

Strategies for Seed Propagation of Native Forbs

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Abstract: Native forbs are an increasingly important component of container production for many public and private nurseries. Propagators are often called upon to grow species with unknown requirements. A systematic approach is required to obtain plants from seeds of these species, beginning with determining what is a propagule and evaluating seed quality. Next, seed dormancy status must be determined, and appropriate dormancy-breaking treatments applied. Finally, germinable or germinated seeds must be sown into a propagation system that maximizes chances of survival and growth. The propagation system may need to be tailored to the requirements of the species being grown. Most native forbs can be grown successfully in containers, but a few present seed dormancy or seedling growth problems that we have not yet learned to overcome.

Keywords: dormancy, dry after-ripening, germination, hard seed, seed quality, stratification, viability

Introduction

The native flora of North America includes a wealth of broadleaf herbaceous species commonly referred to as forbs. Many of these forb species are coming into nursery production. Forbs are increasingly recognized as important components of the biodiversity of natural ecosystems, and they are frequently included in ecological restoration efforts. In addition, many forbs are traditionally recognized as medicinal plants whose over-collection in the wild is leading to efforts to establish them in cultivation. Native forbs also offer exciting possibilities for horticultural use as drought-tolerant, low-maintenance ornamentals. All of these factors play into the fact that many propagators are faced with the need to propagate forb species with unknown requirements.

In contrast to most species with a long history of cultivation, native forb species often have seeds that are not readily germinable. Seed dormancy mechanisms operate in nature to maximize chances of seedling survival by limiting germination to a favorable season or by spreading germination across years. Many cultivated species have wild ancestors whose seeds show these adaptive dormancy release patterns. A few generations in cultivation, however, are often sufficient to apply selection, either inadvertently or deliberately, for reduced dormancy. Consequently, propagators who have worked mainly with cultivated plants are often not prepared for the sometimes elaborate and time-consuming measures needed to overcome dormancy in the seeds of wild plants.

Components of a Forb Seed Propagation Strategy

Fortunately, there is some rhyme and reason to patterns of dormancy release in native forb seeds. By examining seed traits, family relationships, and habitat of origin for a particular seedlot, it is often possible to narrow down the possibilities for dormancy-breaking treatments. Approaching the problem systematically usually makes it possible to obtain plants within a reasonable amount of time. The key components to this approach are: determining what is a propagule, checking seed quality, determining seed dormancy status and germination requirements, and addressing seedling growth needs.

Determining What Is a Propagule

While the step of determining what is a seed or propagule may seem self-evident to some, a paper bag containing seeds of a wild-collected forb usually contains far more than the seeds in question. This is especially true if the collection was made by

an inexperienced person, as is often the case with native forbs. The first task, even before seed cleaning, is to determine exactly what subset of the seed collection actually consists of seeds or propagules. The term propagule includes seeds, but also includes fruits that contain seeds, or seed-containing fruits with accessory floral structures. It refers to the unit that is capable of producing a seedling.

In trying to determine exactly what is the seed or propagule for a collection of an unfamiliar forb, the best first step is usually a quick perusal of a taxonomic description for the genus. This will determine, for example, whether the fruit is a capsule that must be ruptured to extract the seeds or a one-seeded fruit that is best handled intact. It will also give some information about seed size, which will determine whether to look for the seeds in the dust at the bottom of the bag or in the chunky debris on top of the coarsest screen. Once some of the attributes of the seeds and fruits are known, it is time to rummage around in the bag or dump it into a tray and attempt to find some propagules. Knowing what they look like before commencing seed cleaning can prevent embarrassing mistakes, such as throwing out the *Penstemon* seeds and saving the capsule partitions to plant, as has happened to at least one inexperienced student technician.

It is not always clear whether seeds need to be removed from their fruits prior to planting, especially for one-seeded fruits. For example, it is evident that the hard, one-seeded fruit of *Mirabilis multiflora* (desert four o'clock) constitutes a propagule, but in the related genus *Abronia* (sand-verbena), the wall of the fruit is papery and easily removed by threshing. Moreover, many of the papery fruits are not filled, so that threshing out the seeds results in a much higher quality lot that can be treated and sown with more precision. In the sunflower family, on the other hand, the one-seeded fruits are always treated as propagules, although the accessory floral structure (pappus) is often removed by rubbing to facilitate handling.

