Selection, Production, and Use of Riparian Plant Materials for the Western United States[1]

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Abstract.--Riparian plantings are established to restore native plant communities, stabilize streambanks and shorelines, restore fish and wildlife habitat, improve surface and groundwater quality, and control weedy phreatophytes. Native planting stock may be collected from local sources or provided by commercial nurseries. Source guidelines are based on relatively narrow target areas inferred from riparian site classifications and constrained by limited knowledge of the genetic structure of plant populations. Riparian plant cultivars are developed with specific structural attributes. Nurseries should emphasize production of large plant materials, such as stumps and poles.

INTRODUCTION

Resource managers in the western United States have given increasing emphasis to riparian zones in the past 15 years, as evidenced by numerous symposia on the subject and allocation of funds to riparian management projects.

The first documented riparian revegetation projects were installed in the eastern United States during the thirties and forties (see Altpeter 1944, Edminster 1949, Edminster and others 1949). The technology for revegetating riparian zones, based on European experience, was augmented and refined during the fifties and sixties (Porter and Silberberger 1960, Stanton and McCarlie 1962), and its use has spread to other parts of the country (Roseboom and White 1990, Roseboom and others 1991), including the west (Lines and others 1979, Carlson 1979, Anderson and others 1979, Monsen 1983, Patterson and others 1984, York 1985, Stanley and others 1989, Carlson and others 1991).

Based on the earlier plantings, two willow cultivars have been released for commercial production and use in riparian plantings in the eastern states. Streamco purpleosier willow *(Salix purpurea),* selected from a naturalized population of the European species imported to North America for basket-making during colonial times, was released in 1975 (Carlson and Preston 1976) and has been used extensively. Bankers willow (*S. x cotteti*), released in 1983, is a clone from a natural hybrid of two species (S. *retusa* and S. *myrsinifolia)* occurring in the European Alps, and has proven useful for riparian plantings (Gilbert and Henry 1983). Moreover, both have been produced and used to a limited extent in the west, with good results.

In the western states, riparian plant screening and selection for the past 15 years has focused on native species, resulting in the recent release of 15 cultivars and anticipated release of several more during the nineties (table 1). Commercial production is just underway.

The Soil Conservation Service (SCS) defines riparian zones as natural ecosystems occurring along watercourses or water bodies, occupying the transitional area between terrestrial and aquatic ecosystems. SCS makes a distinction between riparian and wetland plantings with two conservation practices, (1) Channel Vegetation and (2) Wetland Restoration and Development. The former emphasizes (but is not restricted to) woody plants, the latter herbaceous aquatic/wetland species. This paper concentrates on the need for, selection, and production of woody riparian plants for revegetation projects in the western states.

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Table 1. Released or pending woody plant cultivars selected for revegetation of riparian zones in the western United States.

Cultivar	Year Released	PMC	Source
Long barclay willow *(Salix barclayi)*	1985	Alaska	Palmer, AK
Roland pacific willow *(Salix lucida* ssp. *lasiandra)*	1985	Alaska	Palmer, AK
Wilson bebb willow *(Salix bebbiana)*	1985	Alaska	Palmer, AK
Oliver barren ground willow *(Salix brachycarpa)*	1985	Alaska	Palmer, AK
Rhode feltleaf willow *(Salix alexensis)*	1985	Alaska	Palmer, AK
Multnomah Columbia River willow *(Salix fluviatilis)*	1988	Oregon	Multnomah Co., OR
Nehalem pacific willow *(Salix lucida* ssp. *lasiandra)*	1988	Oregon	Columbia Co., OR
Placer erect willow *(Salix eriocephala* ssp. *ligulifolia)*	1988	Oregon	Placer Co., CA
Plumas sitka willow *(Salix sitchensis)*	1988	Oregon	Plumas Co., CA
Clatsop hooker willow *(Salix hookeriana)*	1988	Oregon	Clatsop Co., OR
Rogue arroyo willow *(Salix lasiolepis)*	1990	Oregon	Curry Co., OR
Bashaw douglas spiraea *(Spiraea douglasii)*	1990	Oregon	Snohomish Co., WA
Mason redosier dogwood *(Cornus sericea* ssp. *stolonifera)*	1991	Oregon	Mason Co., WA
Snowbar snowberry *(Symphoricarpos albus)*	1991	Wash.	Okanogan Co., WA
Trailar western clematis *(Clematis ligusticifolia)*	1991	Wash.	Columbia Basin, WA
9020059 drummond willow *(Salix drummondiana)*	--	Wash.	Ferry Co., WA
9020099 coyote willow *(Salix exigua)*	--	Wash.	Columbia Co., WA
9020100 Mackenzie willow *(Salix eriocephala* ssp. *prolixa)*	--	Wash.	Columbia Co., WA
9020121 lemmon willow *(Salix lemmonii)*	--	Wash.	Lake Co., OR
9035395 Rio Grande cottonwood *(Populus fremontii* ssp. *wislizenii)*	--	N.Mex.	Belen, NM
9035372 black willow *(Salix gooddingii)*	--	N.Mex.	San Acacia, NM
9045531 black willow *(Salix gooddingii)*	--	N.Mex.	San Antonio, NM
9032491 black willow *(Salix gooddingii)*	--	N.Mex.	Ojo Caliente, NM

