not significant.

amendment (0.65) compared with the control (1.3) or the Terra-sorb AG treatment (1.2). No other effects due to amendments were observed on flowering shoots per plant. Gray-headed coneflower seedlings grown in 18-cm-long containers had more ($P < 0.05$) flowering shoots per plant (1.2) compared with seedlings grown in 13-cm-long containers (0.8).

PLANT HEIGHT. Plant height of gray-headed coneflower and pale-purple coneflower seedlings was reduced ($P < 0.05$) by amendment with GLK-8924 compared to the control (Table 1). We observed no significant differences in plant height in response to container size.

SHOOT DRY WEIGHT (DATA NOT PRESENTED). Shoot dry weight in year two of the study was not affected by media amendment. Container size did influence shoot dry weight of two prairie species. Gray-headed coneflower and pale-purple coneflower produced in 18-cm-long containers weighed more ($P < 0.05$) than seedlings grown in 13-cm-long containers (Table 2).

SURVIVAL (DATA NOT PRESENTED). 75% of all seedlings survived through June, 1995. Little bluestem seedlings grown in a medium amended with hydrogel survived at 89% for Terra-sorb AG and 86% for Liqua-Gel, but only 70% for control plants. Rough blazingstar in the hydrogel treatments survived at rates of 26% for Terra-sorb AG and 34% for Liqua-Gel, while a 40% rate was observed for the control. Survival of GLK-8924-treated gray-headed coneflower and pale-purple coneflower plants was 100% and 78%, respectively, while control values were 97% and 90%. For rough blazingstar, 41% of seedlings from 18-cm-long containers survived, while 26% of seedlings from 13-cm-long containers were alive in June 1995.

Discussion

Container size influenced the growth (dry weight) of our selected prairie species to different degrees. Gray-headed coneflower and pale-purple coneflower seedlings grown in 18-cm-long containers grew larger by the conclusion of this experiment than those produced in 13-cm-long tubes. Rough blazingstar and little bluestem showed no significant dry weight response to container size. Milks et al. (1989) attributed improved growth of transplants from larger containers to increased water availability. Gray-headed coneflower may have benefitted most from increased water due to its broad-leafy vegetative morphology as compared to rough blazingstar with its short, narrow, pubescent leaves (Kirt, 1989). Little bluestem is a dry-adapted species and may have been unable to capitalize on increased water availability. Simple physical form of the container may have played a role, too. Pale-purple coneflower produces a deep, thick, tuberous taproot (Kirt, 1989). The longer tube-shaped container (18 cm) may have been perfectly suited to the plant's root form and the greater length a benefit to a deep taproot-producing species.

Although dry weight was not affected, rough blazing star from 18-cm-long tubes survived at a 41% rate compared to a 26% rate for plants from the 13 cm containers. This species forms a corm as a rootstock, so it may be poorly suited to narrow, tube-shaped containers, thus the overall low survival. However, among those that did survive, the longer container may have allowed for more extensive development of the feeder roots below the corm.

We observed a minimal and inconsistent effect of hydrogel amendment on growth of the prairie species. The only growth increase was noted during the first season and in only one species, with Terra-sorb AG. Henderson and Hensley (1986) observed a similar limited response, especially in fine textured field soils. Wang (1989) found no commercially justifiable benefit of hydrogel for foliage plants under greenhouse production conditions. In our experiment, the lack of response to hydrogels may have been due to the above normal precipitation that occurred in 1994, diminishing any benefit that might have accrued during extended dry periods. Also, the practical realities of the seedling growing system (Ray Leach Conetainers) prevented use of full manufacturer's rate amendment, thus potentially limiting effectiveness.

For both species tested, GLK-8924 significantly reduced plant size. This result is consistent with earlier observations by the manufacturer of GLK-8924 (Joly, personal communication). As a root zone stress inducing material, GLK-8924 increases plant tolerance to drought through reduced plant size and therefore reduced surface area for water loss. This effect had been observed in seedlings only several days after treatment, but in this experiment, the effect was evident well into the second growing season. While plant size was reduced, treatment with GLK-8924 did not appear to alter survival rates.

We conclude that seedlings of prairie perennials can be successfully established on a steep slope with extreme exposure. Container size can influence plant growth. Therefore, restorationists and native plant landscapers should consider using the largest practical container size to maximize success of some species. Commercially available hydrogel amendments in the container medium may influence transplant performance. However, our growth data provided minimal support for hydrogel use.

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