PRODUCING NATIVE PLANTS AS CONTAINER SEEDLINGS

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ABSTRACT: Crops of native plants should be planned to allow enough time for seed collection, seed processing, seed treatments and stratification, greenhouse growth, and hardening. An ideal container nursery consists of **a** production greenhouse, a cold frame, a shadehouse and refrigerated storage. Four propagation methods can be used to produce native plants: direct seeding, germinants, transplants, and rooted cuttings. The choice of container should consider seedling growth, species characteristics and outplanting site. Most native plants can be grown reasonably well under a standard greenhouse environment and in commercial potting mixes. The type and amount of hardening will depend on the species characteristics and the future use of the plant. Nursery managers must be aware of variation between species, seed sources, and annual seed crops. Successful growers must acquire direct experience in producing each species tinder their own nursery system.

INTRODUCTION

The large scale production of native plants is still a relatively new enterprise and the growing of container seedlings in greenhouses is the newest production technique in western forest nurseries. Producing native plants in containers is a logical operation, however, because some species have proven difficult to grow as bareroot seedlings. For example, Mormon tea *(Ephedra spp.)* has very brittle stems and fragile root systems which are sensitive to breakage during bareroot lifting operations and the expansive root system of elderberry *(Sambucus* spp.) makes it hard to culture in seedbeds. Other native plants such as Arizona cypress (Cupessus arizonica*)* just seem to grow better in containers.

Container seedlings have been reported to have several advantages over bareroot seedlings such as a shorter production period and improved survival and growth after outplanting (Stein 1974). As already mentioned, some species are easier to grow in containers compared to bareroot stock and there is no root disturbance during seedling processing. On the outplanting site, container seedlings suffer less transplant shock and are generally easier to plant than bareroot seedlings. Instead of the limited spring planting period for bareroot trees, container seedlings have been successfully outplanted during the fall and may be suitable for other planting times as well (Stein 1974).

Although tree seedlings have been grown in containers for well over a decade, only a few nurseries are producing native plants as container seedlings. Compared to commercial tree species, very little is known about the culture of native plants in greenhouses. Many nursery managers are reluctant to try and grow natives because they have heard horror stories about the difficulty of breaking seed dormancy, and the availability and quality of native plant seeds have been unreliable.

The objective of this paper, therefore, is to discuss some of the cultural practices useful in growing native plants in containers. Because of their years of experience and good reputation in the field, the greenhouse operations of Native Plants Inc. of Salt Lake City, Utah, will be used as a model throughout the paper. Other pertinent literature will be referred to whenever appropriate

PLANNING AND CROP SCHEDULING

Before the decision is made to produce native plants in containers, the grower should assess the potential market. This assessment requires business and marketing skills which are beyond the scope of this paper. Basically, though, there are two business approaches: (1) contract growing, or (2) speculation on future demand. Growing contracts are typically for a designated number of one or more plant species which are to be grown to certain size and quality standards by a specified time. Speculative growing is often risky and requires a keen appraisal of future markets. Some nurseries like Native Plants Inc. operate with a combination of contract and speculation growing.

The market analysis should result in a list of plant species to be produced. The grower must next decide whether the species can best be propagated by seeds or by vegetative cuttings. Seed dealers should be consulted to determine seed availability as some native plants do not produce a good seed crop every year and seed of some species does not store well. The grower must be certain that he can secure seeds or cuttings before proceeding with the planning process.

When the crop species have been selected, the grower should develop detailed production schedules that delineate the duration and sequence of the various operations (fig. 1 & 2). Crop planning is normally done during April or May so that there is enough time to secure seed later in the summer or early fall.

