# A Quality-Control System for Improving Conifer Nursery Stock

**Peyton W. Owston, Richard G. Miller, W. ). Rietveld, and Stephen E. McDonald**

*Principal plant physiologist, USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR; geneticist, USDA Forest Service, Washington, DC; supervisory research plant physiologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Lincoln, NE; and assistant station director-north, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO*

*The U.S. Department of Agriculture, Forest Service, has begun a program to develop better quality control in its nurseries, refine nursery practices, and identify gaps in fundamental knowledge. Electronic technology is used to monitor factors affecting production and field performance of nursery stock.* Tree Planters' Notes 41(1) 3- 7 ; 1990.

The U.S. Department of Agriculture, Forest Service, which manages about 57 million acres for timber production, currently operates 11 bareroot nurseries (one will be phased out in 1990). Nursery production, which exceeds 100 million seedlings annually, is primarily 2+0 conifer stock. Over the past 8 years, the Forest Service has planted an average of 270,000 acres annually.

The Reforestation Improvement Program (RIP) of the Forest Service is an effort to improve the quality of bareroot seedlings produced in its nurseries. The program was conceived in the early 1980's as electronic technology blossomed and collecting and analyzing enormous amounts of data at moderate costs became feasible. The program could thus provide much more definitive information on problems leading to plantation failures. A team of nursery managers and scientists developed the plan, and plots were established beginning in 1986. This paper describes the objectives, procedures, and current status of the program.

**Justification and Objectives**

The importance of successful reforestation has become widely recognized. An internal study in 1983 found that even a 10% reduction in reforestation failures would save almost $3 million annually. Less tangible, but very important, are the environmental and social justifications for successful reforestation.

Generally, the goal is to make reforestation more predictable and successful. This will be achieved by reaching the following specific goals:

1. Development of a standardized system for collecting and analyzing data, to facilitate interchange of information among nurseries, research groups, and silviculturists.
2. Increased awareness of seedling biology through testing and observation, to improve the knowledge and skills of those conducting nursery and planting programs.
3. Improved practices to lower the quantities of seed needed, reduce production costs, and increase the consistency of producing high-quality stock.
4. Greater knowledge of nursery environments and seedling physiology, to enhance current research and identify knowledge gaps requiring further study.

**Program Organization**

A steering committee, which monitors the overall program, consists of an administrator, a nursery manager, a silviculturist, and a scientist, who serves as program coordinator. A team of forestry research scientists and a biometrician helps develop and conduct analysis procedures. Ten nurseries are participating fully (fig. 1). The managers agreed to follow standard data collection and analysis proce-

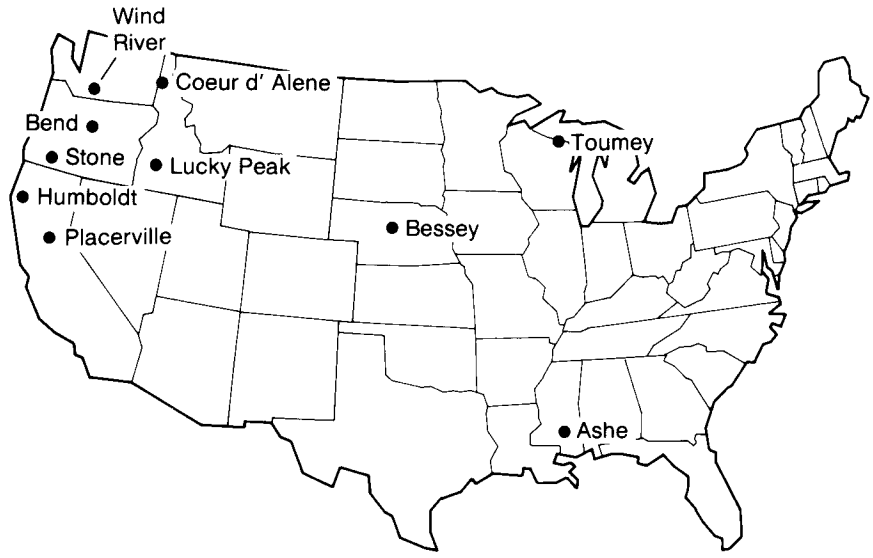


**Figure 1**—*Locations of National Forest System nurseries.*

dures. Pathologists are conducting pathogen and mycorrhiza analyses. Forest Service districts interested in participating in the outplanting were identified before the seed sources to be monitored were selected.

