Container Size and Planting Zone Influence on Transplant Survival and Growth of Two Coastal Plants

Mack Thetford[1], Debbie Miller[2], Kathryn Smith[3], and Mica Schneider[4]

Additional index words. *Schizachyrium maritimum*, *Ilex glabra*, beach restoration

Summary. Survival and subsequent growth of two beach species produced in containers of differing volume and depth were evaluated following transplant on Eglin Air Force Base, Santa Rosa Island, Fla. Rooted cuttings of gulf bluestem (*Schizachyrium maritimum*) were produced in four container types: 1-gal (gallon), 0.75-gal treepot, 1-qt (quart), or 164-mL Ray leach tube (RLT) containers. Root and shoot biomass of gulf bluestem harvested after 12 weeks in container production were greatest for plants grown in treepot containers and root:shoot ratio decreased as container size increased. Regardless of container size, survival of beach-planted gulf bluestem was 100%. Basal area of plants from standard gallon and treepot containers was similar 11 months after transplant and basal area for plants from treepot containers remained greater than plants from quart or RLT containers. Effect of planting zone [92, 124, 170, and 200 m landward of the Gulf of Mexico (Gulf)] on transplant survival was also evaluated for inkberry (*Ilex glabra*). Seedling liners of inkberry were produced in 3-gal treepot or gallon containers. Inkberry was taller when grown in 3-gal treepot containers than when grown in gallon containers. Regardless of container size, all inkberry planted 92 m from the Gulf died. Inkberry survival (>75%) when grown in 3-gal treepot containers was two to six times greater than plants grown in gallon containers (15%, 50%, 40%; 124, 170, and 200 m from Gulf, respectively). After 15 months, inkberry grown in 3-gal treepot containers remained larger with 1.5 times the mean maximum height and twice the mean canopy area compared to those grown in gallon containers.

Beach restoration following tropical storms and hurricanes focuses on dune building and stabilization. An additional goal is to provide a diversity of food and other habitat requirements for endangered or threatened barrier island species such as beach mice (Gore and Schaefer, 1993; Swilling et al., 1997). Both restoration goals can be accomplished by planting a variety of native plants. However, production and beach planting protocols are available for few species. Among the dominant food plants for beach mice (*Peromyscus poliontus*) are two grasses, sea oats (*Uniola paniculata*) and gulf bluestem (Holler, 1992; Moyers, 1996). Along the Gulf coast, sea oats are commonly planted to build and stabilize foredunes (Oosting and Billings, 1942; Wagner, 1964; Woodhouse, 1978), while gulf bluestem is found most frequently on the inland slope of the foredune and is the main stabilizing species of interior dunes (Johnson, 1997). Behind the primary dune line, gulf bluestem is considered a good consolidator of sand and persists after sea oats decline. While considerable information is available on use of sea oats in dune restoration, little information is available for use of gulf bluestem. Endemic woody species, covered by moving sand, are also considered good for long-term stabilization of dunes (Brown and Hafenrichter, 1962) and provide increased diversity of structure and food for barrier island wildlife.

Inkberry is a stoloniferous shrub forming extensive, dense colonies. While the species may reach up to 10 ft in pine (*Pinus* spp.) forest systems, it is often shorter in coastal systems. The species is dioecious, producing small, nearly black, shiny berries, 0.8 cm in diameter (Dirr and Alexander, 1991). The fruits ripen in fall, persist into the following spring, and are reportedly eaten by birds and small mammals (although not beach mice) (Halls, 1977; Holler, 1992). Reestablishment of inkberry via nursery transplants following complete loss of primary and secondary dunes was attempted because the colonizing nature of the plant serves as habitat in the coastal dunes. Additionally, natural inkberry seedlings are rare and virtually all new growth in established natural areas originates from vegetative sprouting (personal observation), suggesting this plant may remain absent from the disturbed dune system for an extended period. Seed rain underneath trees, presumably due to the dispersion of seeds by birds, was thought to be the primary mechanism for seedling occurrence in a study of a slash pine (*Pinus elliottii*) savannah in Mississippi (Brewer, 1998).

Low available soil moisture limits transplant survival on barrier islands. Soil moisture in the upper 15–20 cm of course sands is rapidly depleted in the windy environment of barrier islands. Just 2 d after a 5-cm rainfall,

University of Florida, Institute of Food and Agricultural Sciences, West Florida Research and Education Center, 5988 Highway 90, Bldg. 4900, Milton, FL 32583.

