



PROPAGATION PROTOCOL FOR

CONTAINER WILLOWS

in the Southwestern US using Seeds

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KEY WORDS

Salix arizonica, *S. bebbiana*, *S. exigua*,
S. irrorata, *S. scouleriana*,
arizona willow, bebb's willow,
coyote willow, bluestem willow,
Scouler willow, height growth,
stem diameter growth,
caliper, Salicaceae,
controlled release fertilizer

NOMENCLATURE

ITIS (2002)

The genetic and sexual diversity provided by seed propagation of *Salix* L. (Salicaceae) species is an important consideration when planning riparian restoration projects. A standard seed propagation protocol has been successful with a number of *Salix* species from montane habitats as well as low elevation floodplains. Despite the very small seed size, most *Salix* are extremely rapid growers, which helps negate some of the advantage typically attributed to cutting

propagation. Perhaps the largest hurdle to seedling propagation of *Salix* is the collection of seeds in the wild. However, rapid development of nursery seed orchards is possible using reproductive cuttings representing a mix of male and female plants or seedling stock which rapidly becomes reproductive for many species.

Two principal differences between *Salix* and *Populus* L. (Salicaceae) influence seedling propagation strategies if nursery seed stock plants are desired. The

first relates to the location of juvenile and mature wood in the 2 genera and where cuttings are usually taken. Often, *Populus* cuttings are juvenile because they are taken from stems close to the root crown, not from mature stems in the upper canopy. Therefore, cuttings are unlikely to have preformed floral buds that can be forced in the current year. In contrast, *Salix* cuttings (particularly those from shrub-form willows) are often taken from mature wood allowing same-year flowering of stock plants. Secondly, the progression from juvenile to mature phase in *Salix* seedlings can be very rapid (2 to 3 y) especially when grown under near optimum conditions; such early maturing species include *Salix bebbiana* Sarg., *S. irrorata* Andress., and *S. scouleriana* Barratt ex. Hook. Conversely, *Populus* seedlings after more than 5 y of growth in the nursery have yet to become reproductive even after attaining appreciable size.

Some of the willow propagation protocols that follow address using reproductive phase cuttings to produce seed stock plants, and probably would be effective for reproductive phase *Populus* cuttings; this approach is currently being investigated for *Populus fremontii* S.Wats. *Populus* seed production from seed grown stock, however, will likely be a very prolonged endeavor, as with most tree species.

OBTAINING SEEDS

Two approaches can be used for collecting *Salix* seeds: 1) collect seeds from wild plants on an annual basis; or 2) bring back either cuttings or seeds to grow plants to establish a seed orchard for future collections.

Annual Collections from Wild Plants

The identification of female plants before cotton emergence can be determined by examination of the individual flowers or maturing seed capsules on the catkins. The most critical factor in the collection of viable *Salix* seeds is frequent observation of catkin develop-

ment. For this reason, establishment of stock plants in a nursery provides significant advantages over wild-land collections. Catkin harvest is typically planned to coincide with the appearance of cotton emerging from partially opened capsules (Schreiner 1974). I have harvested high percentages of viable seeds if harvest is timed to coincide with this stage of capsule opening. It might be preferable to wait until the capsules are almost fully open, but spring winds can disperse seeds very quickly once capsules reach this stage. Female catkins are placed in paper sacks to capture seeds as the capsules open during drying (Figure 1). In a normal room environment, seeds are released from the catkins in a few days. If the number of catkins collected forms a layer 1 or 2 catkins thick in the sack, the seeds will disperse easily without much oversight. If a thick layer of catkins is placed in the sack, occasional turning and stirring of catkins will be required to facilitate uniform drying and seed release. Avoid plastic bags as they cause moisture buildup and subsequent decomposition.

