Revegetating Desert Plant Communities[1]

David A. Bainbridge[2], NaDene Sorensen[3], and Ross A. Virginia[4]

Bainbridge, David A; Sorensen, NaDene; Virginia, Ross A. 1993. Revegetating desert plant communities. In: Landis, T.D., technical coordinator. Proceedings, Western Forest Nursery Association; 1992 September 14-18; Fallen Leaf Lake, CA. General Technical Report RM-221. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 21-26. Available at: http://www.fcnanet.org/proceedings/1992/bainbridge.pdf

Abstract.--Research and revegetation projects in the low desert of California have demonstrated the feasibility of transplanting native plant species to very severe sites, with annual rainfall <3 inches, temperatures >90°F possible any month, high winds with sand blast, and heavy grazing pressure. The keys to success are plant protection, limited irrigation, and careful plant preparation and planting.

INTRODUCTION

Six years of research in revegetation and restoration work in the low desert of California (>90°F in any month, <3 inches rainfall per year) has demonstrated the importance of transplanting key species to enhance recovery. Excellent survival can be expected with minimal irrigation if plants are well prepared, planted carefully, and provided with protection from herbivory, sand-blast, and microclimatic extremes.

Our experience suggests that the most economical method for plant establishment is putting out very young plants from small containers (supercells or plant bands). Most species should be grown in a fast draining, high sand content soil mix (low or no fertilizer), inoculated with rhizobia and Vesicular-Arbuscular (VA) Mycorrhizae if appropriate, and outplanted before the tap roots are distorted (often within 3-6 weeks of germination).

The primary leaves may just be started with a top 1-2" tall and roots 8-12" long. These should be hardened off in the nursery with gradual reduction in water and exposure to full sun before outplanting. Pruning the tops back a week before transplanting may be helpful.

If planting will be done in an area where soil has been compacted it should be loosened before planting with a tractor mounted ripper, tree planting auger, or garden fork.

Timing is less critical than many people expect. We have had excellent survival of mesquite (*Prosopis glandulosa*) seedlings planted from supercells in midsummer. Palo verde (*Cercidium floridum*) seedlings were more sensitive to the 115°F air temperature and drying winds.

THE ESSENTIALS

Despite the increasing recognition of the global importance of desert degradation, revegetation and restoration in arid environments have not been extensively studied. Extreme temperatures, intense solar radiation, limited moisture, and the low fertility of desert soils combine to make natural recovery of these areas very slow after disturbance. Conditions for plant establishment are infrequent, and it may take many decades to reach predisturbance biomass and hundreds of years for recovery of species diversity. Experiments in the Sonoran and Chihuahuan Deserts beginning as early as 1890 have demonstrated the difficulties involved in direct seeding, with a successful planting only in one of ten years. As a result we have emphasized transplanting key species to enhance recovery.

Recent ecological studies of plant growth, nutrient cycling, water use, and herbivory and long-term experiments in the low desert of California have provided information that will aid revegetation efforts in many arid and semi-arid regions. These studies have demonstrated that successful transplanting in these difficult conditions requires a coordinated effort to reduce plant stress and optimize conditions for survival. Key elements in this process include: plant protection, irrigation, inoculation with symbiotic micro-organisms, appropriate plant preparation, and careful planting. These are described in the following sections.

---

[1]Paper presented at the Western Forest Nursery Associations Meeting, Stanford Sierra Camp, Fallen Leaf Lake, CA. September 14-18, 1992.

[2]David A. Bainbridge is staff Restoration Ecologist, Biology Department, College of Sciences, San Diego State University, San Diego, CA 92182

[3]NaDene Sorensen is a graduate student in Ecology, College of Sciences, San Diego State University, San Diego, CA 92182

[4] A. Virginia is Professor and Chairman of the Environmental Studies Program, Rm 324, Murdough Center, Dartmouth College, Hanover, NH 03755

PLANT PROTECTION

Hungry animals and reptiles are fond of fresh salad greens. Protection from herbivory (particularly black-tailed jackrabbits) and high winds with sand blast is desirable and often essential. There are three primary options and two less effective alternatives.