This research was funded, in part, by grants from Department of Defense, Eglin Air Force Base, Jackson Guard, and US Fish and Wildlife Service. Florida Agricultural Experiment Station (FAES) journal series no. R-09856. Mention of products or trade names does not constitute an endorsement by FAES.

[1]Associate Professor of Environmental Horticulture. To whom reprint requests should be addressed. E-mail: Thetford@ufl.edu

[2]Associate Professor of Wildlife Ecology and Conservation.

[3]Graduate Student.

[4]Research Assistant.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
2.5400	inch(es)	cm	0.3937
6.4516	$inch^2$	cm^2	0.1550
0.5933	$lb/yard^3$	$kg{\cdot}m^{-3}$	1.6856
1000	mmho/cm	$\mu S{\cdot}cm^{-1}$	0.0010
1.6093	mph	$km{\cdot}h^{-1}$	0.6214
0.9464	qt	L	1.0567
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-17 via free access

soil moisture was less than 2% in the upper 15 cm of a quartz-dominated barrier island beach (Miller et al., 2003). Plants are also subjected to further injury associated with saline aerosol deposited on plant surfaces. Wind speed and deposition of salt spray generally decline sharply with distance from the ocean (van der Vaulk, 1974). Decreases in salt deposition with increased distance landward follow an exponential or power function (Ehrenfeld, 1990). Along the Carolina coast, on average 55% of the salt spray is deposited on the front of the foredune, 31% on the top and 14% on the back (a distance of about 40 m from front to back of foredune). After complete loss of vegetation and dune ridges on some areas of Santa Rosa Island, Fla., in 1995 from several strong storm surges, newly developing foredunes and small secondary dune ridges were sparsely vegetated. The effectiveness of these newly developing dunes as protection from desiccating winds and salt spray is unknown.

Conventional horticulture production systems use low profile containers resulting in transplants with fairly shallow root systems. The introduction of new container configurations has allowed for the production of more effective stock types for these types of plantings. The narrower and deeper pot designs generate a deeper root system, allowing transplants to maintain contact with the available soil moisture for a longer period of time than is the case with traditional shallow and wide container types with the same root volume. Production of transplants with root systems deep enough to access available soil moisture may improve transplant success. Optimal container volume and dimensions to produce a root system capable of surviving transplanting in coastal environments have not been identified. The objectives of this study were to 1) investigate the influence of production container on the survival and subsequent growth of gulf bluestem and inkberry transplants, and 2) document the effect of planting zone on survival of inkberry transplants.

Materials and methods

Gulf bluestem. Rooted cuttings of gulf bluestem were grown for 12 weeks in a nursery production mix containing 100% 0.5-inch screened, composted pinebark. This medium, and all other media used in the study were amended with 8.0 lb/yard^3 controlled-release fertilizer with minors (18N–2.6P–9.9K, Osmocote 18–6–12, 8–9 months; The Scotts Co., Marysville, Ohio). Plants were produced in four container types: gallon [round, 19 × 19 cm diameter (Lerio 015; Nursery Supplies, Inc., Kissimmee, Fla.)]; 0.75-gal treepot [square, 4 × 4 × 14 inches tall (Tall One treepot; Stuewe & Sons, Inc., Corvallis, Ore.)]; quart [round, 12 × 12 cm diameter (Classic 100; Nursery Supplies, Inc.)]; or 164-mL RLT [round, 8.25 × 1.5 inches diameter (Ray leach tubes SC-10; Stuewe & Sons Inc.)] as shown in Fig. 1. Containers were spaced based on the standard spacing of each container production system (pot to pot). Production densities increased as pot size (diameter) decreased. Root and stem biomass were measured for eight plants from each container type at the time of out planting. All plant tissues were dried at 70 °C for 72 h and weighed. These data were used to calculate a mean root:shoot ratio (w/w) for each pot type.

Gulf bluestem was planted on 8 Aug. 2000, 170 m landward of the Gulf mean high tide line on Eglin Air Force Base, Santa Rosa Island, Fla. Each plant received about 3.8 L of water on 9 Aug. 2000, and initial mean basal width (two widths measured), height, and tiller number were measured on 10 Aug. 2000. Survival, width, height, and tiller number were measured in Apr. and July 2001. Mean basal area was calculated as [π(½ mean basal width)^2]. No additional supplemental water was applied for the duration of this experiment.

