Container Optimization—Field Data Support Container Innovation

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INTRODUCTION

Container planting is essential for successful revegetation or restoration of most dry sites. Therefore, one of the most important choices in developing a planting program is determining the container that best meets biological and bureaucratic requirements and will provide the maximum number of survivors in the field at minimal cost. The primary function of the container is to hold the growing medium, which supplies the roots with water, air, mineral nutrients, and physical support. Although surprisingly little research has been conducted on container considerations for dry sites since (Goor, 1963), evidence suggests that deeper (taller) containers may be beneficial (Bainbridge, 1987; Smith, 1988; Felker et al., 1988; Newman et al., 1990; Holden, 1992).

This study reviews the field experiences of the desert revegetation group at San Diego State University over the last 8 years with transplanted container plants. We have found that excellent seedling survival and growth can be expected even in areas with less than 3 inches [75 mm] of rain per year if plants are well prepared and provided with minimal water (2-3 supplemental waterings totalling about 2 quarts) and protection (cages and/or treeshelters).

The most economical method for plant establishment has been outplanting seedlings from relatively small containers (Super-cells or plant bands) with a fast draining high sand content soil mix (limited or no fertilizer). Out-planting before tap root dominance is affected and roots are distorted (often within 3-6 weeks of germination) is desirable for smaller containers. At this stage, the primary leaves may be just emerging with a 1-2" shoot and 10-12" roots. Plants should be hardened off in the nursery by gradually reducing water and increasing exposure to full sun before outplanting. Pruning the tops a week before transplanting may be helpful.

Planting dates should be based on plant species characteristics. Mid-summer may be hard on labor but well suited for plant survival and growth. Winter planting, at least for deciduous species such as mesquite, has been less effective. Spring planting appears to be most promising, especially if soil moisture has been recharged.

BIOLOGICAL CONSIDERATIONS

Seedlings destined for dry sites are a **root** crop and survival on difficult sites is often deter-

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mined by the ability of the root system to access soil moisture and generate new roots. Many of the containers we use are designed to encourage seedlings to form a good root system and to protect the roots while the seedling is planted. A high root:shoot ratio is desirable, and plants may be pruned before planting to improve this ratio.

The size of the seed or cutting, growth rate, disease sensitivity, temperature preferences and other environmental requirements of the seedling influence container choices. The desired size of the plant at planting, desired growth rate after planting, available irrigation methods and water quality, access to, and environmental conditions at the site all affect container options.

Although container type has traditionally referred simply to volume, it should also include shape. One of the most biologically important container dimensions is height (depth), because of its effect on the water-holding properties of the potting mix. The relation of height to width is the aspect ratio (AR=W/H). Aspect ratios of common containers range from 0.14 to 0.85. The emphasis on deep rooting leads to preference for containers that are tall but narrow.

Seedling size can be increased with larger containers. Containers for desert planting range from less than 10 in^3 (164 cm^3) to more than 850 in^3 (14,000 cm^3). Larger containers are more expensive to buy and fill, take up more growing space, require longer growing periods for the seedling root system to effectively occupy the container, and are difficult and more costly to handle in the nursery, during shipping and when planting.

While almost any soil mix can work with sufficient attention to water and nutrient management, the key is finding a mix that requires as little attention as possible. Species that tolerate a wide range of soil conditions may require little customizing, but species that are more sensitive can require careful mix development and nursery management. We have found that sand with some perlite or pumice is often a good starting point for desert shrubs.

Growth media in deep containers and containers with a high aspect ratio has different physical properties, water relations, and porosity than in traditional shallow containers. Soil mixes may need to be adjusted to compensate for these changes. Nutrient and water availability should also be tested for different media compositions.

Most species are mycotrophic (Allen, 1991) and pre-inoculation with mycorrhizal (ecto or VAM) fungi is recommended for planting on large scale, severely disturbed sites where native inocula are likely to be limited. Experimentation may be necessary to develop growth media appropriate for the plant, its microsymbionts, and container characteristics. The VA mycorrhizal fungi are oxygen demanding and often phosphorus sensitive.

Excessive root temperatures (hot or cold) can inhibit or kill roots and root symbionts. Darker colored containers may reach surface temperatures above 160°F in the summer in the low desert. Plant bands, which are assembled with heat set glue, can melt and delaminate unless seams are placed to the inside of blocks.

BUREAUCRATIC CONSIDERATIONS

The potential for delays in delivery, acceptance date, and irrigation and maintenance scheduling must be considered. Cost and availability of the container, soil mix, irrigation, cost of handling and planting, and available growing space are also important. Container seedling quality commonly increases with decreased growing densities so a nursery manager often struggles to minimize spacing without reducing health. Developing a vigorous and resilient seedling is critical because survival in the field is the primary goal.

Racks with individual cells are desirable because they can be readily sorted. This is particularly important with poorly understood plant species or low quality seeds. Diseased or otherwise undesirable seedlings and non-filled cells can be removed or replaced. When matched cohorts are needed for experiments these can be selected. Consolidation also saves space in the greenhouse and during storage and shipping.

CONTAINER COMPARISONS

The best container to use depends on the season, the handling process, the species, and the project. One of the most important considerations is determining which size and depth is most cost-effective, **providing the lowest cost per survivor**. Bigger containers will be more expensive, both to grow and plant; but may improve survival significantly.