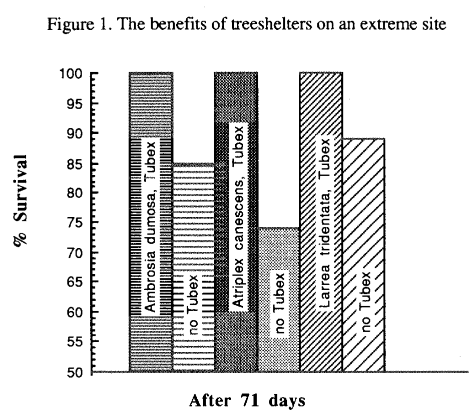
Tree shelters

Tubex™ treeshelters (various heights 8"-6'). Oak stakes or pencil rod (and a 2 lb. hammer) for taller shelters and heavy gauge wire and wire cutters to make pins to hold down the short tubes.

These commercial twin wall translucent plastic shelters are expensive but require very little preparation time and are easy to install. The 8" tall tubes were $0.55 in summer 1990, 2' were $2.05. These tubes have an inside diameter of 3-4" and are not well suited for spreading plants. Diameters vary so the treeshelters can be nested for shipping. They are easy to handle, install, and reuse. Plastic nets or sticks placed vertically in the tube may be needed to keep lizards out of the treeshelters in the desert (and birds in more temperate areas). Nets are available from the supplier.

Tubex™
75 Bidwell Street, Suite 105
St. Paul. MN 55107
(800) 328-4827 ext 1906

Figure 1. The benefits of treeshelters on an extreme site



Anza-Borrego Desert State Park, from supercells with 1 liter per month by deep pipe irrigation

Wire cages

Pliers and wire cutters, aviation shears, 1/2" hardware cloth or aviary wire and aviary clips with special pliers, bubblepack plastic, scissors, wire or tape, 2 lb. hammer, pencil rod (1/4" reinforcing steel) cut in 2-3 ft lengths.

Wire cages can be custom made to fit every occasion. They should be big enough so the plant will not grow into the wire soon and should be removed before the plant becomes entangled. Cages three feet tall and 1-2 feet in diameter are often suitable. Rabbits are controlled with a vertical fence but some rodents may require a complete cage. A wrapping of bubblepack plastic greatly improves the value of the shelter and will promote more growth in cooler months. This should be wired or taped to the mesh.

Window screen or fine mesh plastic may be required for insect protection (rarely needed). Protection from cattle and wild horses and burros can be provided with concrete reinforcing wire mesh and 3/8" or 1/2" rebar or T-posts.

Peat collars

Peat collars, wire pins.

Peat collars provide moderate protection and are inexpensive and biodegradable. They reduce herbivory, sand-blast, and environmental stress and make irrigating easier.

International Reforestation Suppliers (IRS)
P0 Box 5547
Eugene, Oregon 97405
(800) 321-1037

Rock mulch

Gloves, rocks (fist-sized and larger) and labor.

Arranging large rocks around seedlings provides decent protection. Rock mulch may slow growth by reducing soil temperatures but may be least objectionable aesthetically and doesn't need to be removed.

Less effective but still worth considering:

Plastic mesh protectors

IRS protective plastic mesh tubes, hammer, pencil rod.

Less costly than the Tubex™ and adequate if grazing pressure is moderate to low. The pencil rod is woven through the mesh and hammered in. The mesh is available with different decay rates and fertilizer content. A plastic film sleeve is available but awkward to install and short-lived.

IRRIGATION

It is difficult to establish plants in arid areas without supplemental water. Survival often runs 1-2% (or less) without irrigation. Planting after heavy rains or flood events can be very successful but it is very hard to plan and mobilize for these rare events.