The experiment used a randomized complete-block design with four plants of each container type planted 1 m apart in each of eight blocks for a total of 32 plants for each container type. Data were subjected to analysis of variance using the General Linear Model (GLM) procedures of SAS (SAS Institute Inc., Cary, N.C.). Significant differences between container sizes were determined by the LSMEANS/PDIFF option within the GLM procedure of SAS.

Inkberry. Seedlings of inkberry were produced from seed collected on Santa Rosa Island, Fla., and sown in Jan. 1999 using 72-cell insert flats containing a medium of Fafard Mix #2 (Canadian sphagnum moss, horticultural perlite, and vermiculite; Conrad Fafard Inc., Agawam, Mass). Seedlings were transplanted in April to quart containers with the same amended pinebark medium as used for gulf bluestem. Plants were transplanted to 3-gal treepot [round, 15.5 × 9 inch diameter (CC915; Nursery Supplies, Inc.)] or gallon containers in Sept. 1999 (Fig. 1). Eighty inkberry plants in gallon containers and 120 3-gal treepot containers were planted on Eglin Air Force Base, Santa Rosa Island, Fla., on 10 and 12 Apr. 2000. Plants were placed four distances landward (92, 124, 170, and 200 m) of the Gulf mean high tide line. At

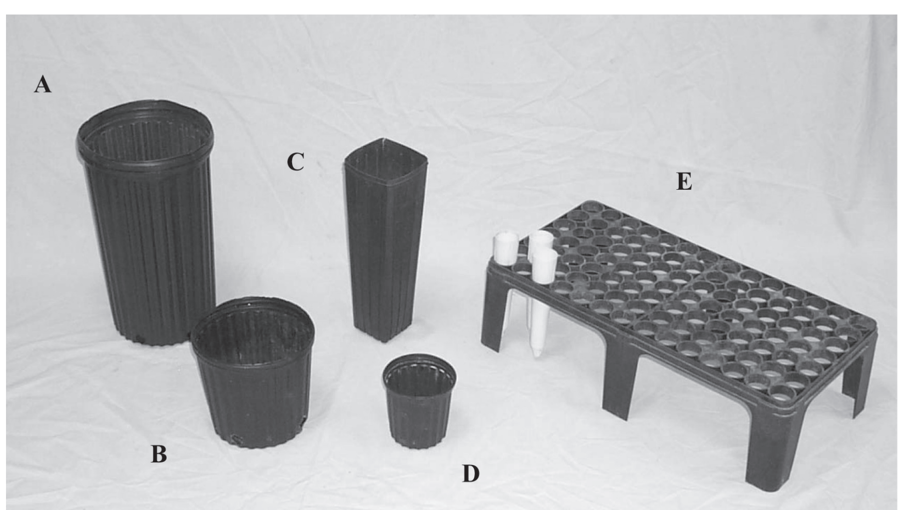

Fig. 1. Examples of containers used to produce beach plant transplants: (A) 3-gal treepot, (B) 1-gal (gallon), (C) 0.75-gal treepot, (D) 1-qt (quart), and (E) 164-mL Ray leach tube (1 gal = 3.7854 L; 1 qt = 0.9464 L; 1 mL = 0.0338 mL).

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-17 via free access

each distance, plants were planted in five blocks. A newly developing dune ridge of less than 1 m was found in front of the 92-m planting site. Also, newly developing ridges, all <1 m, were found between each of the subsequent distances. Within each block, four inkberry plants grown in gallon and six plants grown in 3-gal treepot containers were randomly planted 2 m apart. There were insufficient plants grown in gallon containers to provide six plants per plot. In addition to natural rainfall, plants received about 1 gal of water each week from 12 Apr. to 9 June by hand-watering from a local potable water source. Water application was directed both to the original root ball and the sand immediately surrounding the transplant to ensure adequate moisture in the production substrate until new roots established in the native sand. Direct irrigation of the bark-based production substrate was necessary because the abrupt difference in texture between the beach sand and the production media limits movement of water from the sand into the pinebark substrate of the root ball. The applied water would not accumulate in the production media because water can move freely from the course texture of the pinebark production substrate into the fine texture of the native sand.