Supercells

We have extensive experience with the ten cubic inch Supercell (from Stuewe and Sons). They are relatively easy to fill, sort, ship and plant. However, the rigid plastic trays that hold the cells are relatively fragile and easily damaged if they are repeatedly handled while loaded with seedlings. A Supercell weighs approximately 1/2 pound when it is full of sand. A rack of 98 is too heavy for field work and cells are usually transferred to a 5 gallon bucket (with inter-nal rack) which makes handling easier and provides protection from wind and sun.

Seedlings are removed from containers by gently squeezing the supercell or rapping the top of the cell on a hard surface (using momentum to dislodge the plant/soil). Plants with fragile roots can be more gently removed by kneading the cell under water. In general, the sandy soil mixes falls away from the plant and the seedling is effectively bare-rooted.

An experienced planting crew of three (students and desk bound researchers) can plant 150-225 plants per day under typical field conditions using KBC bars. This includes hauling water, watering, and placing grazing protection on the plants. Production decreases rapidly when air temperature exceed 100°F. Inexperienced volunteer teams may plant only half as many plants per day.

Estimated planting cost runs from $0.50 to $5.00 each depending on species characteristics, number of plants and site characteristics. Total planting costs (after two waterings) may be as high as $5-10 dollars for each Supercell (including plant cost, planting, plant protection, labor for watering, and administrative costs).

We like Supercells for predictable planting programs where delay is unlikely. Seedlings for some species should be outplanted in 8-12 weeks.

Plant bands

Plant bands are square tubes made with folded and glued plastic or foil coated cardstock. Standard sizes are available for small orders, but virtually any size can be custom made for larger orders. A wide range of plant band sizes have been tested with generally positive results (up to 3"x3"x24" inches). Taller plant bands improved survival on a harsh site at Red Rock Canyon State Park, Figure 1. Unfortunately, rabbits learned how to kick over treeshelters and terminated this experiment before the searing dry heat of summer.

Plant bands can be placed on screen, filter fabric or paper. They can be grouped on pallets and banded or set in boxes or beverage crates. They can be stapled together at the top to make filling easier. Although they are discrete units, the loose soil mix we use makes sorting and repacking plant bands difficult.

Plant bands 2"x2"x14" weigh about 2 pounds each and are usually racked in groups of 30 and broken into groups of 3-5 for

The L.A. Moran Reforestation Center in Davis, California has developed a 4"x24" smoothwall pipe pot. These Mini-tall pots weigh one third and cost less than half as much as standard tall pots. They should retain many of the advantages of Tall pots while significantly reducing cost and bulk.

Pipe sections are highly recommended for a percentage of total plants for all harsh sites. Tall pots provide a very tough plant with potential for very fast growth. Excellent protection from bureaucratic and biological uncertainty. Container optimization.

Table 1. Container planting rate.

Container	Per person day
Supercell	50-100
Supercell jellyroll	100-200
Plant band 2x2x14	100-120*
1 gallon pot	40
2 gallon pot	30
Tall pot	10

*50-100 if container must be torn off.

Planting seedlings is an essential part of most revegetation and restoration projects. Planting rates and costs depend on temperature, labor, soil moisture, and site conditions. Typical planting rates for remote sites, hand carried plants, including water, watering and plant protection with academic planting crews are outlined in Table 1.

Container grown seedlings are heavy and awkward to ship and handle in the field, making outplanting expensive (Bainbridge and Virginia, 1990). Removing the seedlings from their containers at the nursery and wrapping them in moist fabric (a technique known as jellyrolling) can make handling less costly. An ice chest holding several hundred jellyrolled plants may weigh only 40 pounds. Planting is faster than from containers and survival compares favorably to containerized plants (Fidelibus, 1994). Jellyrolling may not work as well for species with brittle or easily torn fine roots.

COST PER SURVIVOR

Costs are commonly underestimated in planning and reviewing projects. Planting small plants in urban areas may cost more than $15 each if administration and maintenance costs are included. More accurate cost estimates make it possible to determine the best approach for planting on the basis of cost per survivor. Estimates of these costs are shown in Table 2 for small projects on remote sites. Tree planting crews and larger projects may reduce cost 50% or more.

SUMMARY AND CONCLUSION

The smallest container that will work is usually the most cost effective. Under ideal conditions, Supercells can be very successful. In uncertain biological or bureaucratic environments deeper containers such as plant bands (2"x2"x14") are better. Tall pots (6"x32") will have excellent survival and rapid growth even in very difficult conditions. This can be very beneficial when quick visual recovery is important.

Although there is no one container or production system suitable for all conditions and species, seedlings grown in deeper containers improve survival and growth. The cost for 500 surviving plants per acre

Table 2. Container stock, nursery and field (typical).

Container	Cost nursery	Percent survival	Relative cost (plant band=1)
Supercell	0.10-1.50	30	1.5
Supercell jellyroll	0.12-1.70	30	1.4
Plant band 2x2x14	1.50-3.50	70	1
1 gallon pot	3.00-5.00	10	2
2 gallon pot	5.00-10.00	15	2.5
4x24 Minitall pot	3.00-5.00	80	1.5
6x32 Tall pot	9.00-25.00	95	3

can range from $5-10,000. Costs for Tall pot plantings required for fast visual recovery can exceed $40,000 acre $^{-1}$. A combination of small through large containers can be used to maximize survival at reasonable cost. This might include 10% tall pots (32x6), 20% mini-tall pots (4x24), 40% plant bands (2x2x14) and 30% supercells. At the end of one year in the field the sizes of shoots might be expected to be 4-6 inches for a supercell, 12 inches for plant band, 15 inches for a pipe pot, and 24 inches from a tall pot. This provides a wide range of resilience and survivability. Multiple size classes and more diverse plant architecture can be both biologically and aesthetically important.

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