

were compressed to reduce moisture content. The trees were inserted full length into polyethylene sleeves and packed in cartons with any necessary insulation. Instructions were sent with the trees regarding two possible planting alternatives as follows: (1) The rootpads were placed up against 15-cm soil walls. (2) A slit of loosened soil was prepared in advance with a pick axe. Planting took place after rainfall with the possible addition of a little water to completely saturate the soil. The tree was removed from the polyethylene sleeve. The tag end of the pad was placed flush over the end of the sleeve and directly over the slit. A 12-cm-wide blunted metal blade pressed on the tag end forced the rootpad downwards, clamped between the polyethylene and the blade. The blade and sleeve were then extracted. This operation was very fast and especially useful under rough, sloping, and rocky conditions.

Flat root mass tree roots have been examined a year after planting by extraction under water pressure. The root systems were found to have reverted to their natural configuration, sending down anchor roots in a symmetrical manner.

Propagation of Promising High-Elevation Species Native to the Colorado Plateau

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INTRODUCTION

The Arboretum at Flagstaff is located at an elevation of 7150 ft on 200 acres of the world's largest ponderosa pine forest. It is the mission of the Arboretum to study and display native plants and plant communities of the Colorado Plateau. It is also our mission to identify, evaluate, and introduce into cultivation plants adaptable to the climatic conditions of the Plateau.

With an area of 170,000 square miles, the Colorado Plateau includes elevations from 2000 to 14,000 ft. Parts of Arizona, New Mexico, Utah, and Colorado are located on the Plateau. Known throughout the world as the site of the Grand Canyon, the Plateau is one of the most environmentally varied and sought-after environments in North America. It was here that C. Hart Merriam pioneered his system of life zones, with all of the six zones represented on the Plateau.

PLANT COMMUNITIES AND CLIMATIC FACTORS

The Arboretum's living collections include plants from desert grassland, chaparral, pinyon-juniper, ponderosa pine and mixed conifer forests, and alpine plant communities, as well as from riparian zones, seasonal wetlands, and native grasslands.

Included in our collections are plants from USDA Temperature Zones 2 through 6, (Sunset Western Garden Zone 1) reflecting a range of recorded minimum temperatures between -20 and -50°F. Much of the average annual precipitation of less than 25 inches is lost to runoff and evaporation caused by strong winds, bright sun, and low relative humidity.

The Plateau has been described as a "a land of extremes and surprises." Native to the western great plains and mountains of New Mexico, Maximilian's

sunflower (*Helianthus maximiliani*), like many Plateau natives, thrives on the extreme solar radiation and bright sun characteristic of the region. Clear night skies allow for fluctuations between night and daytime temperatures of as much as 50 or 60°F.

Winters can be cold and dry, with patchy snow cover, and early spring snows are usually heavy. The last spring frost may arrive as late as mid-June. Late spring and early summer are warm and dry until the advent of summer monsoons in July. With the onset of high humidity and rainfall from the monsoons, plants burst quickly into full growth. When the monsoons end, the earliest killing frost has been known to arrive in early August. A dry autumn rounds out the year.

COLLECTION OF PROPAGULES

When collecting propagules of native plants we are careful to obtain permission from landowners or government agencies and to abide by state and federal plant laws. We pay special attention to plant identification, characteristics of successful plant propagules, and proper timing of their collection.

With such a brief active growing season, summer is the time for most vegetative propagation. Cuttings from outdoor specimens must be taken between June and September, before the onset of plant dormancy. The seed collecting season runs from June into October or early November; its end is determined by the onset of the first snows.