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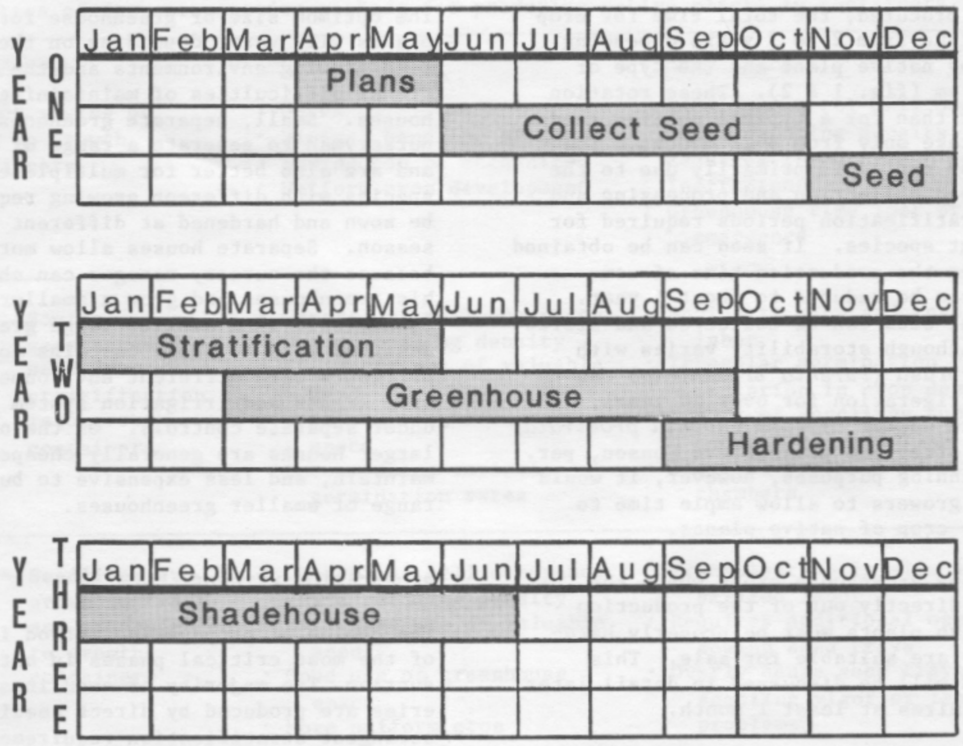

Figure 1.--Production schedule for growing native plants in containers: creeping Oregon grape (Mahonia repens)--germinants

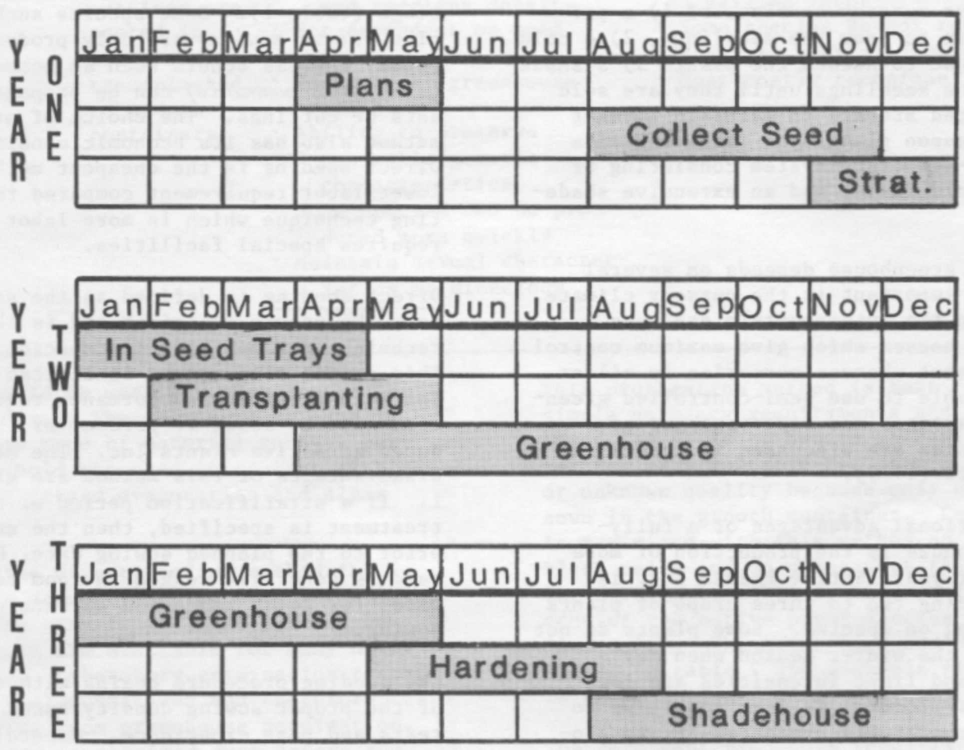

Figure 2.--Production schedule for growing native plants in containers: Rocky Mountain juniper (Juniperus scopulorem)--transplants

If seed must be procured, the total time for crop production may take from 2 to 3 years depending on the species of native plant and the type of propagation system (fig. 1 & 2). These rotation times are longer than for a typical conifer seedling which may take only from 8-12 months. The longer production period is primarily due to the problems with seed collection and processing and the extended stratification periods required for many native plant species. If seed can be obtained immediately, then the production time of some native species can be reduced to about 1 year. Most native plant seed can be collected and stored ahead of time although storability varies with species. Butterbrush *(Purshia tridentata)* can be stored under refrigeration for over 10 years, whereas prostrate summer cypress *(Kochia prostrata)* loses viability after one year (Steve Monsen, per. comm.). For planning purposes, however, it would be wise for new growers to allow ample time to grow their first crop of native plants.