RIPARIAN REVEGETATION OBJECTIVES

A riparian revegetation project produces what SCS terms "conservation effects". These effects benefit soil, water, plant, and animal resources.

Restoration of the Native Riparian Plant Community

The intent of this objective is to establish the major native plant components described in the riparian community type (Padgett and others 1989) or other suitable site description, including on-site species inventory. Plantings may consist of species of various successional stages. However, plantings of only late seral species may leave safe sites for invasion of introduced, undesirables weeds. Knowledge of riparian successional stages and an assessment of native seed sources adjacent to the site help shape a sound planting specification.

Streambank Stabilization

The emphasis in this objective is to maximize root mass and stem densities close to the bank surface. Vegetation increases bank stability with above ground stems which slow the velocity near the bank, reducing the tractive force of water against the surface. Vegetation also provides an erosion-resistant "armored" blanket of roots at the bank surface. Larger vegetative structures (shrub mats, fascines, live crib walls, pole or stump plantings), which root and become well anchored provide stability in the same manner as other engineering structures of inert material. Shrub willows with a decumbent profusion of pliable stems are Ideal plants for stabilization. Tree willows and cottonwoods are ideal for bioengineering techniques.

Shoreline Stabilization

Similar to streambank stabilization, but here the main cause of erosion is wave action. Stump or pole plantings create breakwaters which dissipate wave energy before it reaches the shore. Dense, stemmy woody vegetation may absorb wave energy at the shoreline itself. Sod-forming grasses and other herbaceous plants also may protect shorelines from direct wave attack. Inundation tolerance is important for waterbodies with fluctuating shorelines.

Fish Habitat

This objective focuses on vegetation which provides shading to keep stream temperatures within acceptable limits, provides escape cover (submerged branches and debris), and habitat for insects and other sources of food. In most situations, revegetation involves native species.

Wildlife Habitat

Riparian zones are primary habitat areas for wildlife. Revegetation provides food and cover for key upland species, with emphasis on plant species diversity and creating edge. Native trees, shrubs, and forbs are recommended, unless a non-weedy introduced species provides a significantly better habitat value than can be gained by using exclusively natives.

Maintaining and Improving Water Quality

A heavily vegetated riparian area is a very important filter for removing pollutants from surface water before it enters the stream. Vegetation captures sediment, and the biotic community in a well developed, rich, high humus plant soil interface consumes nutrients and breaks down organic compounds carried in surface water. Riparian buffer strip widths depend on the adjacent surface drainage area. A 30:1 ratio of drainage area to filter area is a common rule-of-thumb for filter strips. Incoming surface runoff should be managed to take full advantage of the buffer.

Riparian forests also are useful in removing nitrogen from near surface groundwater. Cottonwood or poplar whips planted five feet deep in high planting densities adjacent to streams have rooted along the entire length of the buried stem, providing an effective zone for nitrogen uptake (Licht and others 1991).

Control of Introduced Weedy Phreatophytes

Saltcedar *(Tamarix* sp.) is a serious weedy riparian plant in the southwestern U.S., replacing many native communities. It is highly volatile and persists in solid stands through its ability to withstand periodic wildfires that kill competing vegetation. An effective treatment has been to mechanically remove saltcedar and plant tall cottonwood poles into the summer water table to grow rapidly and produce canopy closure within 10 years. The planting provides sufficient shade to preclude the re-establishment of the sun-loving saltcedar.

