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Seeded versus containerized big sagebrush plants for seed-increase gardens

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Abstract

Seed production of big sagebrush (*Artemisia tridentata* Nutt.) plants established from containerized seedlings was compared to plants established by direct seeding. A garden of 'Hobble Creek' mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* (Rydb.) Beetle) and a garden of Gordon Creek Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle & Young) were established in central Utah for this study. Each garden consisted of 10 rows of plants. Seed-derived plants were established on odd-numbered rows and container-derived plants in even-numbered rows. Seed-derived plants produce more seeds, larger top growth, deeper roots, lateral roots nearer the soil surface, and heavier root systems than container-derived plants. Seed-derived plants also produced large prominent tap roots; the containerized plants did not. Seed-derived plants had a zero death rate for the 4 study years. Death rates for containerized plants were 16% ('Hobble Creek') and 13% (Gordon Creek). To help meet seed demands, growers should establish seed-increase gardens with seed-derived plants. A cautionary note: It is unknown if the use of container-derived plants for adaptation trials might erroneously influence the results of such studies. However, the root development problems described in this study should cast some doubt.

Resúmen

La producción de semillas de plantas de artemisia grande (*Artemisia tridentata* Nutt.) a partir de plantas germinadas en recipientes se comparó con otras germinadas en un semillero. Para realizar este estudio se crearon dos jardines en el Centro del Estado de Utah, Estados Unidos; uno de plantas de artemisia grande de montaña 'Hobble Creek' (*Artemisia tridentata* ssp. *vaseyna* (Rydb.) Beetle) y otro de artemisia grande 'Gordon Creek Wyoming' (*Artemisia tridentata* ssp. *wyomingensis* Beetle & Young). Cada jardín estaba formado por 10 hileras de plantas. Las plantas derivadas del semillero se colocaron en las hileras impares y las derivadas de los recipientes en las hileras pares; las primeras produjeron más semillas, fueron más tupidas, con raíces profundas y con más raíces laterales superficiales; el sistema de raíces fue más abundante que en las plantas desarrolladas en recipientes. Las plantas del semillero también produjeron raíces principales; las plantas de recipiente no. Durante los 4 años de estudio, el porcentaje de mortalidad fue del 0% en las plantas de semillero, del 16% en las plantas de recipiente de la variedad 'Hobble Creek' y del 13% en las de la variedad 'Gordon Creek'. Para ayudar a satisfacer la demanda de semillas, los agricultores deberían cultivar granjas productoras de semillas usando plantas derivadas de semilleros.

Nota de advertencia: Se desconoce si el uso de las plantas de recipiente para pruebas de adaptación puede influenciar erróneamente en los resultados de tales estudios. Sin embargo, los problemas de desarrollo de raíces descritos en este estudio deberían presentar ciertas dudas.

Key Words: *Artemisia tridentata*, seed production, root growth, root development, mountain big sagebrush, Wyoming big sagebrush

Big sagebrush (*Artemisia tridentata* Nutt.) provides food, nesting sites, or cover for numerous wildlife, arthropod, and fungi species (Braun et al. 1976, Green and Flinders 1980, Kufeld et al. 1973, Martin et al. 1951, Medin 1990, 1992, Patterson 1952, Shaw and Monsen 1990, Smith and Beale 1980, Welch 1993, 1994, Welch and Nelson 1995). The demand for big sagebrush seed for use in revegetation or restoration projects has increased significantly. Collecting from wildland stands is nearly the only source for big sagebrush seed. Unfortunately, demand seems to be highest after a severe fire season, a time not conducive to big sagebrush seed production.

To help overcome this problem, seed-increase gardens of released germplasms were established, and the feasibility for commercial production of seed determined (Welch et al. 1986, 1990, 1992). These gardens were established using containerized stock. This procedure proved to be labor intensive and expensive. Volunteer big sagebrush plants in these gardens grew rapidly and produced seed the second year—just like their parents (Welch et al. 1990). This, plus the development of technology that allowed cleaning of big sagebrush seed to 95% purity (Booth et al. 1997, Shaw and Monsen 1990, Welch 1995)—facilitating mechanical planting—led to the establishment of 2 gardens to study the performance of seed-derived versus container-derived big sagebrush plants.

