Lessons Learned From the USDA Forest Service Reforestation Improvement Program

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Abstract-The Reforestation Improvement Program gave the USDA Forest Service nurseries and reforestation specialists new tools to track progress of the growth and condition of their crops, including electronic-age capability to collect and analyze data in real time to support management decisions. It developed an information and help network among Forest Service Research, National Forest Systems, and State and Private Forestry to promote successful reforestation.

In 1985 the USDA Forest Service instituted a major Reforestation Improvement Program (RIP) with the goal of making reforestation more predictable and successful by applying the latest knowledge and technology (Owston et al. 1990). It involved setting up an intensive monitoring system of environmental conditions, seedling biology, and nursery and field operations for several test lots of several important species at all 10 Forest Service nurseries. The nursery phase of RIP terminated in 1991 after producing three crops of 2+0 seedlings. Monitoring of the field planting sites continued for two more years.

Now that this program is officially terminated it behooves us to identify its lasting benefits and make them available to the nursery industry at large. The following list represents some of the outstanding accomplishments, but is by no means exhaustive.

ADP EQUIPMENT

Each nursery was equipped with two automatic recording weather stations for a "base" and a 11 seedbed" location, plus a portable computer with software for downloading and processing the data. This gave the nurseries the most complete local weather information they had ever had, and provided documentation of any microsite differences from one part of the nursery to another. The nurseries were given the tools to manipulate the data to correlate important aspects with growth in the nursery, and performance in the field. Electronic recording meant less manual handling of the data, fewer mistakes in translation, and the ability to analyze large volumes of data in real time to supply information to support management decisions.

For instance, they could easily calculate growing degree hours, which could be correlated with height growth, making it possible to have comparisons of growth in one year to that of previous years. Calculation of cold hardening degree hours may yield important information about when the seedlings are ready to be lifted, whether they are fully dormant, and how well they will store.

To calculate growing or hardening degree hours, it is necessary to establish a zero-effect baseline temperature. In the past, these have been "best guesses" supported by very little data. However, the data generated by RIP, and the ease with which it could be manipulated, enabled us to try a series of different base temperatures in search of the best one. In addition, as a member of their Scientific Analysis Team, I was stimulated to reanalyze some growth chamber data on optimum growing temperatures (Tinus and McDonald 1979), and calculate a base temperature mathematically by extrapolating height growth to zero (Fig. 1). The remarkably good correspondence between this method and the empirical method used in RIP gives us confidence in the base temperatures we have found.

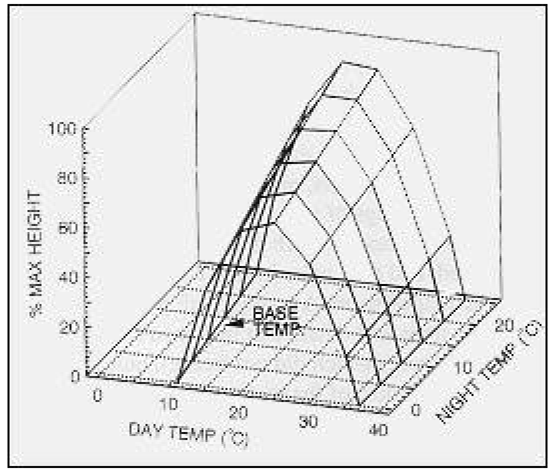

Figure 1. Height growth of ponderosa pine (Ruidoso NM provenance) as a function of day and night temperature. Extrapolation of height growth to zero yields a base growing degree day temperature of 8-11ºC with a small positive effect of increasing night temperature.

Another possible use of the weather data is to calculate potential evapotranspiration on a daily basis and use it to manage the irrigation regime efficiently by adding only the water needed to replace what has been lost (Papadopol 1990). This has not been implemented at Forest Service nurseries, but is coming into use in places such as the New Mexico State University horticultural farm at Las Cruces.