Checking Seed Quality

Usually when seeds are cleaned, most of the unsound or empty seeds are removed so that the cleaned lot is of relatively high quality. This is not always the case, however, and it pays not to assume that the seedlot at hand actually contains a high proportion of viable seeds. One can waste a lot of time and effort trying to get empty seeds to germinate, and the results are disappointing at best. The simplest method of checking seed quality is the cut test. If the seeds are recently harvested and have been dried and stored correctly (that is, not placed directly into sealed plastic bags), a cut test is a good estimate of viability. It consists of placing the seeds on a moist medium for a few hours until they imbibe water (after nicking, if they happen to be hard-seeded; see below), then bisecting them longitudinally with a sharp razor blade. Generally, if the seeds are hard and pale inside, and cut with a nice "vegetable crunch," they are (or were) alive. To make sure, one can dissect out the embryo and see if it has all its parts, especially a firm, white radicle (seed root) end. A shriveled radicle end means an effectively dead seed, while a little discoloration or deformity on the edges of the cotyledons (seed leaves) may have little effect on viability. If the seed goes squish when cut or contains a

pulpy, soft, discolored embryo, it is not viable. Of course, if there is no embryo to be found, the seed is empty and, therefore, not viable.

It helps to know something about the seeds produced by plants of different genera. Seeds of the genus *Penstemon*, for example, are small and have a corky, air-filled outer seed coat. They contain mostly endosperm, with a small, sausage-shaped white embryo up the middle. The translucent, wax-like endosperm can be quite firm. If the white embryo is missing, however, the seed is not viable. Seeds of legumes like *Lupinus*, on the other hand, have very large embryos that completely fill the seed, so that it is easy to see whether or not they are "home" by slitting the seed coat and slipping the embryo out.

It is a good idea to cut at least 10 seeds to get a crude viability estimate. It takes more seeds to accurately assess the viability of a low-quality lot. If several of the first 10 seeds are not good, evaluate at least another 10. Formal quality evaluation includes four replications of 100 seeds each. But it is not necessary to sacrifice nearly that many seeds in order to get a rough idea of seedlot viability for practical purposes; when seed quantity is extremely limited, sacrificing even 10 seeds may seem ill-advised.

It sometimes happens that seeds are filled and can pass muster in a cut test, but are still not viable. Seeds that have been stored dry for such a long time that they have lost viability in storage fall into this category, as do seeds that have been stored for even a short time at a too-high moisture content (as in those plastic bags mentioned above) or temperature. Pathogenic storage fungi begin to operate at relative humidities in excess of 75 percent, which corresponds to a seed moisture content of about 14 percent. Seed viability will drop off rapidly under these conditions. If there is any question of viability loss in storage, it is worth performing a slightly more elaborate viability evaluation. Tetrazolium staining is the usual procedure (Peters 2000). This vital stain turns red in the presence of enzymes that occur in respiring, living tissue. To perform a tetrazolium test, the seeds are set to imbibe as in a cut test and are then pierced to allow entry of the large tetrazolium molecules, or the embryos are dissected out of the seeds. They are then immersed in the tetrazolium solution for several hours (warm temperatures hasten the process), then bisected (if seeds are intact) and scored by examining the staining patterns on the embryos. If the embryo stains completely bright red, the seed is unequivocally viable, while failure to stain indicates lack of viability. It takes some skill and experience to interpret tetrazolium staining, and some seeds stain better than others. *Penstemon* seeds, for example, often do not stain very darkly, even if highly viable as determined in concomitant germination tests. Still, a tetrazolium test is more definitive than a cut test as a viability evaluation procedure, and is sometimes accepted as an official surrogate for a germination test in the quality evaluation of highly dormant species.

Even if a seedlot shows low viability as determined by a cut test or tetrazolium staining, it may still be possible to obtain plants, as long as seed supply is not limiting. Knowing the approximate proportion of viable seeds makes it possible to estimate how many total seeds might be needed to obtain a given number of plants. Or it may sometimes be possible to

clean the lot more vigorously, with a seed blower for example, to increase the proportion of filled seeds.