Compared with many greenhouse crops where the plants are sold directly out of the production greenhouse, native plants must be properly hardened before they are suitable for sale. This hardening period will be discussed in detail later but normally requires at least 1 month.

PRODUCTION FACILITIES

Whereas many ornamental crops can be produced in a single structure, the greenhouse, native plants may require as many as four separate facilities. An ideal container nursery consists of 1) a production greenhouse to grow the seedlings, 2) a cold frame or shadehouse to harden the plants 3) a shadehouse to store the seedlings until they are sold and 4) refrigerated storage to maintain dormant stock for late season plantings. Native Plants Inc. has a three-structure system consisting of greenhouses, a cold frame, and an extensive shadehouse.

The best type of greenhouse depends on several factors but most important is the nursery climate. Most nurseries in the Intermountain area use fully-controlled houses which give maximum control over the environment whereas nurseries in milder climates may be able to use semi-controlled greenhouses. The advantages and disadvantages of different facilities are discussed in detail in Tinus and McDonald (1979).

One of the operational advantages of a fully-controlled greenhouse is the production of more than one crop per year; Native Plants Inc. is capable of producing two to three crops of plants per year depending on species. Some plants do not grow well during the winter season when day length is short and light intensities are low. Squawbush (Rhus trilobata*)* is very sensitive to photoperiod so crop lights are necessary to produce multiple crops (Steve Monsen, pers. comm.). Desert species just naturally grow better during the summer season.

The optimum size of greenhouse for producing native plants will vary, depending on the need for separate growing environments and the cost and operational difficulties of maintaining individual houses. Small, separate greenhouses permit the nurseryman to generate a range of environments and are also better for multiple cropping because species with different growing requirements can be sown and hardened at different times during the season. Separate houses allow more flexibility because the nursery manager can shut down some of his greenhouses and grow a smaller crop more economically. A single, large greenhouse can be designed with moveable curtains to produce compartments with different environments but the crop lights and irrigation system should also be under separate controls. On the other hand, larger houses are generally cheaper to heat and maintain, and less expensive to build than a range of smaller greenhouses.

PROPAGATION METHODS

The choice of propagation method is probably one of the most critical phases in native plant production. The majority of seedlings in forest nurseries are produced by direct seeding but the stringent stratification requirements and limited availability of many native plant seeds may require other approaches.

Native Plants Inc. uses four different methods to propagate woody plants in containers: direct seeding, germinants, transplants, and rooted cuttings (table 1). Some species such as pinyon pine *(Pinus edulis)* are only produced by one method (seed) whereas others such as common juniper *(Juniperus cormnunis)* can be propagated by germinants or cuttings. The choice of propagation method also has its economic considerations. Direct seeding is the cheapest method because of a lower labor requirement compared to the rooted cutting technique which is more labor intensive and requires special facilities.

Direct seeding is defined as the sowing of seed into the growth container and is the standard technique for most conifer species and wildflowers. This propagation method is limited to those species with little or no dormancy requirement which works out to about 10 percent of the species produced at Native Plants Inc. The advantages and disadvantages of this method are given in table 1. If a stratification period or other pretreatment is specified, then the seed is treated prior to the planned sowing date. Otherwise, the seed is generally soaked in room temperature water for 24-48 hours and surface dried before sowing.

The seeding procedure begins with the calculation of the proper sowing density based on germination tests and past experience. Generally several seeds are sown per container and are later thinned to one seedling per cell. Because of the irregular shapes and sizes of most native plant seeds, most sowing is done by hand although a shutterbox or

Table 1.--Properties of four propagation methods for producing native plants in containers

Propagation Technique		Advantages	Disadvantages
1. Seeds	Direct sowing of seed to growth containers	• Quick • Minimal handling of seed • Sowing can be mechanized • Uniform crop development	• Hard to control cell occupancy and seedling density • Requires thinning and consolidation • Inefficient and costly use of seed • Greenhouse time lost prior to emergence
2. Germinants	Sowing germinated seed from stratification into growth containers	• Control of cell occupancy and seedling density • Efficient use of valuable seed • Good use of greenhouse space • Accommodates variable germination rates	• Sowing is slow and involves skilled labor • Irregular germination rate may cause variation in crop development • Number of seedlings subject to quality of seed lot • Requires specialized stratification chambers
3. Transplants	Seedlings are grown in trays and transplanted to growth containers	• Control of cell occupancy and seedling density • Efficient use of valuable seed • Good use of greenhouse space • More uniform crop development • Can use natural or artificial stratification	• Transplanting is slow and involves skilled labor • Requires additional operation of sowing seed trays • Overly dense seed trays could lower seedling vigor or lead to disease problems
4. Rooted cuttings	Vegetative cuttings are rooted in trays and transplanted to growth containers	• Control of cell occupancy and seedling density • Not dependent on seed crops • Good use of greenhouse space • Ability to preserve desirable genetic characteristics • Some species can be produced more quickly • Maintain sexual characteristics of dioecious species	• Transplanting is slow and involves skilled labor • Some species do not root well • Requires special facilities • Most costly technique

vacuum seeder could be used for certain species and large seed lots. The sown seed is usually covered with some type of material such as perlite or grit to hold the seed in contact with the potting soil and retard evaporation and algae growth.