FIELD ENVIRONMENTAL MEASUREMENTS. Soluble salts and percent soil moisture at each planting zone (distance from Gulf) were measured 5 Feb., 9 Apr., 9 May, and 6 June 2001. At each sample date, soil samples were collected from each block within distance (n = 5 for each distance) at a depth of 20 cm. Soil moisture was determined by weighing samples wet, oven-drying at 105 °C for 5 d and reweighing. Soil salinity was established by measuring soluble salts using a 2 distilled water: 1 soil (v/v) dilution method. After 24 h, solution electrical conductivity (EC) was measured with an Orion EC meter (Thermo Electron Corp., Waltham, Mass.). Wind speed was monitored for 5- to 7-d intervals from 4 Apr. to 6 July 2001 with a NRG#2100 Wind Totalizer (NRG Systems, Hinseburg, Vt.). Windborne salt spray was collected for 5 d on five occasions using two different types of salt spray apparatus, exposed and unexposed, with 25-cm^2 filter paper as the collecting surface. Salt-spray apparatus design followed Edwards and Claxton (1964). Total salt spray was determined by adding 200 mL of deionized water to 25-cm^2 filter paper. After 24 h, solution conductivity was measured with an Orion EC meter.

Inkberry were evaluated for percent shoot/leaf necrosis and defoliation and maximum height (centimeters) on 12 to17 May 2000. Height was measured from the top of the sand to the maximum foliar height. Survival, maximum height of live foliage, and mean canopy width [(width 1+ width 2)/2)] were measured Nov. 2000, Apr. 2001, and July 2001. Mean canopy area [$\pi(1/2 \text{ mean canopy width})^2$] was calculated.

The experiment had a factorial arrangement of treatments with distance (four levels) and pot size (two levels) as main factors. Planting followed a split-block design with five blocks randomly allocated to each of four distances from the Gulf and each block split into gallon and 3-gal treepot container sections (20 replicates). Survival was recorded as a binary (yes/no) measurement for each replicate. Test statistics and associated *P* values for survival were based on a chi square distribution. Because of the lack of survival for plants located 92 m landward and low survival for plants produced in gallon containers (15%) planted 124 m landward, differences in growth between container sizes were compared only for plants found 170 and 200 m landward. Survival and growth measurement for plants at 170 and 200 m did not differ. Mean values for plants found in 10 blocks (five per each of the two distances) were considered as replications. Significance of main effect of container size on growth variables was determined utilizing the Proc Mixed procedures of SAS. Significant differences between container sizes were determined by the LSMEANS/PDIFF option within the Proc Mixed procedure of SAS.

Results and discussion

GULF BLUESTEM. Root and shoot biomass of plants harvested after 12 weeks in container production were greatest ($P \leq 0.0001$) for plants grown in 0.75-gal treepot containers. Plants grown in gallon and quart containers were similar in biomass and greater than plants grown in RLT containers (Table 1). Root and shoot biomass were limited for the smaller container because the smaller volume of media provides less water and nutrients. However, root:shoot ratio for plants grown in gallon containers was less than for plants grown in RLT containers. The root:shoot ratio for plants grown in 0.75-gal treepot containers was intermediate between plants grown in gallon and RLT containers. Root:shoot ratio increased as container volume decreased, indicating a greater proportion of the biomass was allocated to root production when plants were grown in smaller containers.

The production systems in the present study place plants adjacent to one another (pot to pot). This spacing for the containers of differing diameters resulted in production densities that increased as container diameter decreased. This response for bluestem is different than results by Aphalo and Rikala (2003), who demonstrated a decrease in root:shoot ratio for silver birch (*Betula pendula*) seedlings as production density increased. The differing densities inherent in each production system may have been a factor in differences of root:shoot ratio. It is interesting to note that root:shoot ratio was a very poor indicator of subsequent gulf bluestem survival and growth in this study. Regardless of container size, survival of beach-planted gulf bluestem was 100%.

By Aug. 2000 (5 months after planting), maximum height of gulf

Table 1. Mean shoot dry weight, mean root dry weight, and root : shoot ratio for gulf bluestem 12 weeks after potting on 16 May 2000 in 1-gal (gallon), 0.75-gal treepot, 1-qt (quart), or 164-mL Ray leach tube containers.

Container[z]	Volume (L)	Root dry wt (g[y])	Shoot dry wt (g)	Root:shoot ratio
Gallon	3.8	9.2 b[x]	11.5 b	0.81 b
0.75-gal Treepot	2.8	12.4 a	15.1 a	0.84 b
Quart	0.9	9.8 b	10.4 b	0.94 ab
Ray leach tube	0.16	7.8 c	7.9 c	0.98 a

[z]Gallon = round, 19 × 19 cm diameter; 0.75-gal treepot = square, 4 × 4 × 14 inches tall; quart = round, 12 × 12 cm diameter; Ray leach tube = round, 8.25 × 1.5 inches diameter (1 gal = 3.7854 L; 1 cm = 0.3937 inch; 1 inch = 2.54 cm; 1 qt = 0.9464 L; 1 mL = 0.0338 fl oz).