Determining Dormancy Status and Germination Requirements

There is a very extensive literature on the subject of seed dormancy and germination, including a plethora of different dormancy classification schemes (Baskin and Baskin 1998). From the point of view of propagation, the most useful scheme is one that is centered on treatments required to break dormancy rather than on its anatomical, developmental, and physiological causes. Such a practical seed dormancy classification scheme is adopted here:

1) Seeds nondormant. Seeds germinate readily over a wide range of conditions, and no dormancy-breaking treatment is required. Predicting which species will have nondormant seeds is a gamble, but experience has revealed some patterns. For example, small-seeded members of the Asteraceae (sunflower family) almost always have nondormant seeds, as do members of the genus *Asclepias*. Within a genus, seeds from low elevation species and populations are more likely to be nondormant than seeds from high elevation.

2) Seeds conditionally dormant. Seeds germinate only under a narrow range of conditions, behaving as if dormant unless these conditions are met. Sometimes conditionally dormant seeds can become nondormant through the application of dormancy-breaking treatments, but these are not necessary as long as specific germination conditions are met. An example of conditional dormancy is found in many species of freshwater marshes, where widely fluctuating temperatures provide a cue that water levels have dropped to the point that seedling establishment is possible. The seeds will not germinate at any constant temperature. Similarly, a light requirement for germination is characteristic of many weedy species of arable land. Light provides a cue that soil disturbance has returned the seeds from depth to a position at or near the surface, where establishment is possible. The light requirement in weeds is usually coupled with specific temperature requirements for germination that exhibit cyclic changes, but such mechanisms are much less common in native forbs.

3) Seeds physiologically dormant, losing dormancy through dry after-ripening. Seeds are dormant at harvest and lose dormancy in dry storage. Often they proceed from dormant to conditionally dormant to nondormant during this process. The rate of dormancy loss in dry storage is directly related to temperature, and for some species dormancy loss is very slow except at high temperature. Many seeds thought of as nondormant actually exhibit dormancy or at least conditional dormancy at dispersal, but quickly become nondormant through dry after-ripening under summer conditions. These seeds also lose dormancy in laboratory storage, albeit more slowly. Many grass species follow this pattern, which is generally characteristic of species whose seeds are produced in early summer and whose seedlings are autumn-emerging.

4) Seeds physiologically dormant, losing dormancy through cold or warm plus cold stratification. Seeds of a large number of species of temperate regions are dormant at harvest and lose dormancy under cold, wet conditions that

simulate winter. This ensures that germination will not take place before the onset of winter, but will instead occur in late winter or spring, when conditions for establishment are most favorable. Rate of dormancy loss is essentially constant over the chilling temperature range 0 to 5 °C (32 to 41 °F), but dormancy loss generally stops at temperatures above or below this range. Examples of native forbs with chilling-responsive seeds include most of the large-seeded members of the Asteraceae and most members of the Scrophulariaceae (snapdragon family), Boraginaceae (borage family), Polemoniaceae (phlox family), Apiaceae (parsley family), Polygonaceae (buckwheat family), and Liliaceae (lily family).

The length of chilling necessary to break dormancy varies among species, among populations within species, and among seeds within a lot. In general, the chilling requirement tends to increase with increasing elevation, which makes sense because winters are longer in the mountains. Chilling requirements of 6 months or more are not unusual for high mountain species such as scarlet paintbrush (*Castilleja miniata*), mountain bluebells (*Mertensia ciliata*), and Whipple penstemon (*Penstemon whippleanus*), which inhabit places where snow pack lingers into the summer. Foothill species and populations of *Penstemon* may require 3 or 4 months of cold stratification, while seeds of lower elevation desert species and populations may respond to stratification periods of only a few weeks (Meyer and others 1995).

Seeds of some species require a period of warm, wet conditions prior to cold stratification in order to lose dormancy during chilling. Seeds with immature embryos that require warm plus cold stratification to induce embryo growth and germination are included here. There are relatively few native western forbs known to have a requirement for warm plus cold stratification. Seeds of baneberry (*Actaea rubra*) and of some forest-dwelling members of the Liliaceae may respond to this treatment.

5) Seeds physically dormant, requiring seed coat breaching to imbibe water. Seeds at harvest are "hard" and unable to take up water. They will germinate readily, usually over a wide range of conditions, once the integrity of the seedcoat is breached. True "hard-seededness" requires very specialized cellular development within the seedcoat and is confined to only a few plant families. North American families with hardseeded forb species include the Fabaceae (pea family), Convolvulaceae (morningglory family), Cucurbitaceae (gourd family), Malvaceae (mallow family), and Geraniaceae (geranium family). To break physical dormancy, the seed coat is usually disrupted using mechanical methods such as nicking or sandpaper, acid scarification, or heat treatments such as a boiling water soak. It is important that these treatments be carefully applied, or the embryo may be damaged.