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The null hypothesis for this study was that seed production from seed-derived plants would not differ from container-derived plants. Alternate hypothesis was seed-derived plants would produce more seed.

Materials and Methods

'Hobble Creek' Garden

Containerized 'Hobble Creek' stock was started in May of 1991. Tinus rootrainers (38 mm × 51 mm × 203 mm) from Spencer-Lemaire were used. These containers are designed with vertical grooves that prevent root spiralling and allows for air pruning of the developing root system (Harris 1992, Moore 1985). The containers were filled to within 12 mm of the top with Fisons Sunshine Aggregate Plus No. 4 Mix containing Canadian sphagnum peat moss, perlite, major and minor nutrients, a wetting agent, and dolomitic lime. Filled rootrainers were saturated with tap water twice to settle the mixture. After settling, enough mixture was added to bring the growing medium to 12 mm of the top. Next, 10 'Hobble Creek' seeds were placed in each cell and covered with about 2 mm of cleaned number 3 sandblasting grit. The containerized stock was grown outdoors on wooden pallets and watered as needed. After 3 months, each cell was thinned to 1 seedling, and each cell received about 2 g of control-release fertilizer (14–14–14; 3 to 4 months). For wintering, the containerized stock was covered to about 25 mm above the container top with sawdust

The 'Hobble Creek' garden site was located 3 km south of Bluffdale, Ut., at The Point of the Mountain. Site preparation consisted of plowing and disking during spring and summer of 1991 to remove all existing vegetation. A turf-roller was used in November 1991 to firm the soil. Next, 10 rows 2.2 m apart and 45 m long were established in late November 1991, and 10 seeds were sown on the soil surface (Jacobson and Welch 1987) of a 4 cm^2 spot every 2.2 m in the odd-numbered rows. Seed came from the same lot used to produce containerized stock. In February 1992, a containerized plant was planted every 2.2 m in the even-numbered rows. The growing medium was covered with about 13 mm of soil to prevent wicking of moisture from the medium.

Elevation at this garden is 1,372 m. Native vegetation is bunchgrasses and big sagebrush. Annual precipitation is about 305 mm. Soil on the site is Bingham gravelly loam. The soil is deep, well-drained, and is derived from igneous and sedimentary rocks. About 100 mm of available water is held to a depth of 1.5 m. Soil pH ranges from 6.6 to 7.5. Rooting depth in this soil is less than 50 to 76 cm. The average frost-free period is about 160 days. Permeability ranges from 102 to 160 mm per hour (Woodward et al. 1974).

Gordon Creek Garden

The Gordon Creek garden was established in the same manner as the 'Hobble Creek' garden, except on different soil types located 1.5 km east of the 'Hobble Creek' garden.

Native vegetation is bunchgrasses, big sagebrush, and gambel oak (*Quercus gambelii* Nutt.). Soil on the site is Wasatch loamy coarse sand. The soil is deep, well-drained, and is derived from quartz monzonite and quartzite. About 76 mm of available water is held to a depth of 1.5 m. Soil pH ranges from 6.5 to 7.8. Rooting depth in this soil is less than 101 to 127 cm. The average frost-free period is about 160 days. Permeability ranges from 160 mm to 508 mm per hour (Woodward et al. 1974).

Data Collected

Data were collected on: grams of pure live seed per plant 1993, 1994, 1995, and death rate of plants for the same years plus 1992. During summer 1995, measurements were taken on air-dried weight of above-ground biomass, air-dried weight of root systems, root depth, depth from soil surface to first lateral root, and the presence or absence of a tap root.

Seed Production

In November 1993, 10 seed-derived plants from each garden were randomly selected for furnish seed data. Seed-derived plants were paired with the nearest live container-derived plant on the seed-derived plant's east side. These pairs were used for seed production measurements in 1993, 1994, and 1995. All test plants were surrounded by living big sagebrush plants.