[y]Means within a column followed by the same letter do not differ ($P \leq 0.05$).

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-17 via free access

bluestem remained influenced by container size with the greatest height evident with the 0.75-gal treepot containers and the shortest plants in RLT containers. Plants produced in gallon and quart containers had similar intermediate heights (Table 2). Differences in plant height were reflective of differences in production density and container width. Between Aug. and Apr. 2001 (12 months after planting), winter sand accumulation occurred around plants and was equal to the decrease in measured plant height, which ranged from 12 to 33 cm. Following winter dormancy, height of new tillers did not differ among the three larger container size treatments and by July 2001 (18 months after planting) maximum height was similar for all.

At the time of beach planting, mean tiller number for gulf bluestem was similar between plants grown in gallon and 0.75-gal treepot containers, which were nearly twice that of plants grown in quart containers, and over triple that of plants grown in RLT containers (Table 2). Tiller number remained highest for plants grown in gallon and 0.75-gal treepot containers and by July plants grown in gallon and 0.75-gal treepot containers again had almost twice as many tillers as plants grown in quart or RLT containers.

Initially (Aug. 2000), basal area was similar for plants grown in gallon and 0.75-gal treepot containers and greater than that of plants grown in quart or RLT containers (Table 2). Eight months after transplanting, mean basal area was over four times greater for plants produced in 0.75-gal treepot containers ($P \leq 0.0001$) compared to plants grown in quart containers and two to three times greater than plants grown in either gallon or 0.75-gal treepot containers. However, after 11 months, plants grown in gallon and 0.75-gal treepot containers were similar. Basal area for plants grown in 0.75-gal treepot containers was nearly twice as great as plants grown in quart containers and about three times greater than plants grown in RLT containers.

Differences in basal area between gallon and 0.75-gal treepot containers in Apr. 2001 may reflect differences in plant height from Aug. 2000, which were an artifact of the production systems (Table 2). Canopies of taller plants (Table 2) spread more in response to winter sand accumulation (generally greater than summer accumulation) than did shorter plants. In contrast, basal area in July 2001 was reflective of differences in tiller number. Height did not differ among container sizes in July 2001 and did not influence basal area. Kemery and Dana (2001) found no effect of container depth [13- vs. 18-cm-long tubes] on the size of little bluestem (*Schizachyrium scoparium*) and rough blazingstar (*Liatris aspera*) 2 years after transplant.

Table 2. Mean maximum height, mean tiller number, and mean basal area of gulf bluestem grown in 1-gal (gallon), 0.75-gal treepot, 1-qt (quart), or 164-mL Ray leach tube containers before planting on Santa Rosa Island, Fla., on 8 Aug. 2000.

Container[z]	Aug. 2000	Apr. 2001	July 2001
	Height (cm[y])		
Gallon	26 b[x]	11 a	15 a
0.75-gal Treepot	44 a	11 a	14 a
Quart	29 b	10 a	12 a
Ray leach tube	19 c	7 b	11 a
	Tiller no.		
Gallon	14 a	9 a	12 a
0.75-gal Treepot	15 a	9 a	13 ab
Quart	8 b	6 ab	7 bc
Ray leach tube	4 c	4 b	5 c
	Basal area[x] (cm^2)		
Gallon	36 a	333 a	986 a
0.75-gal Treepot	44 a	702 b	1417 ab
Quart	24 b	228 b	766 b
Ray leach tube	9 c	164 b	486 b

[z]Gallon = round, 19 × 19 cm diameter; 0.75-gal treepot = square, 4 × 4 × 14 inches tall; quart = round, 12 × 12 cm diameter; Ray leach tube = round, 8.25 × 1.5 inches diameter (1 gal = 3.7854 L; 1 cm = 0.3937 inch; 1 inch = 2.54 cm; 1 qt = 0.9464 L; 1 mL =0.0338 fl oz).
[y]Means within a column followed by the same letter do not differ ($P \leq 0.05$).
[x]Mean basal area = $[\pi(\frac{1}{2}\text{ mean basal width})^2]$.

Table 3. Mean air salinity ($\mu S \cdot cm^{-1}$) measured on Santa Rosa Island, Fla., at four distances from the Gulf of Mexico on five sample dates.