The success of the direct seeding method is dependent on the accuracy of the seed information. Germination tests *vary* from lab to lab and no standardized tests are available for many native shrubs and forbs. Laboratory germination tests are run under ideal conditions and therefore test results may differ from greenhouse germination. Sometimes the seed is obtained just before the sowing date and so there is not enough time for seed testing.

The germinant technique is defined as the sowing of pregerminated seed into the growth container. This propagation method is best for plants with simple dormancy requirements and species with seeds too large to handle mechanically. It is particularly suitable for seed lots of variable or unknown quality because only good seed is sown in the growth container. Cell occupancy is maximized with this method as there are few blank cells and no subsequent thinning is needed. The germinant technique is used for about 15 percent of the native plant species produced at Native Plants Inc. The advantages and disadvantages are listed in table 1 and a sample production schedule is given in fig. 1.

The germinant procedure requires clean seed se seed lots should be surface sterilized with chlorox or Captan to reduce molding during stratification. The seeds are usually hydrated with a 24-48 hour soak and then prepared for the stratification chamber.

Seed can be germinated in "naked" stratification where the bare seeds are kept in a plastic bag or mixed with a moisture-holding material such as peat moss. Native Plants Inc. uses a finetextured, sterile peat moss, mixes the seed with the moss, and places the mixture in a plastic bag in a refrigerator at 30° to 40° F (-1° to +4° C). The acid peat moss helps retard seed molds during the lengthy stratification period which can last up to 8 months. The stratification bags should be checked at least weekly until germination begins. Seeds are ready to transfer to the growth container when a white radicle becomes visible but before the radicle becomes so long that it is easily damaged. Cracked seeds are not necessarily germinating; some species of seed swell and crack long before the radicle begins to emerge. Chokecherry *(Prunua virjiniana)* seeds may take several months to produce a radicle after the seed intially cracks.

The planting operation consists of pouring the stratified seed out in a tray and picking out the germinants by hand or with tweezers. The germinants are placed in a depression or small hole in the potting soil in the growth container and covered with grit or perlite. Seeds should be placed with the radicle oriented downward; if the radicle is pointed upward it will reverse itself in response to gravity which may result in a stem crook in the young seedling. The crews at Native Plants' greenhouse have been able to achieve production rates of 1500-2000 plants per person-day using this procedure. It is a good idea to double sow the last couple of rows of containers in each tray to provide extra seedlings to transplant back into any empty cells.

Once all the germinants have been planted out of the tray, the seeds are placed back into the stratification bag and returned to the refrigerator. The planting crews go through the stratification bags three times per week until the germination rate begins to decline. These bags have been maintained for as long as 8 months for some species (eg. *Prunus spp.)* and germinating seed can be used as long as mold does not become a problem.

<u>Transplants</u> are the third propagation method used at Native Plants Inc. and account for 65 percent of the species produced. Transplants are defined as seedlings which are grown to the cotyledon stage in trays and then transplanted into growth containers. This propagation method is best for woody plants with complex dormancy requirements or for species such as quaking aspen whose small seeds would be almost impossible to plant by hand. This technique is ideal for seed lots of variable or unknown quality. A list of the advantages and disadvantages of the transplant method is given in table 1.

The transplant trays are filled about 2 inches (5 cm.) deep with standard potting mix and broadcast seeded by hand. Very small seed can be applied through a large salt shaker to ensure even seed distribution. Cover the seed with a light application of a fine-textured material such as sand-blasting grit.

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Seeds that require stratification are sown in the fall, irrigated, and placed outside in a sheltered location and protected against dessication. This outside storage allows the seed to naturally stratify over winter. When the trays are brought into the greenhouse in the spring, the seeds germinate readily and can be immediately transplanted. A growing schedule for this propagation method is given in fig. 2.