**Establishment of Nursery Plots**

Each nursery is testing at least two seed sources of a major species (table 1). Species being used are Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), red pine (*P. resinosa* Ait.), loblolly pine (*P. taeda* L.), longleaf pine (*P. palustris* Mill.), and slash pine (*P. elliottii* Engelm). The same seed lots are sown in 30 m of seed bed in each of 3 consecutive years so that they grow under a variety of weather conditions. Standard cultural practices are used to grow the seedlings.

Treatments performed on the test lots are documented and unusual occurrences noted. Treatments include storage, stratification, and sowing of seed; thinning, weeding, and fertilizing seedlings; applying pesticides to seedlings; and pruning roots and tops. This information will be used in interpreting results.

**Environmental Monitoring**

Recording weather stations are the heart of the environmental monitoring phase. One station has been installed on a permanent site at each nursery to collect baseline data. A second station has been erected near the test seed beds so that sensors can monitor the weather and soil conditions to which the seedlings are exposed.

Conditions measured are air temperature at 1.5 m above ground level and at the seedling canopy level (20 cm), relative humidity, precipitation and irrigation, wind speed and direction, incoming radiant energy and photosynthetically active radiation, soil surface temperature, and soil temperature and moisture in the seedling rooting zone. The recorder scans the sensors every 5 minutes and records maximum, minimum, and average daily temperatures; average relative humidity, radiation, and wind direction; average and maximum wind speed; and total precipitation or irrigation for each hour. Data stored in easily removable packs are transferred electronically to microcomputers once a month.

Soil physical characteristics were measured once in the test beds. Soil fertility, pathogen levels, and quality of irrigation and

**ble 1**—*Summary of nurseries in Reforestation Improvement Program*

| Nursery | Species | No. of lots | Lift date | Ranger district & NF of outplanting |
|---|---|---|---|---|
| eur d' Alene<br>aho) | Douglas-fir | 2 | Nov. 87 | Bonner's Ferry/Idaho PH |
| ssey<br>ebraska) | Ponderosa pine | 1 | Nov. 87 | Delores/San Juan<br>Mancos/San Juan |
| cky Peak<br>aho) | Pondersa pine | 2 | Spring 88 | Council/Payette |
| mboldt<br>alifornia) | Douglas-fir | 1<br>1 | Jan. 88<br>Jan. 88 | Gasquet/Six Rivers<br>Salmon River/Klamath |
| cerville<br>alifornia) | Ponderosa pine | 1<br>1 | Jan. 88<br>Jan. 88 | Weaverville/Shasta-Trinity<br>Pacific/Eldorado |
| nd<br>egon) | Ponderosa pine | 2 | Spring 88 | Sisters/Deschutes |
| J. Stone<br>egon) | Douglas-fir | 2 | Spring 88 | Prospect/Rogue River |
| nd River<br>ashington) | Douglas-fir | 2 | Spring 88 | Wind River/Gifford Pinchot |
| W. Ashe<br>ssissippi) | Loblolly pine<br>Longleaf pine<br>Slash pine | 3<br>2<br>2 | Jan. 88<br>Jan. 88<br>Jan. 88 | Evangeline/Kisatchie<br>Black Creek/DeSoto<br>Evangeline/Kisatchie |
| N. Toumey<br>chigan) | Red pine | 1<br>1 | Spring 89<br>Spring 89 | Watersmeet/Ottawa<br>Ontonagon/Ottawa |

runoff water are measured periodically.

Environmental conditions to which the seedlings are subjected during lifting, processing, shipping, and planting are carefully monitored, including details such as root exposure times, temperatures, and number of times the seedlings are handled. Temperatures are measured by placing recording devices inside packing bags.

On the planting sites, weather data and factors such as soil characteristics, competing vegetation, animal damage, insect and disease damage, and stand history are measured or observed.