Using Cuttings or Seeds to Establish Seed Production Areas

If you desire to establish a seed orchard for specific willow species and seed sources, you can use either cuttings or seeds to start the process. Generally, using cuttings already having reproductive tissues speeds up the process (Figure 2). The development of catkins and flower pollination on recently stuck cuttings can have variable results. With vigorous cuttings of certain species, pollination and seed set can occur soon after sticking, resulting in rapid seed production. However, less vigorous wild-collected cuttings will often result in little if any seed set during the first spring. Insects play a role in pollination of many willows so this fact should be considered if cuttings are flowering in a greenhouse. For *Salix* cuttings, you must either know the sex of the donor plants having observed catkins the year before, identified the sex by microscopic observation of

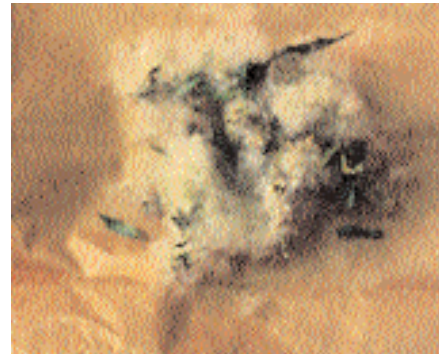


Photo by Thomas D Landis

Figure 1. A collection of willow cotton and the paper bag used to transport it back to the nursery.



Photo by Thomas D Landis

Figure 2. Just a few months after being collected, a female cutting has rooted, flowered, and is dispersing cotton and seeds in the nursery.

reproductive buds (see Landis and others 2003), or collected cuttings from a large number of plants so it is likely that you have collected both sexes. I stick small cuttings into 164 ml (10 in³) Ray Leach Super Cells™ (SC-10) and larger cuttings into 2.8 l (1 gal) Treepots™ (1GTP) (both containers distributed by Stuewe & Sons Inc, Corvallis, Oregon). I either top-dress 1GTPs with 15 g of 5 to 6 mo controlled release fertilizer (CRF) Osmocote Plus 15N:9P₂O₅:11K₂O (Scott's Company, Marysville, Ohio) or

incorporate 3.5 kg/m³ (6 lb/yd³) for SC-10. I tag plants for gender, harvest and clean seeds, and sow seeds to produce initial containerized seedlings. By summer, small stock plants from cuttings can be transplanted into 1GTPs (15 g 3 to 4 month CRF) and the larger stock plants can be planted into seed orchards. During the second growing season, expect abundant catkin production and enough seeds for large-scale seedling production. By fall, all remaining stock plants are transplanted to the seed orchard—males and females can be mixed to enhance pollination.

The process is similar if seeds are collected. Frequent field observations of willow stands of known species will allow seed collection if female plants are present and are flowering or dispersing seeds. If collection sites are remote, it may be possible to identify and tag female plants a year in advance and estimate seed maturation date by observing catkin development so that a well-timed collection trip will yield ripe catkins the following year. Seeds can be cleaned and seedlings grown as described below. Seedlings generally grow the first year in SC-10s and are transplanted into

1GTPs during winter or spring. The plants can be tagged for gender after catkins appear which can be as early as the second year for early maturing species (for example, *S. bebbiana*, *S. irrorata*, *S. scouleriana*). Once the sex is known, plants can be moved to the seed orchard as described above.

OTHER CONSIDERATIONS THAT MAY AFFECT RIPARIAN PLANTING STOCK PRODUCTION

The difficulties encountered in getting an accurate species identification for *Salix* species may complicate restoration activities; however, the lack of positive identification should not necessarily stop propagation endeavors. In addition, the stock size for outplanting will greatly influence the lead time needed to produce plant materials for a riparian restoration project.

Positive species identification is obviously preferred for any propagation activity. A case can be made, however, that because of the difficulty in willow species identification an alternative approach may be acceptable if: 1) the willows are

determined to be native or any exotic willows can be readily identified and disregarded; 2) the willows are collected from the watershed to be restored; 3) the growth characteristics of the willow species present in the watershed are appropriate for the restoration purpose and are consistent with the vast majority of the future planting sites; and 4) if necessary, propagules can be collected and kept separate for each individual wild stock plant throughout the propagation process. This final recommendation will allow the seedlings of an individual species to be differentiated at outplanting in case more than 1 species has been harvested during propagule collection. Otherwise, vegetative characteristics may be the only key to separating species until catkins develop.

STANDARD CONTAINER SEEDLING PRODUCTION PROTOCOL

The most common container stock type we use for montane riparian restoration is 1GTP containers. This container size is generally adequate for acceptable rates of



Photos by Thomas D Landis

Figure 3. Three soil sieves are needed to clean seeds. The bottom sieve is where the seeds collect. Cotton and seeds are placed in the middle sieve. The top sieve holds the cotton from blowing out when a stream of compressed air is blown across it. The cotton remains in the middle sieve and clean seeds are deposited in the bottom.



