The USFS Reforestation Improvement Program[1]

W. J. Rietveld, Peyton W. Owston, and Richard G. Miller [2]

Rietveld, W.J.; Owston, Peyton W.; Miller, Richard G. 1987. The USFS Reforestation Improvement Program. In: Landis, T.D., technical coordinator. Proceedings, Intermountain Forest Nursery Association; 1987 August 10-14; Oklahoma City, OK. General Technical Report RM-151. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 120-125. Available at: http://www.fcnanet.org/proceedings/1987/rietveld3.pdf

Abstract.--The program applies state-of-the-art equipment and methods to input weather, culture, growth, quality, handling, and field data into a computerized database at each Forest Service nursery. The ultimate goals of the program are to increase efficiency, improve reforestation success, and lower costs.

INTRODUCTION

The Reforestation Improvement Program (RIP) is a combined effort of the three divisions of the USDA Forest Service -- National Forest System, Research, and State & Private Forestry -- to improve nursery seedling quality and plantation survival and growth. The concept is to use state-of-the-art data logging and computer technology to monitor selected seedlots and determine the relationships among environmental conditions, nursery culture, seedling handling, seedling characteristics, and performance after outplanting. This information will be used to refine nursery ;and reforestation practices, develop a continuing quality control system, and identify knowledge gaps that require research.

Following the Seedling Quality Workshop at Oregon State University in 1984, representatives from the three divisions of the Forest Service discussed the agency's nursery program and the research needed to improve the production of quality bareroot stock. In January 1985, a team of nursery managers and research scientists developed a draft proposal to implement RIP. The final proposal was approved, all 11 Forest Service nurseries agreed to participate, and plot establishment got underway by spring 1986. This paper describes the objectives, procedures, and current status of the program.

[1]Paper presented at the Intermountain Forest Nursery Association Meeting, Oklahoma City, Oklahoma, August 10-14, 1987.

[2]W. J. Rietveld is Research Plant Physiologist, North Central Forest Experiment Station, Rhinelander, WI; Peyton W. Owston is Research Plant Physiologist, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon; Richard G. Miller is Nursery, Tree Improvement and Genetics, National Fbrest System, Washington, D.C.

JUSTIFICATION

RIP was begun at this time for several reasons. The National Forest Management Act of 1976 requires that the successes and failures in our reforestation program be clearly documented and reported to Congress. Responsibility for successful reforestation has been included in line officers' performance standards. We are making more detailed evaluations of plantation survival and growth, and the results of these evaluations have dramatically increased the visibility of our reforestation program. The "Productivity Improvement Analysis of Reforestation" report published in 1983 states that a 10-percent reduction in reforestation failures in the National Forest System would save $2,624,000 annually and that a 50-percent reduction would save more than $13,000,000 annually. Assuming at least a 10-percent improvement in reforestation success, the program is easily justified on a purely economic basis. This is, of course, desirable, but we feel that the public image and professional reasons for improving reforestation success are even more important.

MAKING A CASE FOR MONITORING

Quality monitoring is done in most industries where market competition, liability, and reputation are important factors. In our "industry", the reasons for monitoring are (1) our desire to refine and improve, (2) our pride and reputation, and (3) our accountability. Beyond these compelling reasons, monitoring is impetus for professional growth. Without recording our inputs and their effects, our expertise grows slowly, because we have no clear records of the factors that contributed to our successes and failures. With monitoring implemented we can learn from both our successes and our failures, and readily pass that expertise on to our associates and successors.

Many plantation failures are difficult if not impossible to explain with the data presently collected. We simply do not know if the problems are occurring at the nurseries, during shipping and handling, during planting, or if they are due to site factors or lack of seedling adaptation. As always, more research is needed to provide answers, but research may not be enough. Presently, the minds of experienced nursery managers and foresters are the databases that hold the wisdom gleaned from years of experience. Two unavoidable problems with this tradition are (1) the memory is volatile, and (2) the databases eventually transfer or retire. To progress from here, we need to develop computerized databases to store the volumes of existing and future data and efficiently put them at our disposal. Once a fairly complete database is developed for each nursery, and research has adequately filled in the important gaps in our knowledge, we will be in a position to attain higher level goals such as: (1) tailoring culture to unique conditions within nurseries and to individual species and seedlots, (2) identifying and manipulating critical factors that most affect planting stock quality, (3) developing an effective system to evaluate planting stock quality and predict field performance, (4) developing planting stock and site preparation prescriptions for individual sites, and (5) developing computer models for the entire reforestation process.