Probably equally important, the instruments and computers introduced the nurseries to electronic data collection and processing, and suggested more ways to use them in other aspects of the nursery business. Whereas the Forest Service as a whole had committed itself to a centralized mini-mainframe computer with limited proprietary software (the Data General system), the nurseries were given a system that was much more flexible. It also was more expandable in terms of capability for data storage and processing (the personal computer).

HISTORY PLOTS

For each of the seedlots used in the program, history plots were installed in the seedbeds. A history plot is one that tracks the life history of a population of first seeds, then seedlings, from sowing to lifting, and documents the losses at each stage of growth and production. These plots were observed and measured intensively and repeatedly, giving a detailed life history of establishment, growth, and the effect of cultural treatments, so that actions could be taken to keep the crop on a trajectory that would yield the expected number of seedlings in the right condition when they were needed (Landis and Karrfalt 1987).

For example, one observation might be to dig up a sample of the seed immediately after sowing to confirm that the drill actually placed the seed at the expected spacing and uniformity. In addition to supplying detailed information about the crop that the nursery manager can use immediately to change the course of growth, history plots focus the attention of nursery personnel on the biology of the seedlings, and many of them will notice things that were not noticed before.

History plots can be used to establish growth curves that will be useful as benchmarks in future years. By comparing growth during the current year with growth in previous years the nursery manager can tell whether the current crop is on schedule to reach its target size and condition, or whether -conditions need to be changed to increase or slow down growth.

SEEDLING QUALITY TESTING

For decades nurseries have used size, shape, and visible damage as grading criteria, and thus have been able to increase outplanting success considerably. However, the physiological condition of seedlings is at least as important as their morphology in determining quality. By 1985 several physiological tests had been developed and were in use in research, but not many considered them practical as operational nursery tools (Duryea 1985). When RIP mandated the use of cold hardiness, root growth potential (RGP), and drought stress tests, it was necessary to come up with convenient and affordable equipment, along with simple procedures for running these tests. As a result, we now have the root mist chamber for RGP tests (Rietveld 1989, Rietveld and Tinus 1987a, 1990) which is a conveniently sized, moveable box, that requires only electricity and a well lighted room to operate. Roots need not be measured, just counted (Burr et al. 1987) to determine RGP. Good root growth potential has been demonstrated to be important to survival and growth after outplanting (McTague and Timis, in press), and is beginning to be specified in Forest Service growing contracts.

Whole plant cold hardiness measurement usually requires a programmable chest freezer, but can be run with an ordinary household freezer and some ingenuity (Rietveld and Timis 1987b). The test can be completed in a day, but it generally takes a week for the damage symptoms to show up. However, with practice, someone with a good nose can smell the damage after one day. More recently, practical quantitative instruments based on this principle have been developed (Templeton and Colombo 1995).

Freeze induced electrolyte leakage of foliage can measure cold hardiness with very good precision in less than three days. The test requires more expensive equipment, and some software to process the data collected, but it can also handle more samples in a single run (Burr et al. 1986, 1990).

Cold hardiness tests are now in use for a variety of purposes. They can indicate when bareroot stock is ready to lift in the fall, and when it is sufficiently dormant to store well. In the spring they can track emergence from dormancy, and supply important information about how to handle the seedlings and the prospects for outplanting success (Rose et al. 1990).

For example, some years ago I was asked to test some ponderosa pine that had been delivered to Flagstaff in a truck in which the refrigeration system had malfunctioned and frozen the trees. RIP had provided the nursery with small electronic temperature recorders, one of which was contained in one of the bags of trees. As a result, we knew the temperatures to which the trees had been subjected, and they were indeed cold enough to have damaged them. A root growth potential test of these trees and others that had been shipped in a different truck (which did not freeze), quickly showed that most of the root systems of the frozen trees was dead and that outplanting would be futile (Table 1). That was bad news, but it saved the Forest Service about $30,000 in direct costs by not planting them and probably a lot more in indirect costs. Before this equipment and tests were available, the dead trees would probably have been planted anyway because managers would not have been willing to take responsibility for dumping them without good evidence that they were not viable.