Figure 4. Willow seedlings growing in mini-plugs prior to being transplanted into SC-10 containers.

survival with little aftercare, except protection from cattle and elk. In lower elevation cottonwood forests, 1GTP stock can be used but typically requires supplemental watering for several years to become established. We use small volume “mini-plugs” to maximize greenhouse space for starting the crop, transplant up to SC-10 containers, and finish the crop cycle in 1GTP containers.

Seed Cleaning

Once seeds are harvested from wild stands or on-site seed orchards, they can be cleaned using an air stream and soil screens similar to that described for *Populus* by Schreiner (1974). A compressed air source and a set of 3 soil screens in a series from top to bottom of 250 μm (# 60), 500 μm (# 35), 125 μm (# 120) are employed; the dry catkins containing open capsules are placed between the 250 μm and 500 μm screens (Figure 3). A jet of compressed air is blown through the top screen in a swirling fashion; the seed is dislodged and sifts through to the 125 μm screen. The cotton and empty catkins re-

main on the 500 μm screen. Seeds can also be cleaned with vacuum systems (see Dawes 2003; Day and others 2003).

Seed Germination

At the Los Lunas Plant Materials Center in New Mexico, we germinate willow seeds within a few days of cleaning in “mini-plug” containers having 512 cavities each 14 x 14 x 29 mm (0.5 x 0.5 x 1.1 in [for short term growth – 2 to 3 wk]) or 341 cavities each 19 x 19 x 63 mm (0.75 x 0.75 x 2.5 in [for longer term growth – 4 to 6 wk]). We rely on mini-plugs because of space restrictions on our automated watering bench that precludes large-scale germination in larger containers. The germination medium is a standard sphagnum peat moss and perlite mix of fairly coarse texture. The coarse texture allows the small *Salix* seeds to infiltrate between the particles of peat moss, allowing optimum aeration, moisture, and light.

One difficult task is hand seeding. Precision is very difficult because willow seeds are very small (the largest being

about 1 mm in length and 0.3 to 0.5 mm in width). Adding a diluent of similar size might be of some benefit in achieving more precise sowing by hand. The seeds are usually sufficiently clean that an automated seeder typically used for bedding plant seeds of similar shape and size would probably be effective if very large-scale seeding was envisioned.

Mini-plug Irrigation

The plug medium surface must be kept continuously moist; germination of willow seeds is often apparent after 1 d as noted by the swelling and separation of the cotyledons. Our greenhouse watering bench has mini-sprinklers and automatically waters plug trays once a day (Figure 4). The bench is covered with a copper-coated fabric (Texel Tex-R® Forestry Fabric, Texel Inc, Quebec, Canada) to reduce root egress from the plug cells; this fabric covers a filter fabric (Dewitt soil separator fabric) which acts to pull excess water out of plug cells via capillary water movement. Soluble fertilizer is applied once or twice a week at a rate of 200 mg/l (ppm)

Photo by Thomas D Landis



Figure 5. A typical seedling of *S. irrorata* growing in a 1GTP (left) and SC-10 (right) after 2 and 1 growing seasons, respectively.

nitrogen (20N:10P₂O₅:20K₂O Peat Lite Special; Peters Professional, Scott's Company, Marysville, Ohio). Ideally, the plugs are transplanted as soon as the root system is sufficient to keep the soil plug intact (3 to 6 wk depending on species and plug size).

Transplanting into SC-10 Containers

Our medium is a mix of 2 parts Sunshine Mix #1 or #2 (Sun Gro Horticulture,

Bellevue, Washington) with 1 part perlite (v:v) that has 2.7 kg (6 lb) of CRF incorporated per 0.765 m³ (1 yd³) of medium. For plants started in the greenhouse during spring, 5- to 6-month release CRF is used, but for summer grown material 3- to 4-month release CRF is incorporated.