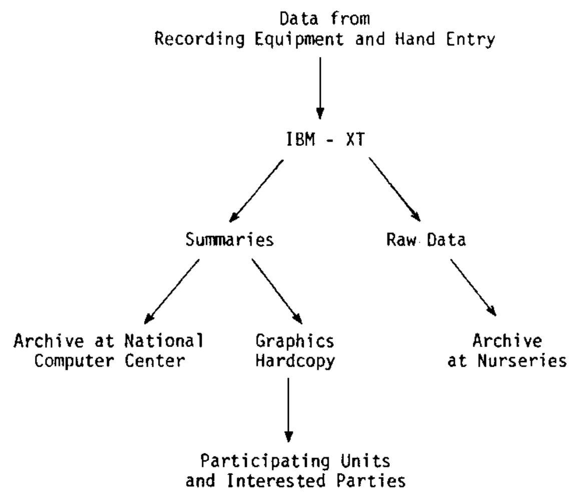
Some of the latest developments in reforestation science illustrate these points. There is a trend towards specific nursery culture of individual seedlote. Jenkinson (1980) has developed time windows for lifting several major timber species and specific seed sources at individual nurseries. Lifting seedlings outside these windows results in reduced survival and growth, and in the worst case, plantation failure. The Weyerhaeuser Company3 has led the way in growing seedlings by family (seed collected from a clone in a seed orchard), observing growth response to cultural treatments, and grouping families with similar growth into "response groups". Cultural treatments are then tailored to each "response group" to grow seedlings to desired specifications. This increasing sophistication brings increasing complexity and the need for more detailed record keeping, a task that computers can help us with nicely.

PARTICIPANTS AND ORGANIZATION

All 11 Forest Service nurseries are participating in the program. The nurseries are the center of RIP and the principal benefactors. The initial level of commitment at each nursery is to monitor three successive crops of planting stock of two seedlots of one species, and to establish two field plots on different sites.

[3]Personal communication with Dr. William C. Carlson, Tree Physiologist, Weyerhaeuser Co., Southern Forestry Center, Hot Springs, AR 71902.

The following organizational structure was developed for RIP in order to maintain communication and continuity:



A national steering committee monitors the overall program and modifies it as necessary. The program coordinator facilitates installation of the monitoring system, and implementation of data collection, summarization, and archival. A scientific analysis team (SAT) was created to select appropriate seedling measurement equipment and techniques, develop data collection and analysis procedures, and provide feedback and recommendations to individual nurseries. The team will evaluate the data from a research perspective and identify specific problem areas that need additional research.

Pathologists from the participating Regions will conduct pathogen and mycorrhizae analyses. National Forests and Ranger Districts interested in participating in the outplanting phase were identified before specific seed sources were selected for monitoring. The program has also arranged for a local research scientist to provide guidance for each nursery, a technician available by phone to provide support and spare parts for instrumentation problems, a software developer to prepare specialized methods to collect, summarize, graph, and archive RIP's data, and a technician to help with data processing.

EXPECTED BENEFITS

Benefits will increase each year as we monitor new seedlots, encounter different weather conditions, modify cultural practices, and accumulate information on field performance. Expected short- and long-term benefits are as follows:

Short-term (1 to 5 years)

1. Installation and implementation of state-of-the-art equipment and methods at the nurseries to monitor weather, culture, growth, quality, handling, and field variables, and efficiently summarize and retrieve the data on a computerized database at each nursery.

2. Development of a standardized system for collecting and analyzing nursery data to facilitate interchange of information and technology among nurseries, research units, and National Forests.

3. Increased awareness of seedling biology through tracking of seedling performance from seed to site.

4. Identification of stages in stock production, handling, shipping, and planting where quality is lost, so that nursery managers, foresters, and researchers can focus their efforts on the most critical areas. Some immediate improvement in reforestation success is expected from recognizing and correcting conspicuous problems.

5. Improved communications between nursery managers, field foresters, and researchers, eventually developing feedback linkages between these groups based on common goals.

6. Improved cultural and handling methods in the nursery by utilizing the database to aid decisions on when to perform certain practices, and to document the effects on seedling quality and performance.

Long-term (5 years and longer)

1. Significantly increased and more consistent tree survival and growth after outplanting, with fewer failures and replants, and lower reforestation costs. We should see increased efficiency through the entire reforestation process.