For seeds that do not require stratification, the transplant trays are taken directly into the green-house. In the greenhouse, the transplant flats are kept moist by frequent hand irrigation and germination usually occurs in 1-2 weeks. Once the seedlings grow to the cotyledon stage and begin to grow primary leaves, they are ready for transplanting. The transplanting procedure consists of working the seedlings loose from the soil, making a dibble hole in the potting soil of the growth container, and transplanting a seedling into the hole. The potting soil is then firmed around the seedling and the growth containers are irrigated and moved to the greenhouse benches. An experienced worker can transplant up to 2,000 seedlings in an 8-hour day.

When all the seedlings have been removed from the transplant trays, the soil is mixed, the trays irrigated, and the plants allowed to sprout again. Depending on the germination rate, the trays may produce up to three successive crops of transplant material.

<u>Rooted cuttings</u> are the final propagation method for native plant production. This technique consists of rooting vegetative cuttings in trays and transplanting them to growth containers. Approximately 10 percent of the species grown at Native Plants Inc. are produced by cuttings which is the best method for plants that are difficult to grow from seed or for which seed is difficult to obtain. The advantages and disadvantages of rooted cuttings are listed in table 1. At the Native Plants Inc. greenhouse, rooted cuttings are used as a last resort when the species cannot be reliably pro-duced by another propagation technique; based on their cost figures, rooted cuttings are four to five times as expensive to produce as seedlings.

The production of rooted cuttings requires a special propagation facility which at Native Plants Inc. consists of a separate greenhouse with heated benches and a special misting system to control relative humidity. The cutting room is maintained at 70 to 75° F (21 to 24° C) and humidities approaching 100 percent. The atomized misting system is designed to maintain high humidities without overwatering the media in the cutting trays because fungal diseases quickly become damaging under saturated soil conditions. Supplemental lighting is used to extend normal day length and permit the production of rooted cuttings year round.

Cuttings are normally collected from plants in the field. The best season for collection depends on the species. Cuttings of two species of saltbush *(Atriplex cuneata* and *A. confertifolia)* rooted best when collected in spring or summer but the rooting percentage dropped markedly when cuttings were taken in the fall (Richardson and others 1979). Cuttings of some species such as big sage brush *(Artemisia tridentata*) root better when collected during winter dormancy (Alvarez-Cordero and McKell 1979).

Native Plants Inc. currently collects most of their cutting material from "mother plants" which are older plants from the production stock at the nursery. To prevent disease spread, these mother plants are sprayed with a broad spectrum fungicide prior to collecting cuttings. Richardson and others (1979) reported that cuttings from greenhouse-grown plants rooted considerably better than field-collected cuttings for greasewood *(Sarcobatus vermiculatus),* a species that is normally difficult to propagate vegetatively.

A good step-by-step procedure for collecting cuttings is described by Norris (1983). Cuttings should be collected early in the day from new growth of active, healthy plants. Cutting the stem at an angle increases the surface exposure to increase new root production sites. All leaves should be removed from the lower third of the cutting and the cuttings should be kept in a shady, moist location. The crews at Native Plants Inc. prefer to plant the cutting the same day as it is collected.

Before the cuttings are planted, they are often treated with a special hormone to stimulate production of root primordia. These "rooting" chemicals can be made from scratch by mixing indolebutyric acid (IBA) with common talc, or you can buy commercial products such as Rootone or Hormodin. The best concentration of rooting hormone depends on many variables but, in general, the more difficult the plant is to root the higher the concentration of rooting chemical that should be used (Norris 1983). The rooting success of big sagebrush cuttings increased with increases in IBA concentration from 0.0 to 2.0 percent (Alvarez-Cordero and McKell 1979).

Treated cuttings should be inserted to a depth of 1 to 2 inches (2.5 to 5 cm) into a well-drained medium in a shallow rooting tray. The best media for rooting cuttings is subject to debate. Norris (1983) recommends a 1:1 ratio of peat to perlite or peat to fine sand. Native Plants Inc. uses different grades of sand and several combinations of sand, perlite, and potting soil. More information is needed on the best rooting media for different native plant species. Generally, the rooting medium does not contain any type of fertilizer because of a possible stimulating effect on disease organisms.

Some cuttings root quickly so it is important to begin checking the cuttings after the first week. Typically, the cuttings "callus-over" first and then produce adventitious roots from the callus tissue. Some cuttings such as those of juniper take as long as 6 months to root, so the cuttings should be inspected regularly for rooting or disease problems. Cutting success can exceed 95 percent with some species and Native Plants Inc. has achieved 75 to 100 cuttings per sq. ft. (6.9 to 9.3 per sq. m) of bench space.

The rooted cuttings should be transplanted immediately into a dibble hole in the growth container being careful to protect the new roots from injury. The transplanting procedure is inherently slower than any of the propagation methods using seeds but it is possible to reach up to a 95 percent success rate if the transplanting is performed conscientiously. The transplanted cuttings are grown under the standard greenhouse environment with special attention to irrigation during the initial period.