EXAMPLES OF RIPARIAN REVEGETATION PROJECTS

Case histories of riparian projects provide insight into how plant materials are used to produce desirable effects. Following are four examples in the last decade, involving input from SCS plant materials centers.

Green River, Washington

This project is located south of Seattle in the largely urbanized meander zone of the river before it enters Puget Sound. It originally was part of a demonstration program administered by the U.S. Army Corps of Engineers. The riparian community includes black cottonwood *(Populus balsamifera* ssp. *trichocarpa),* red alder *(Alnus rubra),* sitka willow *(Salix sitchensis),* scouler willow (S. *scouleriana),* and pacific willow (S. *lucida* ssp. *lasiandra).*

In fall 1980, approximately 1600 feet of an eroding streambank on the outside of a meander was shaped back at 3:1, rip-rapped to the low water mark, and planted to native species, including pacific willow, redosier dogwood *(Cornus sericea),* douglas spiraea *(Spiraea douglasii),* and snowberry *(Symphoricarpos albus).* A total of 16,500 container seedlings were transplanted over the entire bank. Prior to planting, sections of the bank were covered with chicken wire or quarry spalls (1-2 inch gravel). A grass-legume seeding was applied on the upper bank to control surface erosion (fig. 1)

Survival initially was good to excellent along the lower bank. The grass-legume seeding inhibited shrub establishment on the upper bank (fig. 2). In 1984, overall survival was 22 percent, with pacific willow and douglas spiraea the most successful, 34 and 27 percent respectively. The lower one-third of the bank was covered by shrubs. In 1986 survival had dropped to 18 percent but canopy increased as plants matured to cover the lower one-half of the bank. Invading black cottonwood, red alder, and sitka willow became established in significant but sporadic numbers in the sediment deposited in the rip-rap. The upper bank included significant populations of seeded herbaceous birdsfoot trefoil *(Lotus corniculatus)* and invading reed canarygrass *(Phalaris arundinaceous).* Invading native black cottonwood established on the gravel road at the top of the bank. In 1988, shrub cover on the upper bank continued to increase (fig. 3) as the surviving plants, particularly douglas spiraea, produced more canopy.

Figure 1.--Streambank planting along Green River, Washington; June, 1981, start of first growing season.

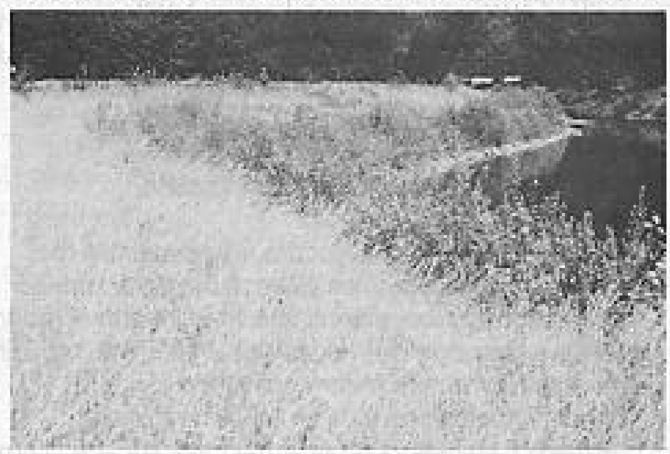

Figure 2.--By August 1983, shrubs perform well on lower bank; grass competition is severe on upper bank.

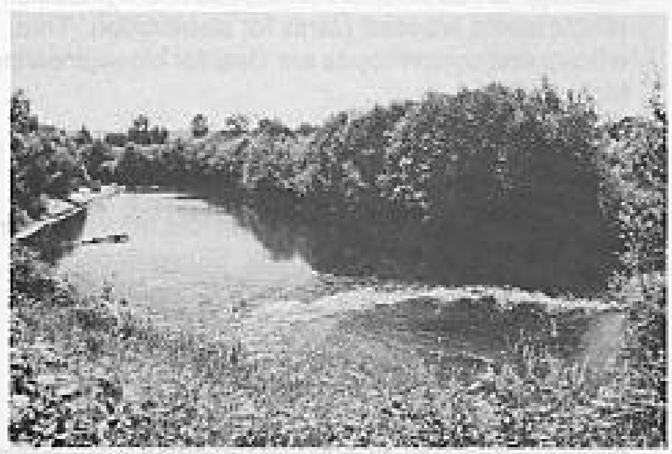

Figure 3.--Photo taken from opposite end of stream reach in August, 1988; shrubs cover most of bank and overhang into the river.