Deep pipes

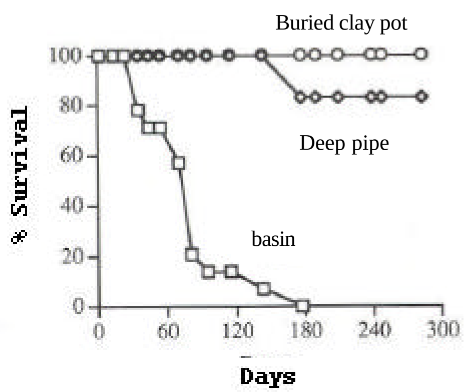
Deep pipe irrigation uses a vertical pipe to place irrigation water in the deep root zone. This is commonly done with 1/2" to 2" diameter PVC pipe* placed 12-18' (or deeper) into the soil. Use 1.5 - 2' diameter pipe for hand watering and smaller diameters for pipe networks. Small holes should be drilled down the side nearest the seedling if the roots will be very far above the pipe bottom when they are planted. The plant should be closer to the pipe in coarse sand and can be further away in clay (check wetting pattern from a test pipe).

A 1/8 inch galvanized mesh wire screen disk (custom cut by TWP Wire Mesh, 2133 Fourth Street, Berkeley, CA 94710 (800) 227-1570)is glued on top with silicone caulk to keep lizards and rodents out of the pipe. Covers can also be used but removing the cover increases the time and cost of watering. The pipes can be filled from a water jug, water truck, or fitted with a drip emitter.

Deep pipe irrigation is better than surface or buried drip systems in several respects. First, it can be used with low quality water. Second, it enables a significant amount of water to be applied quickly (4-5 times faster than basin irrigation) and efficiently with little waste. The deep delivery minimizes evaporation and encourages deep root growth.

Experiments have shown that the deep pipe drip system is much more efficient than surface drip or conventional surface irrigation. Deep pipe irrigation develops a much larger effective rooting volume and produces a plant much better adapted to survive on its own after limited watering during establishment. The pipes can be collected at the end of a year or two and reused.

Figure 2. Survival by irrigation method



Palo verde seedlings from super cell, Coachella Valley

In areas where the materials and technology for drip systems are available the deep pipe system can be used to enjoy the benefits of buried drip systems with greater ease. Drip emitters are fitted so they water inside the buried pipe and in effect become surface mounted deep delivery systems. They can be monitored and repaired much more easily than buried emitters. We have set up a remote tank with a battery powered timer to feed the tubes with good success.

Bamboo with a hole punched through the membrane would work well and be biodegradable. Tin cans with a hole punched in the bottom have been used in Kenya. Waxed cardboard tubes may also work but uncoated cardboard disintegrates rapidly.

Current tests are evaluating a backpack injection system to eliminate the need for drilling holes and setting the deep pipes.

Watering into treeshelters or collars

The Tubex™plastic treeshelters can be pushed or hammered into the ground so that a seal forms at the bottom. They can then be used for watering by pouring about a quart of water into the tube every 2-6 weeks. This has worked very well in the low desert with several species. Disease problems from excessive humidity have been reported when this method is used in humid areas. However, the simplicity of this system and the low water requirements make it a good choice for arid and semi-arid areas or dry seasons. Collars of plastic or peat 3-4" tall and 3-4" in diameter can be used in a similar manner.

Buried clay pots

Buried clay pot irrigation uses an unglazed earthenware pot filled with water to provide controlled irrigation to plants growing near it. Standard red clay garden pots are suitable if the bottom hole is plugged with silicone caulk. The pot is buried so only the rim protrudes above the surface.

Eight inch pots are a good size to use. A clay dish or an aluminum pie tin with a rock glued to it makes a good lid. A hole is drilled or punched into the lid to let rainwater into the pot.

The water seeps out of the buried clay pot at a rate that is influenced by the plant's water use. This leads to very high efficiency – even better than drip irrigation. Buried clay pots can be filled by hand if labor is inexpensive or connected to a pipe network.

Buried clay pot irrigation has been very successful with a wide range of plants in the low desert--including ocotillo, mesquite, palo verde, and white bur sage. It is excellent for germinating and starting seeds, maintaining cuttings, and maintaining seedlings.