Another technique for producing cutting material involves the use of root sprouts. Species that regenerate by root suckers such as quaking aspen *(Populus tremuloides)* can be propagated by planting sections of lateral roots in an optimum environment and harvesting the succulent sprouts (Schier 1978). The excised roots are cut into 6 inch (15 cm.) sections and covered with potting media in a shallow tray and placed in the greenhouse. After several weeks, root sprouts will appear. These sprouts are cut off, treated with rooting hormones, and transplanted to a growth container. This technique is an effective *way* to propagate certain species but is quite costly in terms of the labor requirement.

PROPAGATION OF SELECTED NATIVE PLANT SPECIES

The propagation techniques used by Native Plants Inc. for 23 native plants are provided in table 2.

The stratification periods recommended in Seeds of Woody Plants in the United States (USDA 1974) illustrate the wide ecotypic variation in some species (e.g. Woods rose, 30-365 days) and lack of data for other species. The propagation methods listed are those most commonly used and some native plants can be propagated by more than one technique. Certain species are produced more easily during a particular season in the greenhouse whereas others can be grown any time during the year. Cropping time indicates the amount of time required to produce a saleable plant in the greenhouse and varies from 3-16 months.

GROWTH CONTAINER AND POTTING MEDIA

The best size, shape, and volume of growth container for producing a native plant that will survive and grow well in the field is a subject that is still open to debate. Ferguson and Frischknecht (1981) recommended a container that is 6 to 8 in. (15 to 20 cm) deep and has a volume of 15 to 25 cu. in. (245 to 410 cu. cm.). Barker and McKell (1979) grew four-wing saltbush *(A. canescens)* and greasewood in four sizes and types of containers ranging from 6 to 70 cu. In. (98 to 1147 cu. cm.) and found that shoot length, shoot biomass, and root biomass all increased with size of container.

Table 2 - Propagation procedures for selected native plants

Species	Stratification Period (Days)[1/]	Propagation Method[2/]	Production Scheduling Season[3/]	Production Scheduling Cropping Time (mos)
Acer circinatum, vine maple	120-240	G, T	Spring	4-5
Amelanchier alnifolia, serviceberry	120-180+	G, T, S	Any	3-4
Arctostaphylos spp., manzanita	0-210	T, C	Any	4-6
Artemesia tridentata, big sagebrush	0-10	T, S	Spr, Sum	3-4
Atriplex canescens, fourwing saltbush	30-50	T, S	Spr, Sum	3-4
Cercocarpus montanus, mountain mahogany	30-90	G	Any	4-6
Chrysothamnus nauseosus, rabbitbrush	0-120	T	Spr, Sum	3-4
Cowania mexicana, cliffrose	?	G, S	Spr, Sum	6-8
Ephedra viridis, Mormon tea	-	T, S	Summer	4-6
Juniperus scopulorum, Rocky Mountain juniper	240	T	Spr, Sum	12-16
Pinus monophylla, singleleaf pinyon	28-90	S	Any	8-12
Populus angustifolia, narrowleaf cottonwood	0	T, C	Summer	3-4
Populus tremuloides, quaking aspen	0	T, S	Spr, Sum	3-4
Potentilla fruticosa, shrubby cinquefoil	-	T, C	Any	3-5
Prunus virginiana, chokecherry	120-160	G, T, S	Any	3-5
Purshia tridentata, bitterbrush	60-90	G, S	Any	4-8
Quercus gambelii, Gambel oak	-	G, S	Fall	6-8
Phus trilobata, skunkbush sumac	30-90	G, S	Any	4-6
Rosa woodsii, Woods rose	30-365	T, C, S	Spr, Sum	3-5
Sambucus cerulea, blue elderberry	30-210	T, S	Spring	3-5
Shepherdia argentea, buffaloberry	0-90	T, S	Summer	4-6
Symphoricarpos oreophilus, mountain snowberry	60-300	T, C, S	Spring	4-6
Yucca glauca, yucca	0	S	Spring	4-6

1/ USDA-FS. 1974. Seeds of woody plants in the United States. Agric. Handbook No. 450. 883 p.

2/ S = seed; G = germinants; T = transplants; C = cuttings

3/ Spr = Spring crop; Sum = Summer crop

They concluded that, all other things being equal, these two native plants should be grown in the largest container possible.

The best container size for good field performance is not necessarily the best container for seedling growth in the greenhouse. Plants grown in large capacity containers generally perform best in the field but require too much greenhouse space and are costly to handle and ship. The best container also varies with plant species and environmental and soil conditions on the outplanting site.