American Falls, Idaho

American Falls Reservoir is located in eastern Idaho northwest of Pocatello on the Snake River. It provides irrigation water to farms on the Snake River Plains. It occupies a prehistoric lakebed, with shorelines of lacustrine deposits of volcanic ash and loess soils. Wind driven wave action has scoured shorelines producing 20 to 40 foot vertical cliffs during the 60 year life of the reservoir, and in some places the shoreline has retreated hundreds of feet. An estimate 20 miles of shoreline need treatment.

Since 1986, various plantings have been made to explore lower cost options to rip-rap, jetties, and other structural measures to control bank erosion (Young 1989, Hoag 1991). Fluctuating waterlines from spring re-fill to summer drawdown impose harsh conditions not conducive to plant establishment. This is reflected by a paucity of native vegetation along the shore, despite ample seed sources nearby. Woody vegetation is limited to three species of willow *(Salix exigua, S. lutea,* and introduced S. *fragilis),* confined to relatively protected areas.

Planting experience quickly revealed the need to use large-sized plant material, such as dormant whips, stumps, or poles at least 1 inch in diameter. Smaller plants were easily washed away the year following establishment, even those with root growth spreading twenty feet or more along the shore. Plantings now consist of dormant willow or cottonwood stumps 8 to 12 in length, 3-5 inches in diameter, planted at least 3 feet deep to the midsummer water table. The stumps are sufficiently anchored to withstand wave action and have access to moisture to ensure adequate rooting (providing further anchoring). Above ground, the stumps provide a breakwater to dissipate wave energy against the bank.

Despite improved success with larger stock, winter ice can damage new plantings. Ice can form around partially inundated stumps, and during breakup may pull them out of the ground. Ice chunks during spring breakup also are abrasive to stumps during windy periods. The problem appears to be tolerable with damage repair accommodated within normal maintenance.

Rio Grande, New Mexico

The floodplains of the Rio Grande in central New Mexico have experienced substantial loss of native riparian plant communities in the past 50 years. The introduced, weedy, low-value saltcedar now occupies significant areas because it tolerates abusive management and is very competitive. Flood control, drainage, livestock grazing, irrigation diversions, and saltcedar wildfires appear to preclude conditions for natural re-establishment of native riparian species.

Cottonwood *(Populus fremontii* ssp. *wislizenii, P. angustifolia, P. deltoides* ssp. *monilifera)* and black willow *(Salix gooddingii)* poles have been planted in deteriorated riparian areas at several sites along the Rio Grande since 1981 (Swenson and Mullins 1985, Fenchel and others 1988, SCS 1990). For example, at a USDI Bureau of Reclamation site near Percha State Park north of Las Cruces, pole plantings established in 1985 demonstrated good survival and growth after 4 years. Dormant cottonwood poles 1.5 to 3 inches in diameter, 8 to 16 feet long, and black willow 1.5 to 2.5 inches diameter, 8 to 12 feet long were planted to the low water table (30 to 60 inches depth). Four years later, black willow survival was 96 percent, with height and canopy width averaging 17.2 and 10.3 feet; cottonwood, 61 percent, 19.7 and 9.0 feet respectively.

Further north at Bosque del Apache Wildlife Refuge, more than 15,000 poles have been planted in previously saltcedar infested areas with good success where salinity levels are low enough to permit establishment (John Taylor, pers. comm.). Experience has shown that black willow will tolerate salinities up to 2500 ppm, whereas cottonwood must be confined to areas below 2000 ppm. The refuge inventories potential planting sites on a half-acre grid system (148 feet intervals) for electrical conductivity, soil texture, and depth to water table. In most cases, about 70 percent of the site is suitable for planting. June water table depths range from 4 to 15 feet. Planting rate is 100 plants per acre, with the expectation that 8-10 mature trees per acre will provide complete canopy closure after 10 years. Plantings established since 1988 have survival rates exceeding 80 percent, with growth after 18-24 months exceeding 25 feet on good sites.