Distance	Mean air salinity ($\mu S \cdot cm^{-1}$)				
(m)[z]	Feb. 2001	Apr. 2001	May 2001	June 2001	July 2001
			Exposed[y]		
92	6.86	5.90	31.86	77.10	3.02
124	4.12	3.83	24.06	30.60	2.70
170	4.08	3.67	8.17	14.80	2.86
200	3.70	2.90	5.87	9.30	2.75
			Unexposed		
92	6.28	60.90	222.00	42.20	28.80
124	6.02	27.24	248.00	37.70	11.20
170	6.16	26.24	36.40	14.20	8.20
200	6.84	11.97	25.80	11.80	7.70

[z]1 $\mu S \cdot cm^{-1}$ = 0.0010 mmho/cm; 1 m = 3.2808 ft.
[y]Exposed = filter paper open to rainfall; unexposed = filter paper not exposed to rainfall.

Inkberry. Height of inkberry produced in gallon and 3-gal treepot containers differed when planted on the beach. Inkberry was taller ($P \leq 0.0001$) when grown in 3-gal treepot containers than when grown in gallon containers with mean plant height of 94 and 73 cm, respectively. Regardless of container size and across distances, 52% to 85% of the inkberry canopy defoliated within 1 month and 71% to 95% within 7 months of beach planting. All inkberry planted 92 m from the Gulf died. Most plant death occurred within 3 to 6 months of planting. Plants received supplementary water for 2 months and plant loss began about 1 month after watering ceased. Plants at 92 m were periodically subjected to greater windspeed, salt spray, and soil salinity, and lower soil moisture compared to all other distances (Tables 3 and 4).

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-17 via free access

Table 4. Mean soil moisture and soil salinity measured on Santa Rosa Island, Fla., at four distances from the Gulf of Mexico on four sample dates.

Date	Distance (m)[z] 92	124	170	200
	Soil moisture (% ± SE)			
Feb. 2001	4.48 ± 0.35[y]	4.59 ± 0.31	4.22 ± 0.27	7.84 ± 1.59
Apr. 2001	2.78 ± 0.22	2.80 ± 0.15	3.00 ± 1.04	9.26 ± 2.69
May 2001	1.72 ± 0.19	1.67 ± 0.17	1.99 ± 0.32	2.22 ± 0.97
June 2001	1.66 ± 0.20	1.94 ± 0.64	6.93 ± 5.16	9.26 ± 6.08
	Soil salinity ($\mu S \cdot cm^{-1}$ ± SE)[x]			
Apr. 2001	9.44 ± 3.04	5.72 ± 1.38	4.64 ± 0.30	5.32 ± 1.57
May 2001	15.64 ± 3.81	9.46 ± 4.15	6.74 ± 0.41	7.56 ± 2.11
June 2001	8.22 ± 3.34	5.60 ± 0.64	6.62 ± 1.25	8.70 ± 2.18

[z]1 m = 3.2808 ft.
[y]Mean of five samples ± SE.
[x]1 $\mu S \cdot cm^{-1}$ = 0.0010 mmho/cm.

Table 5. Survival of inkberry grown in 1-gal (gallon) and 3-gal treepot containers 15 months after planting on Santa Rosa Island, Fla., at four distances from the Gulf of Mexico.

Distance (m)	Container[z] Gallon	3-gal Treepot
	Survival (%)	
92	0 c[y]	0 b
124	15 b	83 a
170	50 a	87 a
200	40 a	77 a

[z]Gallon = round, 19 × 19 cm diameter; 3-gal treepot = round, 15.5 × 9 inches diameter (1 gal = 3.7854 L; 1 cm = 0.3937 inch; 1 inch = 2.54 cm).
[y]Means within a column followed by same letter do not differ ($P \leq 0.05$).

Table 6. Mean maximum height of live foliage, and mean canopy area for inkberry grown in 1-gal (gallon) and 3-gal treepot containers before planting at Santa Rosa Island, Fla., on 10 and 12 Apr. 2000.

Container[z]	Nov. 2000	Apr. 2001	July 2001
	Mean maximum ht (cm)[y]		
Gallon	29[x]	27	28
3-gal treepot	55	50	43
	Mean canopy area[x] (cm^2)		
Gallon	277	356	585
3-gal treepot	1420	1356	1388

[z]Gallon = round, 19 × 19 cm diameter; 3-gal treepot = round, 15.5 × 9 inch diameter (1 gal = 3.7854 L; 1 cm = 0.3937 inch; 1 inch = 2.54 cm).
[y]For all variables, within each date, means differed significantly between container sizes ($P \leq 0.0004$).
[x]Mean canopy area (cm^2) = [π(½ mean canopy width)^2].