6) Seeds with multiple dormancy mechanisms. Species with multiple seed dormancy mechanisms fall into two categories, those whose seeds require a specific sequence of dormancy-breaking treatments and those whose seeds lose dormancy in response to different dormancy-breaking treatments applied singly. Hardseeded species like *Astragalus utahensis* (Utah ladyfinger milkvetch), whose seeds usually require cold stratification after hardseededness is broken, exhibit a requirement for a specific sequence of dormancy-breaking treatments. Seeds of some populations of *Linum lewisii* (Lewis flax) are dormant at harvest but can lose

dormancy either through dry after-ripening or through cold stratification. They represent seeds that can lose dormancy through multiple pathways.

7) Seeds with cue nonresponsive dormancy. Some native forb species have seeds that are programmed for persistence in the soil seedbank for long periods of time. Many hardseeded species fall in this category. However, because their physical dormancy is easily broken, they are usually not too hard to propagate. Other species have physiological dormancy that is not broken by any of the dormancy-breaking treatments that correspond to environmental cues such as dry heat or cold stratification. Most of the seeds in a population are programmed to ignore these cues, with only a small fraction becoming cue-responsive each year.

Species with cue nonresponsive seeds can be difficult to propagate. One method that has been effective involves injuring the seeds, for example by piercing, which seems to disrupt their ability to remain dormant. This is similar to mechanical scarification of hard seeds, but seeds of these species readily take up water. Sometimes such damage to imbibed seeds will induce immediate germination, and sometimes it will render the seeds responsive to cold stratification. Another method that is sometimes used is the application of a plant hormone such as gibberellic acid (GA_3), which can also induce immediate germination or increase chilling-responsiveness (Kitchen and Meyer 1991). A disadvantage to this latter method is that the resulting seedlings tend to be etiolated. Careful attention to GA_3 concentration and to handling of the resulting seedlings can result in successful propagation. Unfortunately, many species with cue nonresponsive dormancy do not respond to GA_3 .

Variation in Dormancy-Breaking Requirements—One of the hallmarks of natural populations of plants is variation, and this applies to traits associated with seeds as much as those associated with actively growing plants. This variation is grist for both natural and artificial selection, but it can be quite a nuisance for the propagator. Successfully propagating a species from one seedlot is no guarantee that the method employed will work with other collections of that species. Among-population differences in seed dormancy status were mentioned in the section on cold stratification. Such variation makes it difficult to generalize about germination requirements for many native species. In *Penstemon palmeri*, for example, dormant lots may respond positively to cold stratification, while nondormant lots actually tend to go into secondary dormancy following the same treatment (Meyer and Kitchen 1992).

Even more troublesome to the propagator than dormancy variation among different seedlots is dormancy variation among individual seeds within a seedlot. For example, for propagation of chilling-responsive species, the desirable scenario is for all the seeds to have the same cold stratification requirement and for none of the seeds to germinate during chilling. Unfortunately this is rarely the case for native forbs. Most have seeds that germinate in chilling soon after they become germinable at higher temperature. And the chilling requirements for individual seeds vary widely, so there is no one chilling time when the majority of ungerminated seeds can be removed from stratification, planted, and expected to emerge.

In addition to simple variation in the chilling duration required to break dormancy, an added difficulty for many species is the presence of a sometimes sizeable fraction of seeds that are cue nonresponsive and do not germinate even after very long chilling periods, much longer than the duration required for germination of the cue-responsive fraction of the seedlot. These seeds are clearly programmed not to germinate in response to the first winter they experience. Sometimes it is possible to get another pulse of germination out of such a seedlot by drying the stratified seeds for a few weeks, then placing them back into cold stratification. This may in effect trick the seeds into responding as if a summer had passed and a second winter had commenced.

A Decision Tree for Approaching Seed Propagation of a Forb With Unknown Requirements—Once seeds are identified, cleaned, and checked for viability, the first question to address is whether they can take up water (figure 1). Again, this is only an issue for seeds of species that belong to the families where hardseededness is a possibility. If hardseededness is present, the next step is to scarify a few seeds and determine whether they are rendered readily germinable under laboratory conditions. If the answer is yes, then the lot needs scarification as the only dormancy breaking treatment prior to planting. If the answer is no, then the scarified, imbibed seeds should be subjected to cold stratification. Usually a short chill (2 to 4 weeks) is sufficient to remove physiological dormancy of formerly hard seeds.