Bylas, Arizona

Flood damage to a 2000 foot levee in the Gila River drainage northwest of Safford, Arizona was repaired in 1980 and further protected along the toe by a dormant cottonwood *(Populus fremontii)* and willow *(Salix gooddingii)* stump planting (York 1985). The techniques used were based on work done by the Civilian Conservation Corps near Safford in 1936.

Dormant stumps or logs, 3-6 inches in diameter, and 6-7 feet long, were planted 6 feet apart and 3 feet deep to the water table. The stumps were cut at an angle at the bottom and flat cut at the top. The bottom 1 foot was scored with an ax to promote rooting. After planting, above ground cut surfaces were sealed with white paraffin or tree paint.

Initial survival exceeded 90 percent, with willow outperforming cottonwood, which experienced dieback before re-sprouting at the crowns. Results demonstrated the need to level planting areas on the contour to correspond with water table depths. Use of longer and larger diameter plant material was recommended to access deeper water tables and to extend tops beyond the reach of browsing livestock. It was noted that large, bark-covered plant material was more resistant to wind, sun, and sand abrasion, and insect attack. Lack of native planting stock sources was identified as the primary limitation to large scale use of the practice. Commercial pole orchards were recommended as a possible solution.

In the ensuing 5 years after the initial planting, an additional 13,000 feet of levees were protected with dormant pole and stump plantings with good success (fig. 4, 5). The practice has spread to become a preferred approach to riparian revegetation in other western states.

SELECTION AND PRODUCTION OF SUITABLE PLANT MATERIALS

Commercial supplies of native riparian plants generally are low compared to ornamental crops, although they are increasing to meet current demand, and are likely to continue rising in the future. Emphasis on riparian zone restoration among the agencies managing western public lands likely will sustain demand for riparian plant materials in the years to come.

Species

Major native woody plant species recommended for riparian areas in the western states are listed by region in Table 2. Some have relatively restricted areas of adaptation, but most occur over wide areas and are highly variable in growth form and phenology. Most are available commercially at least in limited quantities, but it is sometimes difficult to obtain reliable information on origin. Commercial sources of material local to the project site often are not available.

Figure 4.--Dormant stump planting along ephemeral stream in Arizona.

Figure 5.--Third year growth of goodding willow and fremont cottonwood from dormant stump planting.

Species established in the field by rooting from dormant cuttings, stumps, or poles are the most likely to be produced in large quantities for riparian revegetation. These include primarily cottonwoods *(Populus)* and willows *(Salix),* but dogwood *(Cornus),* hardhack *(Spiraea),* snowberry *(Symphoricarpos),* and grape *(Vitus)* can be established in the field under favorable conditions. The other species must be produced from seed or vegetatively in nurseries prior to outplanting in the field, which greatly increases their cost if larger stock is used.

Native cottonwood and willow are featured in nearly all riparian plantings, particularly where large-sized planting stock is used. Climax riparian hardwoods, such as ash *(Fraxinus),* sycamore *(Platanus),* walnut *(Juglans),* and maple *(Acer),* are planted in sufficient numbers in many projects to permit restoration of the

Table 2. Common native woody species recommended for riparian revegetation projects in the western United States

	PNW	INT	NRM	SRM	NGP	WGP	DSW	MED
Acer circinatum Vine maple	X							
Acer glabrum Rocky Mountain maple		X	X	X				
Acer negundo Boxelder		X	X	X				X
Acer macrophyllum Bigleaf maple	X							
Alnus incana ssp. *tenuifolia* Thinleaf alder		X	X	X	X			
Alnus oblongifolia Arizona alder				X			X	
Alnus rhombifolia White alder		X	X					
Amelanchier alnifolia Serviceberry	X	X	X	X	X	X		
Atriplex canescens Fourwing saltbush		X				X	X	
Atriplex lentiformis Quailbush							X	X
Baccharis salicifolia Seepwillow							X	
Betula occidentalis Water birch		X	X	X				
Betula papyrifera Paper birch					X	X		
Cephalanthus occidentalis Buttonbush							X	X
Celtis reticulata Netleaf hackberry		X	X	X		X		
Celtis occidentalis Western hackberry						X		
Chiopsis linearis Desert willow							X	
Cornus sericea ssp. *stolonifera* Redosier dogwood	X	X	X	X	X			
Crataegus spp. River hawthorn	X	X	X	X	X			
Elaeagnus commutata Silverberry					X	X		
Forestiera neomexicana New Mexico olive						X	X	