**Seedling Measurements**

Monitoring begins with establishment of history plots at time of sowing to determine germination rates. These plots are followed until seedlings are lifted to determine numbers of plantable seedlings as a percentage of seeds sown and numbers of cull seedlings by type of problem. In addition, randomly chosen seedlings are measured periodically for height and diameter growth in the seed beds, and detailed observations are made of seedling color and bud activity. As lifting time approaches, root activity and plant moisture stress are measured periodically.

When seedlings are lifted, their height, stem diameter, bud length, and foliage color are

measured or observed; and their mineral nutrient status, carbohydrate reserves, root-growth capacity, cold hardiness, and resistance to moisture stress are assessed.

Analyses requiring sophisticated equipment are done by outside laboratories. Root-growth capacity, cold hardiness, and stress tests, however, are done at the nurseries. This is more economical, and the seedlings are not subjected to storage and shipping that might alter their physiology. Also, onsite tests give nursery personnel more appreciation of seedling biology.

**Establishment of Performance Tests**

Two forest sites were selected for outplanting the test seedlings from each nursery, and each site was equipped with a recording weather station. The sites are ones that can be partially planted in each of 3 consecutive years (table 1).

Site preparation is the biggest problem on many sites. Because one-third of each site must be planted in 3 different years, sites must be prepared so that the conditions of competing vegetation are as similar as possible.

As in the nurseries, environmental conditions, handling, treatments, and seedling performance are recorded.

**Data Handling and Analysis**

Data collection and analysis are critical phases of the RIP. Each nursery is equipped with a microcomputer, electronic data loggers, and software to make the task as standardized and accurate as possible. Data are transmitted electronically from the weather stations and hand-operated data loggers, or manually through the computer keyboard, to spreadsheet files in the computer. A standard spreadsheet program is used to summarize the weather data and produce monthly and yearly graphs. Indices such as growing-degree days and chilling hours are also calculated.

The information produced is readily available for planning and evaluating day-to-day nursery operations, as well as for building a strong data base to guide future quality control. The data will also be used for scientific analysis.

The RIP is not a single, controlled experiment; instead, it provides comprehensive input-output information on growth of seedlings under a wide variety of conditions. We will make comparisons within the nurseries (for example, weather versus seedling growth in the seed beds), between nurseries and forest sites (seedling size and weight at lifting versus survival and growth after outplanting), and within forest sites (weather on the sites versus survival and growth).

Once we have performance data for all three crops, regression techniques will be used to develop predictive indices. Such indices should help to reduce significantly the number of unexplained failures and to indicate when corrective measures are needed to prevent performance problems.

**Current Status of the Reforestation Improvement Program**

All three crops have been sown and one or more crops have been outplanted from most of the nurseries. Several nurseries have decided to sow a fourth crop. Nearly 50 spreadsheet formats have been developed, and data are accumulating rapidly.

Implementing the RIP has not been free of problems. Long distances between nurseries have made standardization of procedures and training difficult. The data loggers and weather sensors need closer attention than we had expected, and changes in the data collection and recording procedures have been necessary.

We think, however, that problems have been more than offset by benefits. Nursery personnel are more attuned to nursery environment and seedling biol-

ogy. Several nurseries have expanded seedling diagnostic procedures beyond their two assigned seed lots. In one instance, test results provided data to help determine the source of a specific performance problem. Stress tests showed that fall-lifted seedlings were capable of breaking bud after similar seed sources had failed to break bud in operational plantings; field conditions or procedures were thus implicated.

We have learned several lessons already. Investing in high-quality weather sensors is important for reliability of operation and accuracy of data. Responsibility for collection and entry of data should be assigned to employees who are apt to stay in place for several years. In addition, employees should be trained in the use of computers beyond merely being able to follow step-by-step procedures.

**A Look to the Future**

We anticipate that the conclusion of the three-crop RIP plan will mark only the beginning of a higher level of quality control. Despite the increased workload, program participants seem eager to continue monitoring at a reduced but significant level. Procedures will probably not become fully set until near the end of the three crops. We plan to publish our experience and findings in enough detail so that others can use them to improve their nursery programs.

Once an interactive data base for quality control and decision support has been. developed and research has filled gaps in knowledge, we should be well on our way to tailoring nursery stock for particular planting sites and reforestation situations.