Buried clay pots are not as Sensitive to clogging as drip emitters, although they may clog over time (3-4 seasons) and require renewal by reheating the pots. Buried clay pots are less likely to be damaged by animals or clogged by insects than drip systems (spaghetti tube is often a favorite of chewing rodents). And finally, while even a brief interruption of water supply to a drip irrigation system can lead to serious plant damage the buried clay pot systems may require water only once every two to four weeks. Buried clay pot irrigation can be very effective in areas affected by salinity or where only saline water is available for irrigation.

HANDLING WATER

Water is heavy and awkward to carry. From many years of experience we have developed methods that use as little water as possible, but water must often be transported to remote planting sites.

Thirty gallon plastic drums (available used for.$10-15--get food grade with sealing plug threads in good condition) are the mast reasonable size to put in most vehicles. These should be well secured with load straps and load bars. A hand or 12 volt transfer pump can be used to set up a siphon to fill smaller jugs. A water trailer or collapse-a-tank for a pickup would be useful.

Most fit people can carry 3 gallon jugs, two jugs are almost as easy to carry as one. Older people and volunteers may do better carrying two 1 gallon jugs full of water.

INOCULATION

Most desert plant. species form symbiotic associations with VA mycorrhizae. Mycorrhizae can increase a plant's. effective root volume by infecting roots and producing fungal threads or hyphae. These can improve the host plant's ability to access nutrients (particularly phosphorus)and water. One centimeter of infected root may produce 80 centimeters of fungal hyphae. Mycorrhizae also help the host plant compete with weeds for available water and nutrients.

Mycorrhizae may also reduce plant pathogen problems. The mycorrhizae can protect the root from infection by blocking pathogens or simply by improving nutrition and plant health.

Mycorrhizal fungi also contribute to improved soil aggregation and recovery of soil structure. Aggregation of soil particles can increase infiltration of rain water, improve root growth, and enable greater hyphal extension..

Rhizobia (bacteria) are also important in revegetation in the desert because they enable leguminous plants (lupine, mesquite, astragalus, psorothamnus, etc.) to convert atmospheric nitrogen to a form available to plants in these nitrogen limited environments. Once atmospheric nitrogen is made available to the plant much of it will be recycled to the soil through litter, fall and root turnover, improving soil fertility. Soil under mesquite trees in the Sonoran desert has been found to have nitrate levels as high as the most productive agricultural soils.

Procedures

Since VA mycorrhizae are needed most by plants growing on nutrient limited soils, healthy plants from areas near the site often provide the best inoculum. Inoculum can be collected by gathering soil and fine roots from under these healthy plants. This soil/root inoculum can then be placed in the planting holes of transplants. Rhizobial inoculum may need to be taken from the deep roots (2 m deep) with a soil auger. Pure single or preferably multi-strain inocula can also be prepared to inoculate plants in the nursery or during planting.

SOIL AMENDMENTS AND FERTILIZER

Fertilizer is rarely used in desert plantings despite the low inherent fertility. Phosphorous fertilizer can inhibit mycorrhizal infection and nitrogen can inhibit nodule formation and nitrogen fixation: The nutrients also encourage excessive shoot development and transpiration -- a big risk in the desiccating desert environment.

Other soil amendments are usually not required. When amendments are needed, bark and chunks of wood have worked better than more decomposable materials such as straw. The larger chunks deteriorate slowly and do not blow away as easily as lighter materials. Material with these higher carbon: nitrogen ratios provides a long-term food source for fungi and these in turn provide grazing for microarthropods. This can make nitrogen available to plants for a longer period of time. Application rates of bark may be high, up to 10 tons per acre or more.

Straw can be used if it is crimped in or tackified. Rice straw is preferred as it is very durable and less likely to contain weeds. Bundles of rice straw set vertically into the soil have worked well in restoration efforts, probably by limiting wind erosion and increasing infiltration. These bundles have persisted for several years even in more humid coastal environments.

PLANT PREPARATION

Seed from the site or from the same ecotone should be collected, cleaned, and stored for plant production. Seed quality is very variable from year to year in the desert and there may be no seed of many species for several years in a row. Fortunately the seed for many species will keep well for decades with simple storage.