Inflorescences were harvested by use of a hand clipper before seed shattering and placed in plastic bags for transport and drying. Bags were left open to dry in heated (22°C) laboratory. The inflorescences were hand stirred each day. When dried, inflorescence stems were hand stripped of seeds, achenes, floral bracts, fine stems, and leaves. A 14 × 14-mesh screen was used to separate fine stems and intact leaves from seeds, achenes, floral bracts, and broken fine stems and leaves. The resulting material was rubbed on a finely serrated board to further free achene from the florets. Final cleaning was done with a small-lot, air-lift seed cleaner.

Cleaned seed and achenes from each plant was weighed to the nearest 0.1 g. Seed purity was determined from a 0.3 g subsample by separating filled seeds or achenes from broken or aborted fruits and chaff. These 2 allotments were weighed to 0.00001 g and purity calculated. Viability was determined by using the tetrazolium staining test (Grabe 1970) as outlined by Meyer et al. (1987), except that the seeds were immersed in the buffered tetrazolium solution for 24 hours instead of 6 hours. Seed lot weight, purity, and seed viability were used to calculate the amount of pure live seed produced by each plant.

Vegetative Measurements

In June 1995, five additional plant pairs from each garden were randomly selected to provide vegetative measurements. First, the above-ground portion of each plant was cut off at the soil line, placed in an open plastic garbage can, and air dried at ambient temperature in a storage building for 2 weeks. After air drying, the above-ground portions were weighed to the nearest gram. Next, root systems of the pairs were hydro-extracted from the soil by digging a trench about 3.7 m deep with a backhoe. The trench was within about 2 m of 1 side of each plant allowing the soil being washed away from the root systems to flow from the plants. Periodically, the trench had to be cleared of the washed soil. Washing of the root systems started at the base of the plants and moved to the outside. This approach allowed easy identification of sagebrush roots from roots of non-target plants. After extraction, the following measurements were taken: depth of deepest root (cm), depth from soil surface to first lateral root (mm) (for container-derived plants 13 mm was subtracted from this measurement to correct for the depth of soil covering the growing medium), and the presence or absence of a tap root was noted. All extracted root systems were placed in individual open plastic garbage cans and air dried at ambient temperature for 2 weeks in a storage building. When dried, the root systems were weighed to the nearest gram.

Statistical Analysis

Paired t-tests were used to test the null hypothesis. A normality test was performed on each data set to check the assumption that the differences, if any, were normally distributed (Hintze 1992).

Results and Discussion

Seed Production

All seed production data sets with the exception of 'Hobble Creek' 1993, showed that plants derived from seed produced significantly ($p \leq 0.05$) more seeds than plants derived from containerized stock (Table 1 and 2). The most dramatic difference occurred during 1994. Seed-derived plants out performed container-derived plants by a factor of nearly 3.4 for 'Hobble Creek' and 3.8 for Gordon Creek. For 1993 and 1995, the superiority of seed-derived plants was less, ranging from 1.5 to 1.9 times greater. The growing seasons (April through September for 1993 and 1995) were cooler and wetter than normal (1993—117% of normal precipitation and 1.7°C below normal temperatures; 1995—152% and 2.0°C below normal; NOAA 1993, 1995). These 2 growing seasons contrast with the hot and dry growing season of 1994 (68% of normal precipitation and 3.9°C above normal temperatures, 7°C above normal for July; NOAA 1994).

Table 1. Comparisons of 1993 to 1995 seed production and vegetative measurements of 'Hobble Creek' (*Artemisia tridentata* ssp. *vaseyana*) plants established from direct seeding and from containerized stock. Data are expressed as means ± standard deviations.

	Seed	Containerized
Seed production		
1993 (g)	33 ± 16[a1]	33 ± 13[a]
1994 (g)	31 ± 10[a]	9 ± 3[b]
1995 (g)	35 ± 7[a]	23 ± 3[b]
Vegetative measurements		
Above-ground biomass (g)	2081 ± 504[a]	958 ± 199[b]
Root mass (g)	728 ± 179[a]	255 ± 66[b]
Root depth (cm)	207 ± 3[a]	172 ± 10[b]
Depth to first root (mm)	2 ± 0.4[a]	51 ± 14[b]
Death rate (1993–95 %)	0[a]	16[b]

[1]Row means with same superscripts are not significantly different ($p \leq 0.05$) paired t-tests.