	PNW	INT	NRM	SRM	NGP	WGP	DSW	MED
Fraxinus latifolia Oregon ash	X							X
Fraxinus pennsylvanica Green ash					X	X		
Fraxinus velutina Arizona ash							X	X
Juglans hindsii California black walnut								X
Juglans major Arizona black walnut							X	
Platanus racemosa California sycamore								X
Platanus wrightii Arizona sycamore							X	
Populus angustifolia Narrowleaf cottonwood		X	X	X	X	X		
Populus fremontii Fremont cottonwood							X	X
Populus deltoides ssp. wislizenii Rio Grande cottonwood						X	X	
Populus delta/des ssp. *monilifera* Plains cottonwood					X	X		
Populus balsamifera ssp. *trichocarpa* Black cottonwood	X	X	X					
Prunus americana American plum		X		X	X	X		
Prunus emarginata Bitter cherry	X			X				X
Prunus ilicifolia Hollyleaf cherry								X
Prunus virginiana Chokecherry	X	X	X	X	X	X		
Quercus lobata Valley Oak								X
Rhus trilobata Skunkbush sumac		X		X	X	X		
Ribes aureum Golden current		X	X		X	X		
Robinia neomexicana New Mexico locust				X		X		
Rosa nutkana Nootka rose	X	X	X					
Rosa woodsii Woods rose		X	X	X				
Salix amygdaloides Peachleaf willow				X		X	X	

	PNW	INT	NRM	SRM	NGP	WGP	DSW	MED
Salix bonplandiana Red or Tourney willow				X		X	X	X
Salix bebbiana Bebb willow		X	X		X			
Salix boothii Booth willow		X	X					
Salix drummondiana Drummond willow		X	X					
Salix eriocephala ssp. *prolixa* Mackenzie willow		X	X					
Salix exigua Coyote or sandbar willow		X	X	X	X	X	X	X
Salix geryeriana Geyer willow		X	X					
Salix gooddingii Goodding willow						X	X	X
Salix lucida ssp. *lasiandra* Pacific willow	X	X	X			X		
Salix lasiolepis Arroyo willow	X						X	X
Salix lemmonii Lemmon willow		X	X					
Salix lutea Yellow willow		X	X	X		X		
Salix melanopsis Sandbar willow		X	X		X			
Salix scouleriana Scouler willow	X	X	X					
Salix sitchensis Sitka willow	X		X					
Sambucus caerulea Blue elderberry		X	X	X				X
Sambucus mexicana Desert elderberry				X			X	
Shepherdia argentea Silver buffaloberry		X			X	X		
Spiraea douglasii Hardhack	X							
Symphoricarpos albus Snowberry	X	X	X		X			
Vitus arizonicus Canyon grape				X			X	
Vitus californicus California grape								X

Legend: PNW - Pacific northwest; INT - Intermountain area; NRM - Northern Rocky Mountains; SRM – Southern Rocky Mountains; NGP - Northern Great Plains; WGP - Western Great Plains; DSW - Desert southwest; MED - Mediterranean California climate area.

native plant community to occur in a reasonable period. Other species are planted to provide diversity and represent other important components of the native community.

Local Sources

For most riparian revegetation projects, cottonwoods and willows are collected from native stands nearby the site to be planted. Advantages to this approach include (1) adapted plants will be established, (2) the genetic integrity of local species populations is maintained (nearly guaranteed), and (3) local sources may be the only material of the species available. Disadvantages include (1) local stands may be decadent with poor rooting percentages as wild collected stock often is not as healthy as nursery-grown material, (2) identification of dormant willows may be difficult, resulting in the collection of large amounts of non-sprouting material, (3) local sources may not be available in sufficient quantities, particularly in the size categories required, and (4) collection sites may be disturbed creating a problem in one area while trying to alleviate a problem in another.