Many desert seeds require scarification by chipping, acid soaks, treatment with hot or boiling water, stratification, heating, or extensive rinsing to remove inhibitors. Desert species often have low resistance to fungi and seed borne. pathogens can be a problem. Surface sterilizing the seed with dilute bleach (1 part household bleach to 3 parts water) followed by careful rinsing may be helpful. Test small lots to ensure that germination is not harmed by scarification or disinfection methods.

Most seedlings should be started in a fast-draining sandy mix in carefully cleaned or sterilized supercells or plant bands. They will grow rapidly during the hot summer months and may be ready to plant in 3-6 weeks.

The seedlings can be removed from the container on site or at the nursery. The plant top is gently held to the side and the opposite edge of the supercell is rapped against a rock or hard surface to loosen the roots. This may take a little practice. The edge should be hit hard against the rock with a short but quick motion so the mass of the plant shakes free. If the roots are sticking to the cell kneading the cell may help. Plants with fragile roots can be extracted underwater by massaging the cell and tilting it back and forth.

Seedlings in plant bands can be removed by unpeeling or cutting the plant band with a razor knife. A sharp hooked blade will make this easier.

The bare-rooted seedling is then carefully held by the stem and placed in the planting hole or in jelly-roll fabric. Seedlings removed at the nursery should be immediately placed in damp Kimtex™ jelly-roll material (from IRS), set in plastic bags, and kept cool or refrigerated. The fabric is rolled up as more seedlings are added. This reduces the weight and space requirements for transporting plants to the field site. While a sand-filled rack of 98 supercells may weigh close to 50 pounds, a 30 pound ice chest may hold 1000 plants in jelly-roll fabric and ice.

PLANTING

You are on site with all tools, materials and plants in racks or in jelly-roll. Give the plants a drink and keep them in the shade or in a cooler throughout the day. Set out materials near the planting spots before beginning work. Location markers (wire flags) with color or easily read codes should be used to identify planting locations, species, and treatments. Markers also make future monitoring easier.

Teams of 4 people work well, with assignments as digger, planter, waterer, and plant protection setter and plant hauler.

Making the planting holes

The KBC bar is forced into the ground to the full depth to create a planting hole. In sandy loose soils the water person pours about a quart of water around the KBC bar to hold the hole open when the tool is removed. If the sides collapse it may help to reverse the bar while reinserting it. An auger or hoedad can be used in more cohesive soils.

Setting the plant

The plant (from container or jelly-roll) is tenderly picked up and the root (essentially a mini-bare root) is gently lowered into the hole. It is placed against the side of the hole made by the edge of the KBC bar while the hole is carefully back-filled. Match the soil depth to the plant collar (where it was buried in the container) and the surrounding soil surface. In sandy soils it may be possible to deep plant the seedling, removing the lower branches and setting it into a deep hole. If inoculum for mycorrhizae or rhizobium is used it should be placed in the hole now.

Some species, including palo verde benefit from a dip in a thin loam slurry before planting. Others, including creosote bush may be adversely affected. The hole is gently back-filled and firmed with hand pressure or gentle footsteps.

Protection

After the plant is in the ground the protection should be added. The Tubex™ treeshelter or peat collar is simply placed over the plant and the stake or pin is driven into the ground. The nylon tie on the Tubex™ is then pulled tight against the stake.

A wire cage is also simple to install. Place it over the plant and thread the pencil rod through the wire before hammering it into the ground. Bubblepack can then be wired to the cage.

Rock mulch is made with fist-sized or larger rocks placed close to the plant to form a small box. Shade from the south and west sun is most important

Irrigation

If no irrigation systems will be installed a basin should be formed around the plant and another quart of water should be applied.

A plant with a treeshelter should also receive about a quart of water. If a clay pot or deep pipe is used it should be filled with water.

If irrigation systems such as clay pots or deep pipes will be used they should be set in place before the planting day. This is a good winter activity for volunteer labor.