2. Development of specific cultural regimes to match seedlots and seedling characteristics to individual sites, thus utilizing the full potential of each site.

3. Improved nursery practices and knowledge of the relations between stock quality, site conditions, and field performance will improve our ability to predict tree survival and growth on a variety of sites and optimize the cost of stock production.

4. Development of a flexible quality control program for individual nurseries that can be continually refined. Seedling production will gradually shift from an art to a science, enabling nursery managers to manipulate numerous variables and consistently grow seedlings to target specifications.

ESTABLISHMENT OF NURSERY PLOTS

Each nursery is monitoring two different seedlots of at least one of the major species that it produces; five western nurseries are monitoring ponderosa pine, four western nurseries are monitoring Douglas-fir, one northern nursery is monitoring red pine, and one southern nursery is monitoring both loblolly and longleaf pines. Ten nurseries made their initial sowings in 1986, and one nursery began this year.

The same seedlots of each species will be sown for 3 consecutive years so that they will be grown under a variety of weather conditions. Standard cultural practices will be used in the 100 feet of seedbed that will be sown for each seedlot and year. All the sowings will be clustered as close together as possible so that they are in similar soil and subject to similar weather conditions.

ENVIRONMENTAL MEASUREMENTS

Electronic recording weather stations are the heart of the environmental monitoring phase of RIP. One station is located on a permanent site at each nursery to collect baseline weather data. A second station is located near the test seedbeds so that sensors can monitor the weather and soil conditions to which the seedlings are actually exposed. Conditions measured are: air temperature at 1.5 m above ground 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 the hourly maximum, minimum, and average temperatures; average humidity, radiation, and wind direction; average and maximum wind speed; and total precipitation or irrigation.

One-time measurements of soil physical characteristics were made in the test beds, and periodic measurements will be made of soil fertility, pathogen levels, and quality of irrigation and runoff water.

Environmental conditions that the seedlings are subjected to during lifting, processing, shipping, and planting will be carefully monitored. This will include factors such as root exposure time; temperatures during grading, storage, and shipping; and number of times the seedlings are handled. Temperatures during storage and shipping will be measured by another recording device, a Datapod[4], that will be placed inside packing bags to record temperature hourly until the seedlings are removed from the bags for planting.

These environmental and history data will be used in graphics, in correlations with seedling growth in the nursery, and in interpretations of observed responses to culture.

---

[4] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

CULTURAL PRACTICES

All cultural activities performed on the test seedlots will be documented by date and specific treatment. Any errors and unusual occurrences will be noted. Cultural practices include seed stratification, sowing, mulching, thinning, weeding, fertilization, irrigation, pesticide application, shoot and root pruning, and wrenching. No experimental treatments will be applied to the monitored seedbeds, but if any practice is changed nursery-wide during the program, the modified practice will also be instituted in the RIP seedbeds. This information will be used primarily for interpreting results rather than for making specific correlations with growth and performance.

SEEDLING MEASUREMENTS

Despite all the high-tech gadgetry, seedlings are the main focus of the program. We will examine them outside and in, i.e. morphologically and physiologically, and correlate their development, growth, and condition with (1) nursery environment and culture, and (2) field performance.

Monitoring will begin with establishment of history plots at time of sowing to determine germination rates and plantable seedlings as a percent of seeds sown. Random samples of seedlings in the seedbeds will be repeatedly measured to determine height and diameter growth, bud activity, and foliage color; and separate samples will be destructively measured to obtain root growth. We will monitor plant moisture stress during dormancy induction and mineral nutrient status in the fall when the seedlings have stopped growing.

Several measurements and tests will be done when seedlings are lifted: morphological (external) characteristics will be measured -- height, stem diameter, bud length, dry weight, and foliage color; and physiological (internal) conditions will be assessed by several tests-- mineral nutrient status, carbohydrate reserves, root growth potential, cold hardiness, and stress resistance.

Carbohydrate and mineral nutrient analyses require sophisticated equipment and will be done by private or university laboratories. The root growth potential, cold hardiness, and stress tests, however, will be done at the nurseries. This will be more economical, and the seedlings will not be subjected to storage and shipping that might alter their physiology. The main reason for doing the tests on site, however, is to give nursery personnel greater familiarity with the specialized measurements and tests of planting stock quality.