Average wind speed was 8.5, 5.6, 4.3 and 4.7 mph, respectively, for beach zones located 92, 124, 170, and 200 m from mean high tide line. However, salt deposition at 124 m was periodically comparable to that found at 92 m and higher than found at 170 and 200 m. Soil moisture was periodically greater at 200 m compared to all other distances. Generally, inkberry is found growing on interior portions of Santa Rosa Island with at least some protection from salt spray (personal observation). Other studies on Santa Rosa Island have also documented diminished salt spray deposition with increasing distance from the gulf (Burkhalter 1987). Survival of inkberry grown in smaller containers was greatest with distances of more than 170 m (Table 5). Other than at 92 m, survival of plants grown in 3-gal treepots (>75%) was similar for all other planting zones and two to six times greater ($P \leq 0.0001$) 15 months after planting than when grown in gallon containers. Necrotic foliage was significantly greater (98% vs. 36%) on transplants from smaller containers. When the entire canopy was lost, regrowth occurred from basal sprouts. Plants with regrowth were considered survivors. Larger, deeper-rooted plants produced in the 3-gal treepot were better able to survive higher wind speeds, periodically greater salt deposition, and periodically decreased soil moisture found at 124 m.

After 15 months (July 2001) at distances of 170 and 200 m landward, plants grown in 3-gal treepots remained larger with 1.5 times the mean maximum height and 2.25 the mean canopy area compared to those grown in standard containers (Table 6). Inkberry produced in 3-gal treepot containers ultimately retained the greatest size in the dry, windy, saline environment of the coastal dune. Retention of the original canopy from the initial production phase and emergence of shoots near the base of the plants was greater for plants grown in 3-gal treepot containers. Even though this alternative production system improved plant performance, it is not possible to determine if the performance for plants grown in 3-gal treepot containers can be attributed to greater volume (3 vs. 1 gal), greater depth (15.5 vs. 7.5 inches), or a combination of these two factors.

Restoration projects in the southwestern United States identified container size and shape as important factors affecting transplant survival and growth. Narrow, deeper containers reportedly increase survival and growth of southwestern desert plants (Bainbridge, 1994; Miller and Holden, 1992). Increased container size increased survival of seedlings of white spruce (*Picea glauca*) (Sutherland and Day, 1988), and seedling height increased when container volume was tripled. Aphalo and Rikala (2003) also noted that the main determinant for performance of container-grown silver birch seedlings after 5 years in the field was the cell volume of the containers.

Conclusions

Container volume and dimension did not affect transplant survival of gulf bluestem. However, the initial differences in transplant size resulting from production density and container volume influenced the subsequent total vegetation cover. The justification for using plants produced in larger or deeper containers would be to achieve greater ground cover in a shorter time frame. In this experiment sand accumulation associated with various container sizes was not measured. If the initially larger plants accumulate sand more rapidly, the initial cost of the larger transplant would be justified for use in

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-17 via free access

restoration where sand accumulation is the goal. However, until these data become available, we recommend the use of the gallon or 0.75-gal treepot container when the goal is the development of cover for sand stabilization while the most economical container can be used if survival is the criteria for project success.

Inkberry survived greater wind speeds, salt deposition, and lower soil moisture found nearer to the Gulf when grown in 3-gal treepot containers. The greater survival for inkberry grown in 3-gal treepot containers suggests the root systems of greater volume and depth increased transplant success for this woody species. In this case the initial cost of the larger transplant could easily be justified by the greater survival and greater area of vegetative cover provided by the plants from 3-gal treepot containers. With a price (PlantFinder 2003) of $2.25 for a plant in a gallon container and $5 for a plant in a 3-gal treepot container, the respective actual plant costs for surviving plants were $4.50 (50% survival) and $6.25 (80% survival) for plant material alone. Additionally, labor costs associated with replacing dead plants, although variable by firm or location, would be an additional consideration and may further increase the cost per plant. Aside from the economics of installation and replacement costs, the ecological objective of adding shrub cover may be achieved more quickly with the use of inkberry grown in 3-gal treepot containers. We recommend planting inkberry grown in the 3-gal treepot containers particularly when planting in areas of high salt deposition, windspeed, and low soil moisture. Regardless of size, we do not recommend planting inkberry except in a beach zone with a foredune ridge (>1 m) or another similar source of protection between the planting and the Gulf and at least 142 m from the Gulf mean high tide line.