DETERMINING CHOICE OF PROPAGULES

Two major considerations in determining which propagules to collect and use are ease of propagation and availability of propagules. Geranium-leaf larkspur (*Delphinium geraniifolium*) germinates readily from seed with 2 months cold stratification. New Mexico locust (*Robinia neomexicana*) will germinate with a combination of scarification and cold stratification. Wax currant (*Ribes cereum*) can be propagated from fresh seed, from stored seed with 3-months cold stratification, or from tip and stem cuttings. One decisive factor in our collecting efforts is always availability of propagules. Animals including elk, deer, grazing sheep, cattle, and grasshoppers abound on the Plateau. One of the challenges of wild collection is finding plants with seed, fruit, and tender shoots intact. Timing collection before the arrival of the elk herd or the movement of sheep through an area is often critical.

When germinating seeds with no known propagation information available, we consider when seeds mature, disperse, and germinate and what temperatures and environmental conditions occur in their habitat during seed maturation and germination.

SOME EASY PLANT PROPAGULES

An example of an easy-to-propagate native plant is *Petrophytum caespitosum* or rock mat. Rock mat is native to dry rock ledges and occurs naturally from South Dakota and Montana to New Mexico, Arizona, and California. It sets very fine seed that germinates with 3 months cold treatment. Cuttings root readily in 2 to 3 weeks. The plant forms adventitious roots easily and can be propagated by division. Although noted in *The Jepson Manual* (Hickman) as “difficult” to cultivate, it is easy to grow in the high, dry west.

A native of temperate regions of North America and Eurasia found in mountains of Northern Arizona at elevations above 8000 ft, common juniper (*Juniperus communis*) is easily propagated from cuttings in the autumn.

Nuttall's linanthus (*Linanthastrum nuttallii*), a showy perennial native to open pine forest at elevations of 5500 to 8000 ft, sets seeds one at a time as flowers bloom, so collection is difficult. Cuttings with #8 rooting hormone take readily when obtained during the early months of summer and circumvent the problems of seed collection.

While many dryland species of evening primrose (*Oenothera* spp.) show irregular seed germination, New Mexico evening primrose (*O. neomexicana*) and other native *Oenothera* species are easily grown from tip and stem cuttings during their active growing season.

Agrimony (*Agrimonia striata*) is another native plant where timing of collection determines the propagules to be used. During the early months of summer, the plant is easily grown from cuttings. Mid-season seed is available and germinates readily given 1 month cold stratification. Once the plant shows fall color, it is no longer easy to grow from cuttings, but can be divided readily.

HANDLING SEEDS OF THE HIGH AND DRY WEST

Once seed is collected, options for seed handling include storage in native soil or fruit and dry storage. Seed of some species should be planted immediately upon collection. For other species, seed handling decisions can be critical to success.

Common in southeastern and central Arizona at elevations of 4500 to 8000 ft, alligator juniper (*J. deppeana*) is difficult to propagate from seed or cutting. Preliminary studies conducted at the Arboretum indicate that storage of seed in native soil (following storage methods outlined in Keeley and Fotheringham, 1998) contributes substantially to increased percentage of seed germination. As alligator juniper is a stump-sprouter following fires, further germination tests involving subjecting the seeds to smoke treatment after storage in soil will be conducted at the Arboretum.

New Mexican raspberry (*Rubus neomexicanus*) is a deciduous shrub native to canyons and forest openings in New Mexico and Arizona. Tip and stem cuttings from young growth root rapidly; once the plant sets fruit in mid summer cuttings root more slowly, while seeds from macerated fruit germinate rapidly at 70°F.

Another native shrub, Fremont barberry (*Berberis fremontii* syn. *Mahonia fremontii*) is quite difficult to propagate from cuttings or cleaned, stored seed. Fresh seed stored briefly with fruit intact germinates readily upon maceration of the fruit and planting of the seed.

Many seeds of Plateau species will germinate readily when fresh seed is sown with light. Examples are willows (*Salix* sp.) with seed viability often as brief as 48 h from dispersal; Arizona alder (*Alnus oblongifolia*) and the autumn-blooming pleated gentian (*Gentiana affinis*). Fresh seed of the pleated gentian will germinate with or without a 3-month cold stratification.