Native Plants Inc. uses two different "tubepak" containers for most of their species: the 6-pack containers contain 13 cu. in. (213 cu. cm.) and the 5-pack has a capacity of 17 cu. in. (279 cu. cm.). Most species can be grown satisfactorily In the 13 cu. in. container but many broadleaved species have to be produced in the larger cells because their large leaves intercept irrigation and shade out adjacent seedlings. Some native plants such as elderberry *(Sambucus* spp.) and mountain-ash (Sorbus spp.) have massive root systems that require larger capacity containers. The density or spacing of the containers in the rack is also important because some species do not grow well at higher densities. Obviously, more work is needed to determine the best container to use for each of the native plant species.

Based on their experiences at the Native Plants' greenhouses, most natives grow quite well in standard potting mixes. Native Plants uses a mixture of equal portions of four materials: peat moss, vermiculite, perlite, and composted bark. They also incorporate a starter fertilizer mix (Osmocote 14-14-14) into the potting soil at 10 lbs. per cu. yd. (7.6 per cu. m.) and Micromax at 1.5 lbs per cu. yd. (1.1 per cu. m.)to supply micronutrients.

The potting mix should be near pH 5.5 and have an electrical conductivity (E.C.) reading of less than 2.0 mmhos.

Other researchers have reported on potting mixes for native plants. Ferguson and Monsen (1974) found that mixes containing peat moss and vermiculite produced better mountain-mahogany *(Cercocarpus ledifolius)* seedlings compared to those containing sand. The SEAM project at the Coeur d'Alene nursery produced 40 different species of native plants using a standard 1:1 mix of peat moss and vermiculite. Ferguson (1980) studied 39 different potting media and found that no one mix was consistently superior. He did report that a potting mix of 50 percent peat moss, 30 percent arcillite aggregate and 20 percent vermiculite is recommended for Bonneville saltbush *(A. bonnevillensis)* and possibly other plant species native to alkaline soils. Mixing native soil into standard potting mixes can increase growth of some chenopod species (Monsen, pers. comm.). A survey of nurseries growing desert shrubs reported a wide variety of potting mixes that contained such diverse components as sand, cinder, peat moss, composted bark, charcoal, sawdust, vermiculite, perlite, and native soil (Anon. 1979). Obviously, there is much variation in potting mixes but it appears that standard commercial potting soils are suitable for most native plants although special mixes may be desirable for some species.

GREENHOUSE CULTURE

Native shrubs have been found to grow well under normal greenhouse environments. Native Plants Inc. uses a uniform environment with day temperatures of 80°F (27°C), night temperatures of 65°F (18°C), a relative humidity of 30-40 percent, 800-1500 ppm carbon dioxide and a 24-hour intermittent photoperiod of 40 ft. candles. The SEAM project at Coeur d'Alene nursery maintained a greenhouse temperature of 65°F (18°C) for the entire growing cycle and intermittent photoperiod lights (20 sec. every 3 min.) at an intensity of 20-40 ft. candles. Monsen (pers. comm.) stresses that many native plants are very sensitive to photoperiod and so greenhouses should have continuous lighting systems.

Fertilization at the Native Plants' greenhouse is applied by two methods, Osmocote 14-14-14 fertilizer is added to the potting soil and Peters 20-20-20 soluble fertilizer is injected through the irrigation system. The injected fertilizer is not applied at any standard rate but is custom-applied based on experience. Because of the wide variation in nutrient requirements between the different native plant species, the grower must visually monitor the growth and color of the plants and fertilize based on experience.

Other greenhouse growers also emphasize the benefits of fertilization of native plants. The SEAM project applied all their nutrients through the irrigation system using a commercial 20-20-20 mix at a 1:100 injection ratio. This solution was applied weekly at the rate of 2 lbs. of fertilizer per 500 ft. (0.9 kg. per 46 sq. m.) of bench space. Once the desired top growth was achieved, the fertilizer mix was changed to a 15-30-15 mixture. Ferguson and Monsen (1974) grew mountain-mahogany seedlings with 3 different rates of Osmocote 18-6-12 slow release fertilizer ranging from 1 to 4 oz per cu. ft (34 to 102 g. per 0.03 cu. m.) of potting soil and found no significant growth differences between the rates.

THE HARDENING PHASE

The hardening phase is one of the most overlooked yet most critical periods in the growing cycle. It is relatively easy to produce an acceptable plant in the greenhouse but these plants are worthless unless they are properly conditioned so that they can survive and grow on the planting site. Many native plant species grow very rapidly under the optimal conditions in the greenhouse but this rapid growth consists of relatively large cells with thin cell walls and little tolerance to cold temperatures. Unlike most ornamental crops, native plants cannot be sold directly out of the greenhouse but must undergo a period of hardening. Ferguson and Monsen (1974) stated that the proper amount of cold hardening was one of the most difficult problems in the container production of native plants.