Numbering or marking

Not enough is known about survival and establishment of desert plants. Marking plants and monitoring long-term survival are important. A double-sided aluminum tag or permanent paint mark will identify the plant for many months. Aluminum tags can be wired to the cage or placed under a rock. If deep pipes, clay pots, or Tubex™ are used the
number can be marked with paint. A hand-drawn map or photos will also help you find plants later. A series of photographs or video tapes is very helpful.

SUMMARY

Plant establishment on arid sites requires careful attention to many factors. Neglect of any one of these may lead to failure. Below-ground conditions are very important and have not always received sufficient attention.

If careful preparation of plants and planting sites is combined with good planting practices and protection excellent survival and growth may be achieved at low cost. Minimal water (1/2 gallon per month for 3-4 months) can improve survival and speed growth.

FURTHER READING

Allen, E.B. ed. 1988. The Reconstruction of Disturbed Arid Lands: An Ecological Approach. Westview Press, Boulder, CO 267p.

Bainbridge, D.A. 1990. The restoration of agricultural lands and drylands. pp. 4-13, In 1. Berger, ed. Restoring the Earth. Island Press, Covelo, CA

Bainbridge, D.A. and Virginia, R.A. 1990. Restoration in the Sonoran Desert. Restoration and Management Notes 8(1):3-14

Cox, J.R., Morton. H.L., Johnson, T.N., Jordan, G.L., Martin, S.C. and Fierro, L.C. 1982. Vegetation restoration in the Chihuahuan and Sonoran Deserts of North America. Agriculture Reviews and Manuals #28. U.S.D.A. Agricultural Research Service, Tucson, Arizona 37 pp.

Virginia, R.A. and Bainbridge, D.A. 1988. Revegetation in the Colorado Desert: lessons from the study of natural systems. pp. 52- 63. In Proceedings of the 2nd Native Plant Revegetation Conference, Society for Ecological Restoration, Madison, WI

ACKNOWLEDGMENTS

Support for this research was provided by the California Department of Transport ation, District 11 and the California Department of Parks and Recreation Stewardship Fund. Special thanks to John Rieger and Jim Dice for their interest and support.

With special thanks and appreciation to the many people who have helped us over the years. Wes Jarrell; Robin McBride; Mike and Edie Allen; Bob Moon, Carol Miller, Mark Holden and the staff at the Center for Arid Systems Restoration at Joshua Tree National Monument; ABD Irrigation; Laurie Lippitt; Tom Landis; Mark Jorgensen; Debbie Hillyard; Ted St. John; and many students and staff at SDSU, William Carey International University, and countless volunteers.

SUPPLIERS

International Reforestation Suppliers
P0 Box 5547
Eugene, Oregon 97405
(800) 321-1037

Ben Meadows Company
3589 Broad Street
Atlanta, GA 30341
(800) 241-6401

Containers– Stuewe and Sons
2290 SE Kieger Island Rd
Corvallis, Oregon 97333
(503) 553-5331

Plant bands--Pacific Western Containers
1535 East Edinger
Santa Ana, CA 92705
(714) 547-9266

Plant bands--Monarch Manufacturing
13154 County Rd 140
Salida, CO 81201
(719) 539-3335

SELECTED DESERT SEED SUPPLIERS

Desert Enterprises
P.O. Box 23
Morristown, AZ 85342
(602) 388-2448
stock and contract collection

Wild Seed
2077 East ASU Circle
Tempe, AZ 85284
(602) 345-0669
stock and contract collection

S & S Seeds
P.O. Box 1275
Carpinteria, CA 93013
(805) 684-0436
stock and contract collecting

Plants of the Southwest
Route 6, Box 11A
Santa Fe, NM 87501
(505) 471-2212 mail order
stock seed only

Granite Seed Co.
Box 177
Lehi, Utah 84043
(801) 786-4422
stock

Figure 3. Mesquite (*Prosopis glandulosa*) after 27 months from supercells. With Tubex™ treeshelters and less than 5 gallons total irrigation water. Near Oasis, California.