on acceptance or decline of stock is made. Morphological assessments are usually made immediately prior to crop harvest, often synchronized with a pre-harvest inventory. But, this is only half of the story—seedlings of high morphological quality might have low physiological quality (Stone and Jenkinson 1971), or, may even be dead!

Physiological quality

A variety of physiological quality tests are available to evaluate seedlings for reforestation, including root growth potential (or capacity); electrolyte leakage from fine roots, taproots, shoots, needles, and buds; water potential; root moisture content; root carbohydrate levels; mineral nutrition; chlorophyll fluorescence; stress-induced volatile emissions; photosynthesis; and bud dormancy status. Colombo et al. (2001) compare most of the popular tests and provide estimates on ease of assessment, equipment costs, and time required to obtain results. Although most seedling physiological assessments have been developed for conifers, some have applicability to hardwood crops, whereas others do not (Wilson and Jacobs *in press*). For example, chlorophyll fluorescence, a rapid nondestructive test is often done on conifer foliage during the winter dormant period to monitor physiological changes related to harvesting and storage, but is less useful on hardwood seedlings without leaves (Wilson and Jacobs *in press*). So, it is important for foresters and managers to realize that no single test can predict outplanting performance (a “silver bullet” does not exist as per Puttonen 1997), and that physiological tests are mere “snapshots” of seedling viability at the time of the test. Whereas a seedling measured before and after storage will have the same height and stem diameter, cold hardiness values will be different before and after storage, and perhaps vary greatly if the storage conditions were severely affected by a prolonged mechanical disruption.

Therefore, foresters and managers, reviewing their description of the target seedling, should determine which factors are most limiting on the outplanting site and focus physiological tests toward those factors. For example, if the site has low nutrient availability, then perhaps a target calls for loading the seedlings via exponential fertilization (Timmer 1997); an appropriate physiological test would be to measure foliar nitrogen content to ensure the values are optimal. Conversely, if severe browsing is expected on a south-facing clearcut in the mountains of the western US, the same test might be advised to ensure a lower nitrogen concentration to discourage browse (Bergquist and Örlander 1998). Or, if the site is harsh in terms of temperature extremes and low moisture availability, a test of frost hardiness might be appropriate—seedlings with high resistance to cold temperatures may better tolerate other stresses as well. Thus, maximizing cold hardiness may infer advantage over seedlings with low cold hardiness.

Seedling quality assessments are also helpful if it is believed the stock has been damaged during production, storage, or shipping. For example, a freak cold event killed the roots of a container crop just days before harvest. The manager had a root growth potential test and a plant moisture stress test completed before harvesting the crop—the tests confirmed that the seedlings were dead, even though they still “looked” fine, saving the manager the expense of harvesting and storing while also providing the forester sufficient lead time to secure seedlings from other sources.

Because physiological tests are “snapshots,” no single test is definitive, conducting tests can be costly, and results are open to interpretation, it is imperative that foresters and managers agree on basic tests to conduct on crops, who pays for the testing, and who interprets results. A minimum testing regime might include a cold hardiness test to ensure the stock is ready to be stored and a post-storage root growth potential test to ensure the seedlings are alive and able to produce new roots.

Storage and Shipping

Seedlings may spend 30 to 50% of the nursery production cycle in storage, or, in the case of container seedlings in the southeastern US or Intermountain areas of the western US, they may be “hot planted” with little or no storage. Traditionally, seedlings destined for spring outplanting are stored overwinter, either in cooler storage for short terms (0^0 to 2^0 C; 1 to 2 months) or cold (freezer) storage for longer terms (-2^0 to -4^0 C; 2 to 6 months). These storage temperatures promote dormancy release (van den Driessche 1977) but at suboptimum rates (Anderson and Seeley 1993) so that stored stock retain higher levels of dormancy and stress resistance than non-stored stock when removed for outplanting. Freezer-stored stock maintains food reserves better than cooler-stored seedlings (Ritchie 2004) and substantially reduces growth of storage molds (Sutherland et al. 1989).

Many nurseries still rely on natural, outdoor storage in the hope being that snowfall will blanket seedlings and insulate them through winter. Using snow-making machines reduces the risk factor. Additionally, many nurseries only have access to cooler storage. Both of these methods can provide satisfactory overwintering of stock. Prudent foresters should ask nursery managers how, and how often, the stock is evaluated during storage