Table 2. Comparisons of 1993 to 1995 seed production and vegetative measurements of Gordon Creek (*Artemisia tridentata* ssp. *wyomingensis*) plants established from direct seeding and from containerized stock. Data are expressed as means ± standard deviations.

	Seed	Containerized
Seed production		
1993 (g)	39 ± 16[a1]	25 ± 17[b]
1994 (g)	34 ± 17[a]	9 ± 6[b]
1995 (g)	64 ± 23[a]	33 ± 10[b]
Vegetative measurements		
Above-ground biomass (g)	2080 ± 306[a]	1531 ± 472[b]
Root mass (g)	946 ± 99[a]	679 ± 201[b]
Root depth (cm)	231 ± 11[a]	191 ± 27[b]
Depth to first root (mm)	38 ± 14[a]	71 ± 20[b]
Death rate (1993–95%)	0[a]	13[b]

[1]Row means with the same superscripts are not significantly different ($p \leq 0.05$) paired t-tests.

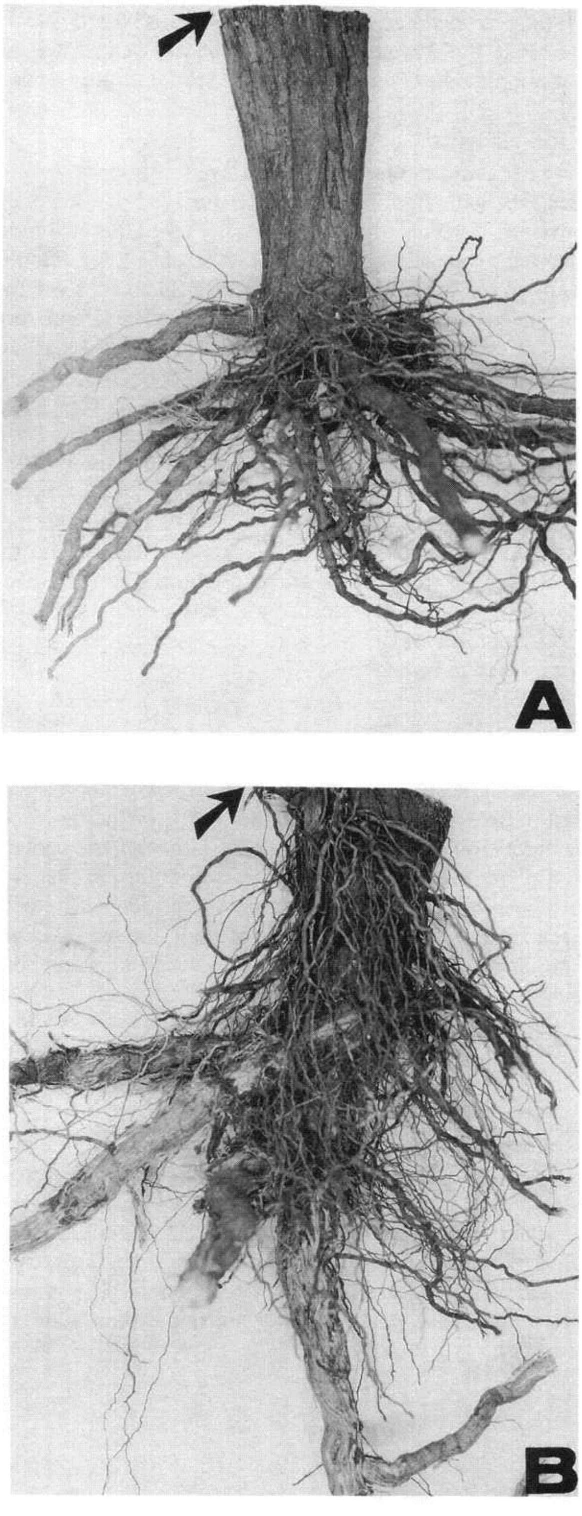

Fig. 1. Upper portions of the root system of (A) a container-derived plant and (B) a seed-derived plant. Containerized plants (A) lacked the large and prominent tap root of seed-derived plants (B). Lateral roots from seed derived plants were initiated nearer the soil surface whereas lateral roots from containerized plants were initiated much deeper (1/3 actual size). Arrow points to soil surface.