For lots that are not hard-seeded, the obvious next question is whether the seeds are nondormant, that is, whether they can germinate without any dormancy-breaking treatment (figure 1). If seeds that are imbibed and placed under laboratory conditions germinate to high percentages within 1 to 3 weeks, the lot can be considered nondormant and can be direct-sown without treatment. Even seeds that are conditionally dormant will usually germinate within a few weeks under conditions of moderate alternating temperatures (for example, 10 to 20 °C [50 to 68 °F]) and fluorescent light. This is the regime we use to define provisional dormancy status. Incandescent light can inhibit germination of light-requiring seeds, and high temperatures (>25 °C [77 °F]) are almost universally inhibitory to forb seed germination. To determine whether the seeds require light to germinate, place a container of imbibed seeds in the dark (aluminum foil works for this purpose) and compare germination success with seeds incubated under fluorescent light.

If seeds are dormant, there are two principal options for breaking dormancy, and if seeds are plentiful, it is usually wise to pursue both of these options simultaneously (figure 1). One subset of seeds can be placed in warm dry storage to hasten dormancy loss through dry after-ripening. Air-dry seeds can be placed in a sealed container, such as a screw-cap vial, and stored at temperatures as high as 40 °C (104 °F) for a few weeks without damage. Even storage at 30 °C (86 °F) will greatly hasten dormancy loss, and is less risky for low-vigor lots that may be more susceptible to heat damage. If controlled temperature, warm storage conditions are not available, the back seat of a car parked outside in summer or on top of the furnace in winter are reasonable substitutes. If these temperatures seem excessive, consider that summer soil seed bed temperatures in desert ecosystems commonly reach 50 °C (122 °F) for several hours during the day and