The use of non-local versus local sources for restoration programs has stirred controversy in recent years over approaches to revegetation. For native plant community restoration projects, it makes sense to use local populations, or populations that existed on-site prior to disturbance. For objectives other than restoration, non-local sources may provide the desired traits more effectively and should be used in an ecologically sound manner. However, when local sources are to be used, definitions are needed as to which populations are local, and which are not.
Local source collection guidelines are difficult to derive from the limited research on this subject. Conservative approaches have been proposed by native plant restoration groups and agencies involved with preservation of wild and scenic areas. One example is to recommend in decreasing preference: (1) collection on-site prior to disturbance, (2) collection as near to the project as possible, using site inventory data to ecologically match the collection site to the planting site; and (3) lacking local sources, collect several non-local sources to provide a broad genetic base for developing a new landrace (Millar and Libby 1989). Source populations also should be collected in such a manner to capture the full range of genetic variation.

Perhaps a logical definition of “local” for major riparian species ultimately will be based on the concept of riparian complexes (Winward and Padgett 1989). Riparian complexes are similar in scope to habitat types, plant associations, and range sites. They are combinations of riparian community types (CTs characterize vegetation on a site regardless of succession stage), manifest a relatively common ecological setting accounting for moisture, temperature, soil characteristics, topography, and other environmental factors. Given that the genetic structure of a population is shaped to a large extent by its environment, it would seem that populations within a single riparian complex would be genetically similar, and could vary with those in other complexes associated with different ecological settings.

Cultivars

Native plant cultivars usually are developed from populations collected within a target use area and evaluated in a common garden nursery. The cultivar of a vegetatively propagated species, such as willow, may be a single clone with traits desired for the intended use, a mixture of clones within a single desirable population, or a composite of clones from several populations. Seed propagated woody plant cultivars may represent a superior population, a composite of several populations, or a polycross of selected individual plants within and among populations.

In general, the benefit of a narrow genetic based cultivar focuses on specific desired traits, such high basal stem densities or other structural attributes. For reclamation, these cultivars often are relatively short-lived early seral species that will give way to longer-lived native vegetation.

Broad genetic based cultivars are useful for reclaiming variable sites, containing sufficient genetic flexibility to adjust to the altered site conditions. We know from plant breeding textbooks that cultivars of cross-pollinated species are populations containing high frequencies of desired alleles and allele combinations in gene complexes. Cultivars or non-local (within reason) sources will not necessarily exclude the presence of alleles that would otherwise occur in a local population, but they will change their frequency (see Hamrick 1989 for discussion of genetic structure in plant populations). We know further from recent developments in molecular biology that genetic variation also results from differences in dosage of the same gene product (dosage positively correlated with gene copy number), and also that small chromosomal re-arrangements (without loss of genetic material) can affect the intensity and timing of biological activity, the result still measured and attributed to genetic variation.

If local genetic variation is due more to changes in gene frequency, gene copy number, and subtle chromosome modifications, without actual loss of unique gene nucleotide sequences (extinction of alleles), then perhaps the guideline associating the term “local” to riparian complexes (discussed above in the section on local sources) is too narrow. Perhaps both local sources and cultivar target areas can be associated with higher level riparian classifications, such as major stream drainages or river basins, which may aggregate several riparian complexes.

The current conservative approach by restorationists to selecting sources for revegetating native plant communities seems based on the initial Mendelian model of static genotypes and variation based mostly on expression of different alleles at specific gene loci. As much remains to be learned about the dynamics of the genetic structure of a plant population, conservative guidelines probably are advisable for the present, but they could become more liberal in the future.

Nursery Production of Riparian Plants

Riparian species can be propagated and grown commercially using standard methods of the nursery trade. However, cottonwoods and willows are most efficiently and cost-effectively produced as dormant hardwood cuttings or whips. Cuttings blocks usually can be maintained for several years, harvested and processed annually using semi-automated procedures.

The greatest need for new commercial production is to produce large stump and pole stock, which may not be readily harvested from local native stands. Much needs to be learned in how to manage pole orchards of cottonwood and willow, building on the experience gained recently in the southwest (SCS 1990). Layout and cultural techniques of hybrid poplar paper pulp agroforestry plantations in the Pacific northwest also may provide Insight into growing poles and stumps for riparian plantings.

Container propagation methods also could be improved, adapting “tall-pot” technology used for mass plantings in desert environments. The containers, which may exceed 30 inches in depth, provide woody plant seedlings with a deep root mass which extends beyond the root zone of grass and weed competition in riparian zones.

Demand for larger commercial riparian stock is largely untapped. The market for larger plant material also includes bioengineering projects to stabilize and prevent mass slumping of steep slopes, which have become popular as “soft-engineering” solutions to environmental problems.

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