Hardening can be defined as the process in which growth is reduced, stored carbohydrates accumulate, and the plant becomes better able to withstand adverse conditions (Penrose and Hansen 1981).

There are three major objectives of the hardening phase:

1. To minimize physical damage during handling, shipping, and planting.

2. To condition the plant to tolerate cold temperatures during refrigerated storage or after outplanting.

3. To acclimatize plants to the outside environment and satisfy internal dormancy requirements of some species.

The type and amount of hardening depends on the individual species characteristics and the future use of the plant. Native plants produced as ornamentals usually require much less hardening compared to plants produced for a high elevation revegetation project. The two most important factors to consider in designing a hardening program are the planting date and the climate of the outplanting site. Most greenhouse nurseries are located at low elevations where the growing season begins earlier than at higher elevation planting sites. Native plants that will be planted in an environment that is similar to that where they were grown may only require a 4-6 week period of hardening. Plants that are outplanted at higher elevations during spring or fall must be able to tolerate colder temperatures and perhaps even frost.

Dormancy is another term that is often used in conjunction with hardiness. Dormant conifer seedlings have been shown to have the ability to produce abundant new roots when planted in a favorable environment. This high "root growth capacity" should increase the ability of seedlings to survive and grow on harsh sites. The role of dormancy and root growth capacity has not been studied for most native plants. Plants stored under refrigeration for extended periods should also be dormant to minimize respirational heat build-up in the storage bags. Both dormancy and cold hardiness can be induced by proper scheduling of the hardening regime.

Hardiness should be induced in stages and the process usually takes at least 6-8 weeks. The hardening begins in the greenhouse by shutting off the photoperiod lights and carbon dioxide generators and leaching excess nutrients out of the potting media. Night temperatures are decreased and the seedlings are fertilized with a low nitrogen/high phosphorus and potassium fertilizer. Some growers also induce a mild level of moisture stress between irrigations which supposedly prepares the plant for the droughty conditions on the outplanting site. Drought stressing should be carefully monitored, however, because overly dry potting soil may be difficult to rewet and stressed plants may not cold harden normally. In the final hardening stages, temperatures are gradually lowered to the freezing level and tolerant plant species may even be taken slightly below 32°F (0°C).

Hardening can be achieved in either of two structures, a cold frame or a shadehouse. Shadehouses are generally used to harden crops that are taken out of the greenhouse in summer or early fall when freezing temperatures are not expected. The shadehouse consists of a frame structure that is covered with snowfence or shadecloth and is equipped with an irrigation and fertilizer injection system. Seedlings are protected from wind, intense sunlight, and light frosts in a shadehouse and usually continue to produce new roots and increase in stem diameter during favorable weather. The shadehouse also provides a good overwintering environment and such plants are well hardened by the following spring and ready for planting.

The cold frame used at Native Plants Inc. is a modified greenhouse structure which is maintained at low temperatures to promote hardening. Cold frame hardening is often necessary for crops that need to be removed from the greenhouse during freezing weather. Often, cold frames are used to induce dormancy and cold hardiness in plants before they are moved to a shadehouse for final hardening and storage.

VARIATION BETWEEN SPECIES AND BETWEEN CROPS

Although it is possible to grow several species of native plants under a standard greenhouse environment, nursery managers should be cognizant of the variable growth requirements and morphological characteristics of the individual species. A grower must directly experience how plants perform under his own nursery system before he will be able to consistently produce uniform crops of native plants. Individual species will not grow the same during different growing seasons or during different years. Some species that grow best during the summer season will not perform satisfactorily if grown over the winter. Because of differences in seed crops from year to year and between seed sources, every crop of native plants will be slightly different in growth characteristics.

CONCLUSIONS

1. Crop planning is very important when working with native plants and a crop may take from 2 to 3 years to produce if seed is not immediately available.

2. Production of native plants may require as many as four separate facilities: production greenhouse, cold frame, shadehouse, and refrigerated storage.

3. Four propagation methods are used to produce native plants in containers: direct seeding, germinants, transplants, and rooted cuttings.

4. The best size, shape, and volume of growth container is dependent on the species of plant and characteristics of the outplanting site.

5. Standard potting mixes are adequate for many native plants but some species may require special mixes.

6. Native plants grow well under normal greenhouse environments but a grower should be aware of individual species differences.

7. Plants should be hardened in several stages by changing the growing environment and moving them to either a cold frame or shadehouse.

8. There is considerable variation between individual species and between seed collections and so each crop of native plants will perform differently.

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