DORMANCY AND SEED TREATMENTS

The most common methods employed at the Arboretum to break seed dormancy are cold stratification; scarification with hot water, sandpaper or sharp object; regimes allowing fluctuation of temperature including alternating periods of 40 and 70°F

(Deno, 1993), and overwintering outdoors for the entire cold season (November to May); and prolonged soaking for 3 to 5 days.

Alkali checkerbloom (*Sidalcea neomexicana*) germinates uniformly and readily when subjected to a 3-day cold-water soak. Without the soak, it germinates sporadically over a period of many months. Pearlseed (*Macromeria viridiflora*) germinates successfully after a 24-h cold water soak.

As is to be expected in a region with a long cold season, many species germinate readily after cold moist stratification of varying lengths. Agrimony (*Agrimonia striata*) requires 1 month cold. Depending on their environmental origin, native penstemons such as Sunset Crater penstemon (*Penstemon clutei*) may require 1 to 5-months cold treatment; treatment too long will actually diminish germination. Six-weeks cold treatment ensures uniform germination in James' golden buckwheat (*Eriogonum jamesii* var. *flavescens*). Two low-growing, high-elevation native perennials, sky pilot (*Polemonium viscosum*) and silvery cinquefoil (*Potentilla hippiana*) require 2 to 3 months cold stratification.

At the Arboretum, we routinely place seeds that will not otherwise germinate outside for a prolonged cold treatment throughout the entire winter season. Seeds are watered in, protected from rodents and birds, and placed where they experience outdoor seasonal weather fluctuations including snow, freezing, and thawing. Three species which have responded well to this treatment are spikenard (*Aralia racemosa*), winecups (*Callirhoe involucrata*), and Parry's primrose (*Primula parryi*).

We have had success germinating several species by allowing their seeds to experience natural diurnal temperature fluctuations during the active growing season. These species include Rocky Mountain beeplant (*Cleome serrulata*), golden aster (*Heterotheca foliolosa* syn: *Chrysopsis foliolosa*) and various coneflower species (*Echinacea* spp.)

CONCLUSION

There are many species native to the high elevations of the Colorado Plateau which warrant cultivation. As the "new west" continues to grow and develop, there is an unmet demand for plants which are native and adapted to the rigors of the high and dry west. At the Arboretum at Flagstaff, we have been experimenting with their cultivation and maintaining propagation records since our founding in 1981. It is our goal to place our propagation results on line at our web site: <http://www.thearb.org> by February 1999, and to link our site to the IPPS homepage.

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Propagation Safety

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As we strive to meet the needs of our nurseries and customers, we focus on production issues that directly affect our success. Production timing, efficiency, labor, supplies, climatic conditions, and inventory all demand attention. But how often do we consider safety or give it the attention, time, and resources deserved? After all, the most valuable asset of any operation is its people. Work related accidents and illnesses can rob the employee, his/her family and the nursery of health, livelihood, and productivity.

Health and safety issues are often perceived as time-consuming, costly, and nonproductive. This perception can become reality for the propagator/manager that adopts it with a negative attitude. However, for the nursery person who embraces a proactive approach, the rewards are significant and long-lasting.

This paper is not intended to be an instructional "how-to guide". It is, however, intended to encourage a second look at safety conditions in our nurseries and to reconsider the importance of safety issues and their impact.

Every type of business has its inherent safety risks and propagation facilities are no exception. Although the hazards may be all around us, they may be invisible to the untrained eye or preoccupied person. When safety awareness becomes a priority, safety issues seem to lurk everywhere.

OBSTACLES

Conditions in and around greenhouses offer hazards in the form of trips and falls from wet, slippery, and uneven surfaces, or improperly stored hoses. Greenhouse construction and maintenance many times requires a person to climb ladders or work from lifts to change poly, often under difficult weather conditions. Thus, ladder safety and proper use of restraints are important.

Many overhead obstacles are also present in the form of greenhouse bracing, heaters, traveling booms, and even hanging baskets.