Literature cited

Aphalo, P.J. and R. Rikala. 2003. Field performance of silver-birch planting-stock grown at different spacing and in containers of different volume. New For. 25:93–108.

Bainbridge, D.A. 1994. Container optimization—Field data support container innovation, p. 99–104. In: T.D. Landis and R.K. Dumroese (eds.). Natl. Proc., For. Conservation Nursery Assn. Gen. Tech. Rpt. RM-257. U.S. Dept. Agr., For. Serv., Rocky Mountain For. Range Expt. Sta., Fort Collins, Colo.

Brewer, J.S. 1998. Patterns of plant species richness in a wet slash-pine (*Pinus elliottii*) savanna. J. Torrey Bot. Soc. 125(3):216–224.

Brown, R.L. and A.L. Hafenrichter. 1962. Stabilizing sand dunes on the Pacific Coast with woody plants. U.S. Dept. Agr., Soil Conservation Serv., Misc. Publ. 892. U.S. Govt. Printing Office, Washington, D.C.

Burkhalter, J.R., 1987. An ecological study of coastal strand vegetation on the western end of Santa Rosa Island near Pensacola, Florida. MS Thesis, Univ. of West Florida, Pensacola.

Dirr, M.A. and J.H. Alexander III. 1991. *Ilex glabra*—The inkberry holly. Arnoldia 51(2):16–22.

Edwards, R.S. and S.M. Claxton. 1964. The distribution of air-borne salt of marine origin in the Aberystwyth area. J. Appl. Ecol. 1:253–261.

Ehrenfeld, J.G. 1990. Dynamics and processes of barrier island vegetation. Rev. Aquatic Sci. 2:437–480.

Gore, J.A. and T.L. Schaefer. 1993. Santa Rosa beach mouse survey. Nongame Wildlife Program Final Performance Rpt., Fla. Game Fresh Water Fish Commission, Tallahassee.

Halls, L.K. 1977. Southern fruit-producing woody plants used by wildlife. U.S. Dept. Agr., For. Serv. Gen. Tech. Rpt. SO-16.

Holler, N.R. 1992. Choctawhatchee beach mouse, p. 76–86. In: S.R. Humphrey (ed.). Rare and endangered biota of Florida: Vol. I. Mammals. Univ. Presses of Florida, Gainesville.

Johnson, A.F. 1997. Rates of vegetation succession on a coastal dune system in northwest Florida. J. Coastal Res. 13:373–384.

Kemery, R.D and M.N. Dana. 2001. Influence of container size and medium amendment on post-transplant growth of prairie perennial seedlings. HortTechnology 11(1):52–56.

Miller, C. and M. Holden. 1992. Propagating desert plants, p. 68–71 In: T.D. Landis (ed.). Natl. Proc., Western For. Nursery Assoc. General Tech. Rpt. RM-221. U.S. Dept. of Agr., For. Serv., Rocky Mountain For. and Range Expt. Sta., Fort Collins, Colo.

Miller, D.M., L. Yager, M. Thetford, and M. Schneider. 2003. Potential use of *Uniola paniculata* rhizome fragments for dune restoration. Restoration Ecol. 11(3):359–369.

Moyers, J.E. 1996. Food habitats of gulf coast subspecies of beach mice (*Peromyscus poliontus* spp.) MS Thesis, Auburn Univ., Auburn, Ala.

Oosting, H.J. and W.D. Billings. 1942. Factors affecting vegetational zonation on coastal dunes. Ecology 23:131–142.

Sutherland, D.C. and R.J. Day. 1988. Container volume affects survival and growth of white spruce, black spruce and jack pine seedlings: A literature review. Northern J. Appl. For. 5(3):185–189.

Swilling, W.R., M.C. Wooten, N.R. Holler, and W.J. Lynn. 1997. Population dynamics of Alabama beach mice (*Peromyscus polionotus ammobates*) following Hurricane Opal. Amer. Midland Naturalist 140:287–298.

Van der Valk, A.G. 1974. Mineral cycling in coastal foredune plant communities in Cape Hatteras National Seashore. Ecology 55:1349–1358.

Wagner, R.H. 1964. The ecology of *Uniola paniculata* L. in the dune strand habitat of North Carolina. Ecol. Monogr. 34:246–252.

Woodhouse, W.W., Jr. 1978. Dune building and stabilization with vegetation. Spec. Rpt. No. 3. Coastal Eng. Res. Ctr. (78-75889), Ft. Belvoir, Va.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-17 via free access