Seed yields of container-derived plants were 2.6 to 3.7 times greater during the 2 wetter years of 1993 and 1995 than the dry year of 1994. For seed-derived plants, seed yields were 1.1 to 1.9 times greater in the 2 wetter years than the dry year. This suggests that supplementary irrigation may stimulate higher seed yields.

Vegetative Measurements

All variables were significantly greater for seed-derived plants than container-derived plants. Seed-derived plants produced greater above-ground biomass by a factor of 2.1 for 'Hobble Creek' and 1.4 for Gordon Creek; produced 2.8 and 1.4 more root mass; produced 1.2 times deeper roots; produced lateral roots closer to soil surface; and plant death rate was 0 versus 16 and 13%. All seed-derived plants produced a distinct tap root. None of the container-derived plants produced a distinct tap root (Fig. 1).

Differences in root development between seed-derived and container-derived plants seem to be wide spread. Moore (1985) made this observation: "Indeed the root system of container-grown plants may never develop the same structure as the 'normal' system of direct sown plants." This study agrees with that observation and extends it to seed production. The differences appear to be developmental because all roots were inspected for signs and symptoms of disease and none were found. All root systems appeared to be healthy.

Miscellaneous Observations

Seven to 10 lateral roots grew downward from the plants at a 30° angle for some 0.5 m to 1.0 m, where they turned directly downward until they nearly reached the depth of the tap roots. This was observed for both types of plants, although, the container-derived plants had no tap root for depth comparisons. It is unknown if use of container-derived plants for adaptation trials might erroneously influence the results of such studies. However, the root development problems described in this study should cast some doubt.

Conclusions

Data collected during this study showed that plants derived from seed produced larger plants with deeper and more massive root systems, and greater seed yields while exhibiting a lower death rate than plants derived form containerized stock. The use of container-derived stock for adaptation trials might erroneously influence the results of such studies. I recommend that growers establish seed-increase gardens with seed rather than with containerized stock.

Literature Cited

Booth, D.T., B. Yuguang, and E.E. Roos. 1997. Preparing sagebrush seed for market: Effects of debearder processing. J. Range Manage. 50:51–54.

Braun, C.E., M.F. Baker, R.L. Eng, J.S. Gashwiler, and M. Schroeder. 1976. Conservation committee report on associated avifauna. Wilson Bull. 88:165–171.

Grabe, D.F. 1970. Tetrazolium testing handbook for agricultural seeds. Contr. 29 to the Handb. on Seed Testing. Assoc. Official Seed Analysts.

Green, J.S. and J.T. Flinders. 1980. Habitat and dietary relationship of the pygmy rabbit. J. Range Manage. 33:136–142.

Harris, R.W. 1992. Two practices to help ensure nursery tree quality. Internat. Plant Propaga. Combined Proceed. 42:321–324.

Hintze, J.L. 1992. Number Cruncher Statistical System, Version 5.03 Installation and Reference Manual, 329 N. 1000 E., Kaysville, Ut. 84037.

Jacobson, T.L.C. and B.L. Welch. 1987. Planting depth of 'Hobble Creek' mountain big sagebrush. Great Basin Nat. 47:497–499.

Kufeld, R.C., O.C. Wallmo, and C. Feddema. 1π973. Food of the Rocky Mountain mule deer. USDA Forest Serv. Res. Paper RM-111, Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo.

Martin, A.C., H.S. Zim, and A.L. Nelson. 1951. American wildlife & plants: A guide to wildlife food habits: the use of trees, weeds, and herbs by birds and mammals of the United States. Dover Publ. Inc., N.Y.