Filled SC-10 containers are dibbled to provide a hole for the mini-plug seedling. Thinning seedlings is often required and can be completed as the mini-plugs are

transplanted into the SC-10 containers if seedlings are large enough to make clipping feasible. Otherwise, thinning is accomplished after some growth has occurred in the SC-10 containers. The mini-plug seedling root ball is removed using a flat powder spatula having a blade about 6 mm (0.25 in) wide and 30 mm (1.2 in) long attached to a handle. The blade is plunged along the side of root ball and the seedling plug is levered out of the cell. The plug is dropped into the dibbled hole and the medium is pressed around the root ball with fingers. Top watering firms and fills any voids around the plug.

Transplanting into Treepots™

Transplanting into 1GTPs usually occurs in the late summer of the first year or spring of the second year. The containers are filled with an aged bark:pumice:peat medium (55:35:10; v:v:v) and dibbled with a SC-10-size planting dibble. CRF is top-dressed at planting or soon thereafter. For pots transplanted in late spring, a 5- to 6-month release CRF is used at a rate of 15 g (0.5 oz) per pot. Seedlings transplanted later in the summer receive a similar rate of 3- to 4-month release CRF. While the plants are establishing themselves in the larger container, irrigation is usually applied 3 times per week. Plants are typically grown without shade. Watering frequency during the rapid growth phase is every day for large riparian plants with substantial leaf areas.

SEEDLING GROWTH RATES FOR SEVERAL WILLOW SPECIES

Examples of height and root collar diameter (caliper) growth for several willow species grown in SC-10s with moderate CRF rates are described below as well as for *Salix exigua* (Nutt.) in larger intermediate containers with high CRF rates. The growth enhancement provided by larger containers with high nutrient levels has been confirmed during the 2003 production season for other species including *S. ir-*

rorata and *S. bebbiana*. One aspect of this willow seedling growth data requires explanation—for some species, seeds from stock plants of montane species grown in the desert environment of the Los Lunas Plant Materials Center (elevation 1463 m [4800 ft]) have been used. It appears, based on the range of willow seed dispersal dates presented by Zasada and others (2000), that seeds are generally produced in our seed orchard at least 1 mo earlier than would be expected from wild collections of montane willows. An example of a typical SC-10 and 1GTP are provided in Figure 5.

Salix irrorata

Male and female cuttings of *S. irrorata* were collected from the Wilderness District of the Gila National Forest in southwestern New Mexico and rooted at the Los Lunas Plant Materials Center nursery. After 1 y, stock plants growing in 1GTP containers were tagged by sex and then transplanted into a seed orchard established in organic rich nursery beds. After 4 y, stock plants were 7 m tall. Seedlings (sown in late April – early May) growing in SC-10 containers for 1 growing season averaged 62 cm (24 in) in height and 5 mm (0.2 in) in caliper measured at the top of the container. After transplanting and growing in 1GTPs for another year, plants averaged 2.6 m (8.5 ft) in height and 14 mm (0.55 in) of caliper.

Salix bebbiana

In March 2001, USDA Forest Service personnel collected *S. bebbiana* cuttings from 2 stands at approximately 2400 m (7875 ft) elevation, and in June they collected seeds from a wild stand (2700 m [8860 ft]) on the Apache-Sitgreaves National Forest in east central Arizona. The cuttings were stuck into 1GTP and the following year (2002) they produced seeds. Seedlings were grown 1 y in SC-10s and transplanted the following year into 1GTPs. Mean heights of 0.5 and 1.6 m (20 in and 5.2 ft) and mean calipers of 4.4 and 13 mm (0.17 and 0.51 in) were achieved

after 1 and 2 growing seasons for the 2001 (sown mid June) and 2002 (sown early May) seedling sources, respectively.

Salix scouleriana

Cuttings for *S. scouleriana* stock plants were collected from 1 male and 1 female plant at an elevation of 2900 m (9570 ft) within the Carson National Forest in north-central New Mexico. These cuttings produced seeds, and the resulting full sib seedlings are maintained in large pots as seed sources. These 2-y-old seedling stock plants yielded seeds in early May and the resulting seedlings, grown in SC-10s, had a mean height and caliper of 28 cm (11 in) and 3.5 mm (0.14 in), respectively, after 1 growing season.

Salix exigua

Seeds of coyote willow (*Salix exigua* Nutt.) were collected in early June from an individual female thicket in the Middle Rio Grande Valley. The mini-plug seedlings were transplanted into SC-10 containers with either a moderate (3.5 kg/m³ [6 lb/yd³]) or high (7.1 kg/m³ [12 lb/yd³]) dose of incorporated CRF (3- to 4-mo release). Additional seedlings were transplanted at the same time into D16 (262 ml [16 in³]) and D40 (656 ml [40 in³]) Deepot™ (Stuwe and Sons Inc) containers containing the same soil-less mix with the high dose of CRF.