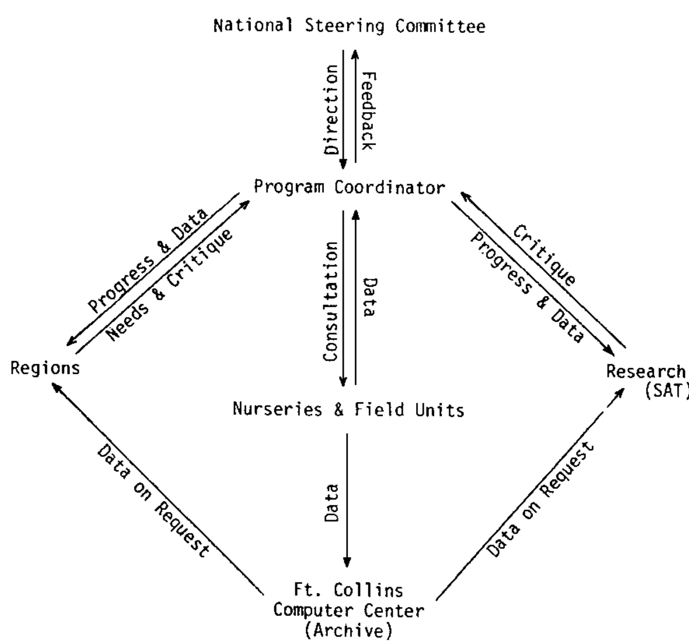
ESTABLISHMENT OF FOREST PLOTS

The payoff is, of course, field performance of the seedlings. It makes no sense to grow high quality seedlings if they are going to fizzle after outplanting, or disappear into the unknown. Therefore, we have asked various Forest Service Ranger Districts to establish and monitor test plantations. Planting stock from each nursery will be outplanted on two forest sites; each will have an electronic weather station identical to those used at the nursery. The sites will be partially planted in each of 3 consecutive years. Depending on the compatibility of the monitored seedlots with the seed zone of each forest site, some test plantations will be planted with both seedlots and others will have only one. Only 200 seedlings per seedlot will be planted and tracked per site, so it will not be a heavy workload. Site preparation will be the biggest problem on many sites because the program requires that approximately one-third of each site be planted in each of 3 consecutive years, but with site conditions as similar as possible. We will work individually with each National Forest to develop a planting plan that is operationally feasible, statistically valid, and consistent with RIP plans and objectives.

As with the nursery phase, environmental conditions, handling, seedling characteristics, and seedling performance on the field plots will be recorded for later analyses and correlations. We are working with the National Forests this year to make sure preparations are made for installing forest plots during the 1988 planting season.

DATA HANDLING AND ANALYSIS

Data collection and analysis are critical parts of RIP. The general plan for data flow is as follows:



Each nursery was provided with a microcomputer, electronic weather stations and data reader, datapods and reader, a portable data collector, and software to receive the transmitted data, automatically summarize it, and archive it.

Weather data are stored in a removable memory pack that holds 32,000 bits of information (64 K packs are now available). The packs are changed once a month. A full pack is plugged into a special reader that transmits the data to a microcomputer where a communications program captures it and stores it as an ASCII file. The pack is then erased and reused. The same scheme is used to retrieve package temperature data stored in the Datapods. The scheme designed for the portable data collector to collect seedling data and transmit it to the computer for processing is covered in more detail in a separate paper (Rietveld and Ryker 1988).

ASCII files containing the data are imported into preformatted spreadsheets where standardized data summaries and graphs are automatically generated through the use of macros. Graphs of weather data show monthly summaries of: incoming radiant energy, photosynthetically active radiation, precipitation, percent relative humidity, air temperature at 1.5 m, air temperature at 20 cm, wind speed, wind direction, soil surface temperature, soil temperature at 15 cm, and soil moisture at 15 cm. Graphs of seedling data are generated showing: seed germination, height growth, caliper growth, root growth, and bud activity, all in relation to time, air temperatures, soil temperatures, soil moisture, and solar radiation. Parameters such as growing degree days, chilling hours, and potential evapotranspiration are also calculated. Raw and summarized weather and seedling data from the nurseries and forest sites are archived at the nursery, and summarized data are archived at the National Computer Center at Fort Collins, CO, for safekeeping and sharing with approved interested parties.

INTERPRETATION OF DATA

Nursery managers can manipulate the data and generate other summaries and graphs as they wish. Such information will be useful in planning and evaluating day-to-day nursery operations and making decisions, as well as building a strong database for continuing quality control.