Medin, D.E. 1990. Birds of an upper sagebrush-grass zone habitat in East-Central Nevada. USDA For. Serv. Res. Pap. INT-433. Intermountain Res. Sta., Ogden, Ut.

Medin, D.E. 1992. Birds of a great basin sagebrush habitat in East-Central Nevada. USDA Forest Serv. Res. Paper INT-452. Intermountain Res. Sta., Ogden, Ut.

Meyer, S.E., S. Kitchen, G.R. Wilson, and R. Stevens. 1987. Supporting evidence for the proposed rule *Artemisia tridentata* big sagebrush. Unpublished report submitted to the Assoc. of Official Seed Analysts, on file, Shrub Sci. Lab, 735 N 500 E, Provo, Ut.

Moore, G.M. 1985. Getting to the roots of the problem. Internat. Plant Propaga. Combined Proceed. 35:105–111.

NOAA. 1993. Climatological Data, Annual Summary, Utah. 95(13):2, 3, 11.

NOAA. 1994. Climatological Data, Annual Summary, Utah. 96(13):4, 5, 11.

NOAA. 1995. Climatological Data, Annual Summary, Utah. 97(13):4, 5, 11.

Patterson, R.L. 1952. The sage grouse in Wyoming. Sage Books, Inc., Denver, Colo.

Shaw, N.L. and S.B. Monsen. 1990. Use of sagebrush for improvement of wildlife habitat, p. 19–35. *In*: H.G. Fisser (ed), Proc.—17th Wyo. Shrub Ecol. Workshop. Univ. of Wyoming, Dept. of Range Management, Laramie, Wyo.

Smith, A.D. and D.M. Beale. 1980. Pronghorn antelope in Utah: Some research and observations. Pub. 80–13. Utah Div. of Wildl. Resources, Salt Lake City, Ut.

Welch, B.L. 1993. Grass is not always king, p. 1775–1778. *In*: M. Baker (ed), Proc. of the XVII Int. Grassl. Congress. Palmerston North, New Zealand.

Welch, B.L. 1994. Rangeland shrubs, p .575–586. *In*: C.J. Arntzen (ed.), Encyclopedia of agricultural science. Academic Press, Inc., San Diego, Calif.

Welch, B.L. 1995. Beyond twelve percent purity, p. 126–129. *In*: B.A. Roundy, E.D. McArthur, J.S. Haley, and D.K. Mann (comps.), Proc.—Wildland shrub and arid land restoration symposium. USDA Forest Serv. Gen. Tech. Rep. INT-GTR-315. Intermountain Res. Stat., Ogden, Ut.

Welch, B.L. and D.L. Nelson. 1995. Black stem rust reduces big sagebrush seed production. J. Range Manage. 48:398–401.

Welch, B.L., F.J. Wagstaff, and G.L. Jorgensen 1990. 'Hobble Creek' mountain big sagebrush seed production, p.167–170. *In*: E.D. McArthur, E.M. Romney, S.D. Smith, and P.T. Tueller (comps.), Proc.—Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management. USDA Forest Serv. Gen. Tech. Rep. INT-276, Intermountain Res. Sta., Ogden, Ut.

Welch, B.L., E.D. McArthur, D.L. Nelson, J.C. Pederson, and J.N. Davis. 1986. 'Hobble Creek'—A superior selection of low-elevation mountain big sagebrush. USDA Forest Serv. Res. Pap. INT-370. Intermountain Res. Sta., Ogden, Ut.

Welch, B.L, E.D. Nelson, S.A. Young, A.R. Sands, F.J. Wagstaff, and D.L. Nelson. 1992. Gordon Creek—A superior, tested germplasm of Wyoming big sagebrush. USDA Forest Serv. Res. Pap. INT-461. Intermountain Res. Sta., Ogden, Ut.

Woodward, L., J.L Harvey, K.M. Donaldson, I. Shiozaki, G.W. Leishman, and J.H. Broderick. 1974. Soil survey of Salt Lake area, Utah. USDA Soil Conserv. Serv., Salt Lake City, Ut.