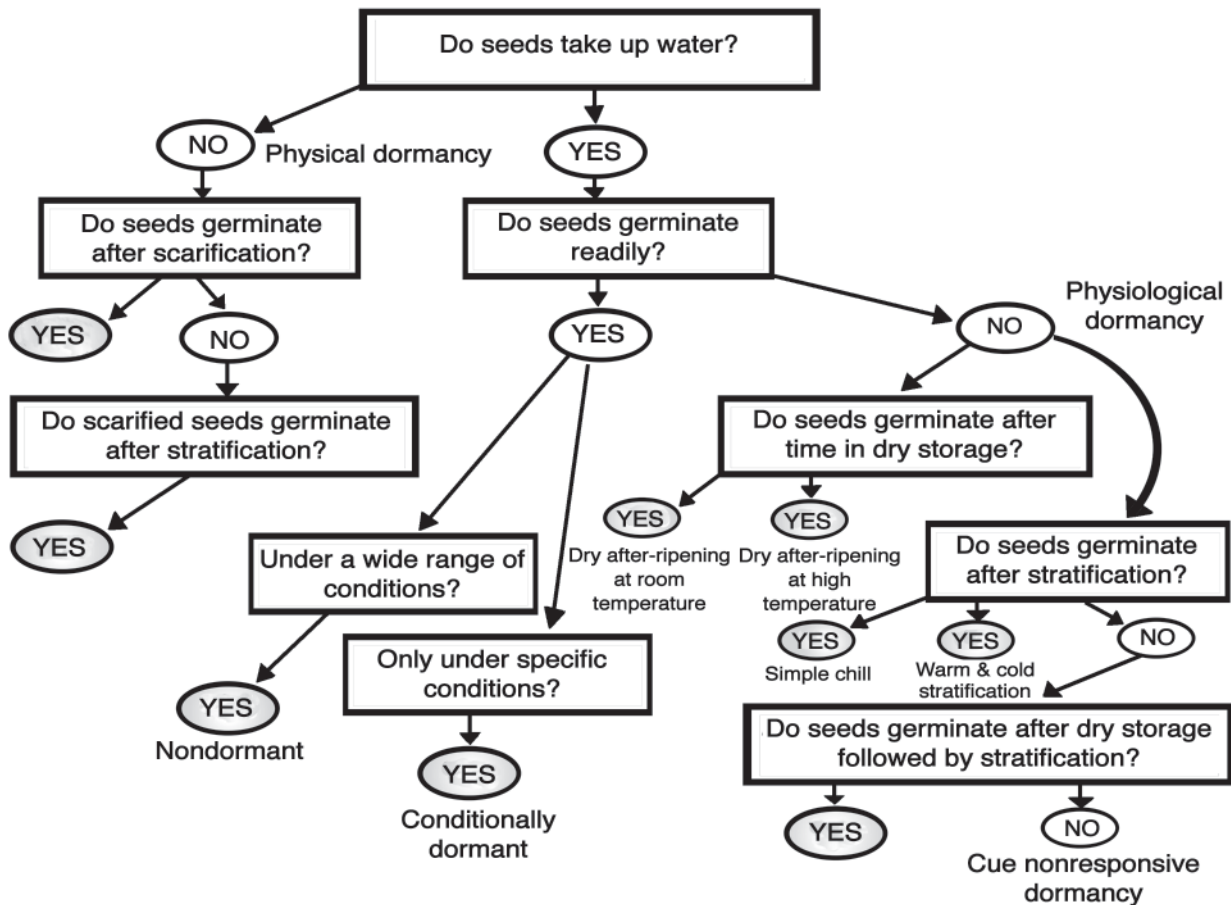


Figure 1—A decision tree for approaching the seed propagation of a native forb with unknown germination requirements.

may go as high as 60 °C (140 °F). The stored seeds should be retested for dormancy status at weekly intervals. If no change is observed after a month or more of warm dry storage, the seeds probably do not lose dormancy through dry after-ripening.

A second batch of seeds can be placed directly into cold stratification (figure 1). Small numbers of seeds can be pulled out of chilling at intervals and germinated under laboratory conditions to check for dormancy status. Depending on species and habitat of origin, chilling periods of 6 months or more may be required. The seeds in chilling should be checked frequently, however, as many species have seeds that will germinate during chilling once dormancy is alleviated. Germinated seeds need to be planted right away. If they are left too long in the cold, the radicles elongate to the point that planting the seedlings without damage becomes impossible.

A third option for seeds that apparently do not dry after-ripen is to take batches of seeds that have been subjected to warm, dry storage and place them into cold stratification. Even though the seeds have not been rendered nondormant in warm, dry storage, their chilling requirement may have been shortened considerably.

A fourth option is to place dormant seeds that have been incubated at room temperature for a few weeks into cold stratification. This is equivalent to applying a warm plus cold

stratification treatment. It is most likely to work with species from summer-moist, mountain, or forest environments.

If none of the treatments described above result in significant germination of a viable seedlot, it is likely that the seeds exhibit cue nonresponsive dormancy, and more drastic dormancy breaking methods are in order. Combining seed coat injury, GA₃ treatment, or drying with cold stratification may alleviate dormancy in some cue nonresponsive lots.

Addressing Seedling Growth Problems

For most native forbs, obtaining germination is the most difficult phase of the propagation process. Some species, however, present serious problems at the post-seedling stage. These generally fall into two categories: problems related to pathogens and symbionts, and problems related to intrinsic growth attributes of the plant.

Seedling Growth Problems Related to Pathogens and Symbionts—Damping-off or root diseases can be a problem in any seed propagation effort, but this problem is generally more acute with native forb species, especially those from dry environments. Using good phytosanitary practices and aerated steam-treated potting medium can certainly help. Coarse, fast-draining mixes and top-dressing with sand can also help protect the young plants from the

wet crown conditions that predispose them to disease. Including some field soil in the potting mix can also be an important disease deterrent. Field soils often contain antagonistic organisms like actinomycetes that can decrease the severity of many seedling diseases (Weller 1988). Finally, chemical fungicides may be used, but these must be applied with caution as native forb seedlings often exhibit fungicide toxicity symptoms much more readily than the crop plants for which these fungicides were developed.

Adding field soil to the potting mix may have other benefits as well. For legumes capable of forming symbiotic relationships with nitrogen-fixing organisms, field soil from the root zone of wild individuals of these species can provide the inoculum needed to form these associations. There is evidence that creating such symbiotic nitrogen-fixing associations in containers produces healthier plants than simply providing an abundance of available inorganic nitrogen.

Another class of symbiotic organisms, endomycorrhizae, can also be provided to container plants through the use of field soil in the potting mix or commercially available inoculum. Almost all native forbs form mycorrhizal associations (Smith 1996). Mycorrhizal organisms aid the plant in several ways. In addition to increasing uptake of relatively nonmobile nutrients like phosphorus by increasing the effective root area and extent, mycorrhizae also improve water relations, and can also protect the roots from harmful organisms in the root zone. This last effect may be the most important benefit for plants in containers, where nutrient and water resources are generally not limiting, but the other benefits are often evident after outplanting.