The data will also be evaluated by RIP's scientific analysis team. Because RIP is not a controlled research experiment, the opportunities to apply statistical analyses will be limited. Initially, the team will be restricted to making inferences based only on observations; after data are collected for three crops of planting stock (fall 1990), it will be possible to apply some limited statistical analyses. The general types of comparisons that will be made are as follows:

<u>Nursery</u>		<u>Nursery</u>
Weather		Seedling growth
History	<u>vs</u>	Seedling morphology
Culture		Seedling physiology

<u>Nursery</u>		<u>Field</u>
Seedling morphology		Seedling cond. on arrival
Seedling physiology	<u>vs</u>	Seedling surv. and growth
Processing & handling		

<u>Field</u>		<u>Field</u>
Site weather		Seedling surv. and growth
Site history	<u>vs</u>	
Pest problems		

Scientific analysis is expected to take the following progression:

Observations

1. <u>Evaluate field performance</u> -- if a seedlot does poorly at one site and not at the other site, look at site data; if a seedlot performs poorly on both sites, look at both site and seedling quality data.

2. <u>Evaluate repeatedly measured variables</u> (seedling height, caliper, root growth, foliage color, bud activity, plant moisture stress, root growth potential, and carbohydrate reserves) -- the only thing that can be done early in the program is to flag anything that looks suspect, since we don't know what constitutes a normal level for the variables at each nursery.

3. <u>Contrast variables</u> -- note differences in selected variables between seedlots, sites, and nurseries (for the same species). Graph selected variables for all nurseries growing the same species (ponderosa pine or Douglas-fir) to become familiar with basic nursery and seedlot differences.

4. <u>Evaluate models and indices</u> -- evaluate the usefulness of various models to relate weather variables to seedling growth and phenology (e.g. degree hours with seedling growth in the nursery, chilling units with cold hardiness, etc); and evaluate the ability of existing stock quality indices to predict seedling quality and performance.

5. <u>Evaluate unusual events</u> -- evaluate the effects of any disasters or any unusual weather events, contrasting nursery practices and field operations.

Statistical Analyses

1. <u>Correlations</u> -- by fall 1990, we will have first-season performance data on three crops of planting stock on each of two forest sites, giving a sample size of six for each seedlot. Correlation analysis of planting stock quality

variables (seedling height, caliper, dry weight, root growth potential, carbohydrate reserves, etc.) with performance variables (survival, height growth, caliper growth, etc.) will be barely possible because of the small sample size.

2. Regression analyses -- simple linear regression will be possible after we have data for three crops of stock. However, the real power of regression analysis cannot be realized until a sufficient range of data points is available, which will come with additional years of monitoring. To some extent, datasets can be expanded by including data from more than one seedlot and nursery (for the same species), but only if they satisfy certain tests for common regressions.

3. Develop standards and indices -- with sufficient data, application of single and multiple regression analyses will allow inferences of cause and effect relations in the nursery, between the nursery and the field, and in the field. Consistently significant relations may be used to develop indices that can be conveniently applied to predict response. In the process, we will evaluate, modify, and adapt existing indices and models for individual nurseries.

SUMMARY

The USDA Forest Service has undertaken an ambitious program to accelerate the transition of nursery management and reforestation from an art into a science. The goals of the Reforestation Improvement Program are to (1) supply each nursery with state-of-the-art equipment and methods for recording weather, cultural, and seedling variables; (2) develop a monitoring system that links the nursery with the field and provides a system for feedback; and (3) develop a computerized database for each nursery that is easily accessed, is interactive with nursery management, and will eventually guide refinements in nursery culture and field operations. The real value of the database will grow in direct proportion with the quality and completeness of the data put in, and with time. There will be only a limited ability to extract information from the databases during the first few years; mostly we will benefit professionally by increasing the depth of our documentation and awareness. The real payoff comes with the accumulation of data over years. Eventually, with the assistance of research, we will develop culture/quality/performance relations for individual nurseries, establish appropriate stock standards, and greatly improve our ability to predict seedling performance on a variety of sites.

LITERATURE CITED

Jenkinson, James L. 1980. Improving plantation establishment by optimizing growth capacity and planting time of western yellow pines, U.S. Dept. Agric., Forest Service, Pacific Southwest Forest and Range Exp. Stn., Berkeley, CA 94701, Research Paper PSW-154, 22 p.

Rietveld, W.J. and Russell A. Ryker. 1988. Applications of portable data collectors in nursery management and research. Tree Planter's Notes (in press).