Table 1. Root growth potential of ponderosa pine seedlings shipped frozen to Mormon Lake and Tusayan or unfrozen to Panguich and North Kaibab.

District	Frozen	New roots/seedling Mean + Std. Error	Mean % of root System dead
Panguich	No	18.4 ±2.9	0
North Kaibab	No	10.2 ± 2.5	0
Mormon Lake	Yes	1.3 ± 0.7	66
Tusayan	Yes	0.0 ± 0.0	86

In a more recent case I was asked to examine a shipment of container ponderosa pine received by a nearby District. There was concern that the trees were not dormant as specified in the contract, and they wondered whether they should accept them. The trees did appear to me to be post-dormant, but the "budbreak" that the District staff was concerned about looked to be a combination of normal prolepsis growth and inadequate time for bud formation in the nursery. We took samples, and I ran RGP and cold hardiness tests on them. The latter showed the trees to have about half of the maximum hardiness, and the shape of the curve suggested that they were coming out of dormancy (Figure 2). However, with the RGP so high, my recommendation was to keep them refrigerated to preserve their current condition and consider them plantable.

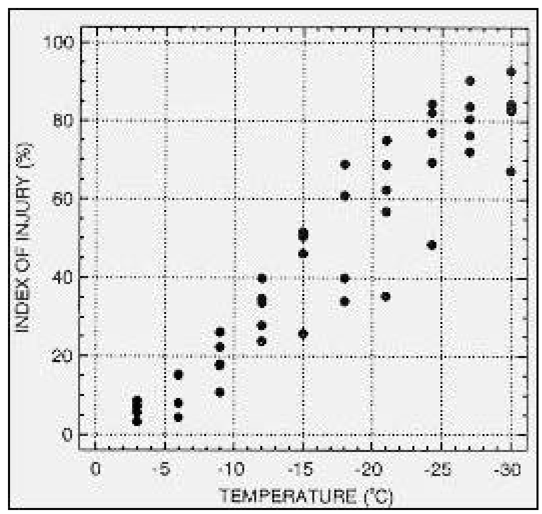

Figure 2. Cold hardiness of a Southwestern seedlot of ponderosa pine by the freeze induced electrolyte leakage test. The shape and position of the curve indicates that the trees are about half of maximum hardiness and probably coming out of, rather than entering into, dormancy.

ADVANCING NURSERY SCIENCE

One of the objectives of RIP was to collect a large volume of data that could be used to generate hypotheses to be tested. However, there also had to be enough year-to-year variation in weather or management practices to produce differences in results that needed to be explained. Most of the RIP plantings were highly successful in terms of survival and growth, which was a nice validation of our current best practices, but offered few suggestions for further improvement.

One exception was the plantings on the San Juan NF which varied considerably in performance among the three years (Table 2). Examination of all of the data collected at Bessey Nursery and at the planting sites suggested that high survival and growth were due to early undercutting in the second year at the nursery that produced short stocky seedlings with large buds in 1987 (Table 3).

Table 2. Survival and growth of ponderosa pine from Bessey Nursery planted in three consecutive years on the San Juan NF. See table 3 for characteristics of the seedlings.

Year Planted	Precip.	1988	Survival (%) 1989	1990	1st Year Ht. growth (cm)
1988	normal	88	76	69	6.3
1989	drought	__	40	26	2.9
1990	normal	__	__	41	2.8

Table 3. Morphology of ponderosa pine produced at Bessey Nursery in three consequtive years.

2nd Year	Height (cm)	S/R*	ST/CAL*	Bud Length* (mm)	Date of Budset* (JD)
1988	17	2.3	25	21	137
1989	29	2.9	41	15	187
1990	23	4.0	33	16	155

*Shoot/root ratio (S/R) is an indication of drought resistance, height to caliper ratio measures stockiness, and bud length indicates height growth potential next season. Budset was induced by undercutting, and the Julian date of budset explains the morphology.