Relative to seedlings grown in SC-10 containers with moderate nutrient levels, mean height growth was increased 29%, 46%, and 93% for the SC-10, D16, and D40 seedlings with high nutrient levels. Similarly, increases in mean caliper of 15%, 51%, and 78% were noted for the SC-10, D16, and D40 seedlings with high nutrient levels.

***Salix arizonica* Dorn**

Arizona willow is classified as a sensitive species by the USDA Forest Service, as a highly safeguarded species by the Arizona Native Plant Law, and has a global rank of rather rare (G3) and state rank of rare (ARPC, undated). USDA Forest Service personnel collected seeds of *S. ari-*

zonica in early July 2002 from 2 previously identified female plants on the Apache-Sitgreaves National Forest. After 8 wk growth in SC-10s, the mean heights and calipers were 11 to 15 cm (4 to 6 in) and 2.2 to 2.3 mm (0.1 in), respectively.

MORE INFORMATION

A more detailed description of techniques we use for riparian restoration, including nursery production of other containerized species, field production of pole cuttings, and descriptions of planting projects in the southwestern US can be found in Dreesen and others (2002) available on-line at URL: <http://www.rngr.net/Nurseries/Publications/Proceedings/2001/dreesen.pdf>.

SUMMARY

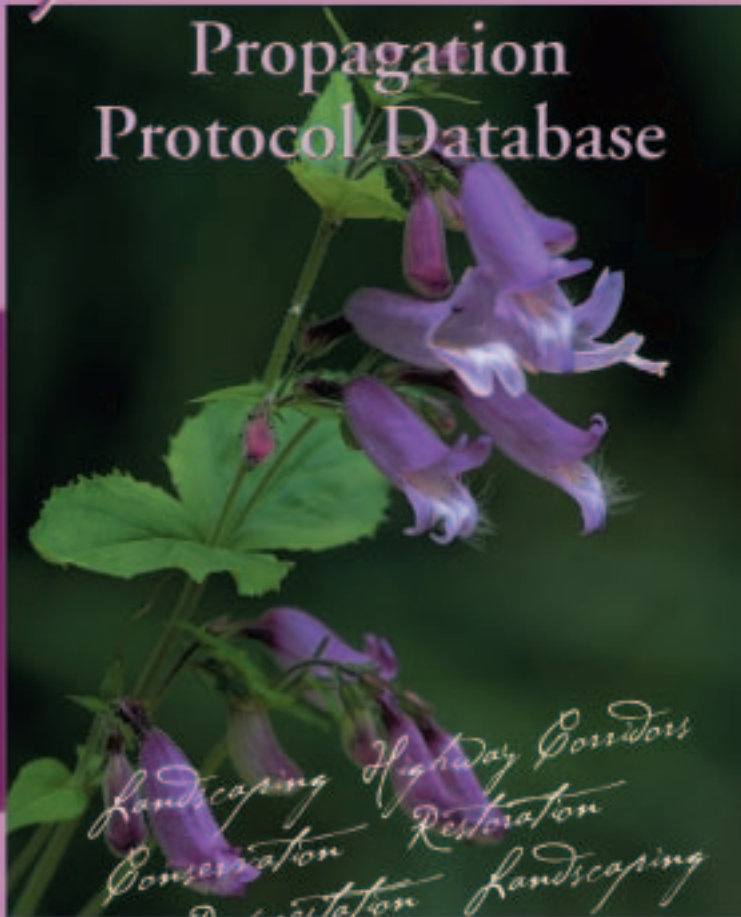
The rapid growth rate of *Salix* seedlings and their almost immediate germination are appreciable advantages for seed propagation. The small seed size and the potential difficulties in collecting seeds from wild stands are among the problems that should be considered before initiating *Salix* seedling propagation. The rapid transition from juvenile to reproductive phase for some willow species offers benefits in establishing seed stock plants with considerable genetic diversity. Large planting stock with enhanced probability of establishment in disturbed riparian areas can be produced in 2 growing seasons.

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