Seedling Growth Problems Related to Intrinsic Growth Attributes—Problems related to intrinsic growth attributes of a particular species are inherently more difficult to deal with than those involving interactions with other organisms, which can be often mitigated by managing cultural conditions. Intrinsic growth attributes that cause problems in container culture include features of root architecture and phenology of shoot growth.

Fibrous-rooted plants are much easier to produce in containers than tap-rooted plants for at least two reasons. They do not require deep containers as seedlings, and they quickly form a coherent root ball that makes transplanting easy. Fortunately for native forb growers, many timber tree species are taprooted as seedlings. The problem of container shape has already been resolved, and there are many useful variations available in the trade. The important thing is to recognize which forb species require deep containers. For example, *Astragalus* (milkvetch) species tend to be strongly taprooted and hardly progress past the seedling stage when planted in shallow flats. Even in deep containers, it takes a long time for them to develop a lateral root system than holds the planting medium together during transplanting. Using containers like Spencer-Lemaire Root Trainers™ (Spencer-Lemaire, Edmonton, Alberta, Canada) that open up for seedling removal can reduce wear and tear on weak root systems during transplanting. An alternative is to use a stabilized medium such as a Q-Plug™ (International Horticultural Technologies, Hollister, CA), which retains its shape upon removal from the container and can protect the roots of weakly rooting forbs during transplanting. We definitely need more research on methods for increasing lateral root development in slow-growing, taprooted species.

Even more problematic than taprooted plants like *Astragalus* species, which at least continue active growth in containers for an indefinite period of time as long as conditions are favorable, are species that combine the deep-rooted habit with summer dormancy. Many of the most beloved western wildflowers, including some native lilies, belong in this category. The seeds are generally fairly easy to germinate, requiring only cold stratification, and the seedlings emerge readily and begin growth. But after a few weeks, and usually after the production of a only single true leaf, growth ceases and the plants go into dormancy, even if conditions remain apparently favorable.

Plants with the summer-dormant pattern of growth are usually found in desert and foothill habitats where summers are dry. In nature, they have everything to gain by spending their energy building roots to get through the summer rather than leaves, which are destined to wither quickly in any case. Such plants are often long-lived and require many years to reach flowering size. For example, species of desert parsley (*Lomatium*) follow this summer-dormant pattern. Cow parsnip (*Heracleum lanatum*), a relative from the mountains, is much easier to grow in containers. It continues shoot growth all summer in the cooler, wetter mountain environment where capitalizing on leaves to maximize light capture is the best strategy. Other examples of summer-dormant forbs are balsamroots (*Balsamorhiza*) and foothill species of waterleaf (*Hydrophyllum*) and bluebell (*Mertensia*).

One thing that makes summer-dormant plants so difficult to handle in containers is that, once the plant is dormant, it is difficult to know how much to water. Clearly, too much water will cause the roots to rot and die; no water at all over a long period of time in a container not in physical contact with the soil may be equally damaging. Also, we do not know how to bring these plants back out of dormancy. In some cases, a dry-down may be sufficient for the plants to reinitiate growth. But many of these plants do not grow at all in autumn in nature, no matter how much it rains. This suggests that they may need cold stratification to break bud dormancy and reinitiate growth. If this is true, it may be possible to speed growth by putting the plants through multiple simulated springs (temperate and moist), summers (dry), and winters (cold and moist) in a single year. To my knowledge, no one has tried to do this systematically, but it is certainly an area that would benefit from serious research. From a restoration standpoint, it might be sufficient just to plant out the dormant first-year seedlings and let nature take its course.

Conclusions

Seed propagation of native forbs is one of the most satisfying activities available to plant propagators. By following a systematic protocol for determining germination and growth requirements, it is usually possible to obtain plants in a reasonable period of time. Native forb species present a variety of problems, but it is most intriguing to work with these plants and solve the problems they present. It is hard to match the thrill of producing healthy container stock of a species that may never have been seen before except in the wild. If one can follow the temptation to take some of these container-grown plants and place them in a horticultural setting, the interest level increases even further. The reward

may be an outstandingly beautiful plant worthy of display in the garden of even the most demanding flower connoisseur.

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