A study was initiated to test this hypothesis and reproduce the different seedling morphologies produced in RIP, and see how they performed in the field. Unfortunately, 1993 was unusually wet, and the undercutting seemed to have little effect on the morphology, although it did increase the uniformity of RIP somewhat. When outplanted, the height and caliper of trees from the three undercutting treatments were not different, but first year height growth and survival of trees undercut with a stationary bar was less than that of trees undercut with a reciprocating blade, or trees not undercut at all (Figure 3). However, because of the weather and some practical difficulties in the execution of the experiment, it needs to be repeated before the results can be considered definitive.

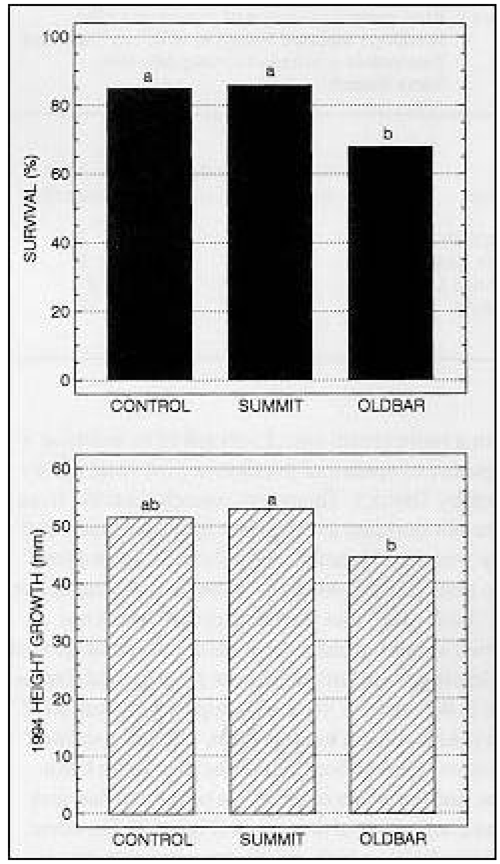

Figure 3. First year survival and height growth of ponderosa pine after outplanting on the San Juan NF. The stock (100 trees per treatment) was not undercut (control), undercut with a reciprocating blade (Summit) or with a stationary blade (oldbar). Bars not having the same letters are significantly different (P=.05) by the Chi Square test (survival %) or Tukey's multiple range test (height growth)

INFORMATION EXCHANGE

During the seven years that RIP was underway, nursery managers and technicians, and the researchers associated with the program, met annually to discuss progress and exchange information. These meetings brought together nursery-related people who were working on the same, or similar, problems to network among themselves and trade ideas, observations, and solutions. This included not just the top echelon, but also the people who actually did the work, and who might not have had a chance to join their counterparts at other nursery meetings. The result was a strengthened professional network, and an enthusiasm that raised the level of nursery practice and reforestation to a higher plane throughout the country.

It is also worth noting that RIP was a joint venture of all three branches of the Forest Service: Research provided the latest scientific information and packaged it in ready-to-use form, while State and Private Forestry contributed technology transfer services, and National Forest System nurseries and Forests implemented the Program. RIP has been a good model of close cooperation among the three branches, which is one reason it was successful. Another key reason for success is that nursery managers and staff embraced RIP enthusiastically. It is not easy to take on an extra workload that means learning to use new tools and techniques and bringing them into practice, but they did, and did it well.

In summary, the Reforestation Improvement Program accomplished many of its original goals. It gave the nurseries new tools to track the progress of the growth and condition of their crops. It brought them to the cutting edge of the electronic age with tools to collect large quantities of data and analyze it soon enough to support management decisions. It put everyone in contact with each other, so that solutions would only have to be invented once. Finally, it showed that, on the whole, the Forest Service is indeed doing a very good job of reforestation.

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