Improving Seed-Use Efficiency and Seedling Quality Through the Use of History Plots

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History plots are permanent plots established at the time of sowing that are monitored throughout the nursery rotation. In the recommended procedure, the actual seed sowing density is measured immediately, which supplies information on seed drill efficiency and permits accurate monitoring of seed and seedling losses during the entire nursery period. Information from history plots has many different applications in nursery management, such as monitoring seed-use efficiency, producing seedling growth curves, scheduling or modification of cultural practices, and nursery problem-solving. Tree Planters' Notes 38(3): 9-15; 1987.

One for the squirrel,
one for the crow,
one for the weather,
and one to grow

Old Indian Proverb

This old saying reveals that Indian farmers observed the causes of seed losses in their cornfields and made allowances for them in the amount of seed that they sowed. Efficient tree nursery management involves producing the maximum number of high-quality seedlings with the least amount of seed. Often, however, seed and seedling losses are hard to identify and quantify in the nursery seedbed. Because the sown seed is buried, preemergence losses are hidden from view and even post-emergence mortality happens so quickly that it often goes unnoticed. With history plots, the nursery manager can measure these losses empirically and obtain objective data on their amount and timing.

History plots are seedling monitoring plots that are permanently established in seedbeds at the time of sowing. They are not a new concept, as many different aspects of the history plot procedure have been used in forest tree seedling nurseries for many years. Belcher (1) provided one of the first published procedures for monitoring tree seedlings with history plots. Johnson (3) used a series of "monitoring plots" to identify the major causes of seed loss in a Washington nursery, and Landis (4) used a similar procedure in a similar effort in a Rocky Mountain forest nursery. Steinfeld (6) describes a seedling monitoring procedure that includes "intensive monitoring" of plots in which growth, mortality, and soil characteristics are measured. This publication is the first attempt, however, to incorporate all the various aspects of seed and seedling monitoring practices into one comprehensive procedure.

The information from history plots has several uses in nursery management. One of the principal uses is to develop or refine nursery sowing rate factors which govern sowing density and seed-use efficiency. Many nursery managers use sowing factors that were developed through years of experience but are not based on any actual measurements. Monitoring history plots yields specific information on the fate of sown seed that can be used to adjust future sowing rates. The major sowing rate factors and the associated seed and seedling losses are illustrated in figure 1.

In addition to supplying data on seed-use efficiency, history plots also provide several other incidental benefits to nursery management. When the procedure includes excavating seed immediately after sowing, they provide a check of seed drill calibration and sowing depth. Measurements of seedling growth and observations of seedling phenology (table 1) can also be used to produce seedling growth curves that will help the manager properly time cultural practices.

Installing History Plots

There is no standard procedure or sampling sequence for establishing and monitoring history plots because the specific procedures and timing will differ depending on the needs and

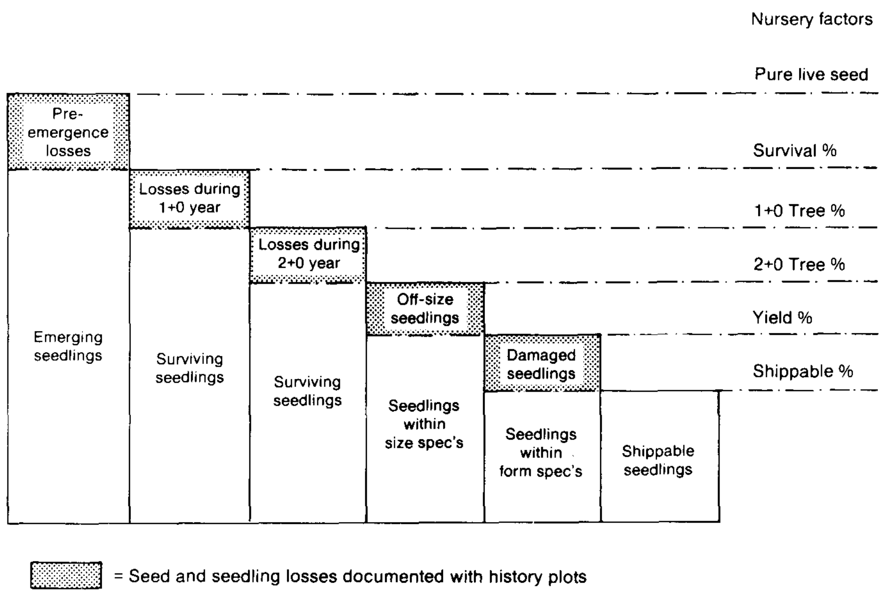

Figure 1—*History plots identify and quantify seed and seedling losses that can be used to establish or refine nursery factors for calculating sowing rates.*

Table 1—*Seedling growth and phenology events that can be measured with history plots*

Measurement
Growth
Shoot height
Shoot caliper
Relative root growth
Seedling biomass (ovendry weight)
Shoot/root ratios
Phenology
Speed of emergence
Period of cotyledon formation
Period of primary needle formation
Period of secondary needle formation
Timing of shoot flushes, including lammas growth
Periods of root activity

objectives of each nursery manager. A general, all-inclusive procedure is outlined here so that readers can adapt and modify this general model to their specific needs.

History plots are generally established at the time of sowing. The actual location of each plot is best chosen immediately before sowing, so that plots can be quickly marked out soon after the beds are sown. Plot locations should be chosen randomly, but the following areas should be avoided: ends of beds, locations where the seed drill had to stop or start, and any other areas that are not typical of normal seedbed conditions (1). History plots can be located near other nursery monitoring sites such as soil sampling pits or weather stations to exploit these other sources of valuable information.

The sampling population for history plots is the individual seedlot, and the number of plots is usually a function of available labor, although ideally the number of plots should be set using statistical procedures. The minimum number of history plots per seedlot should be at least 4, because this number of plots will supply the manager with useful information while providing some protection against plot loss. Johnson (3) recommends a sampling intensity of 6 plots per acre.

A crew of 2 or 3 should be used to install history plots, although later plot checks can be done by 1 person. The number of workers required will depend on the number of factors being monitored, but complete history plots can usually be established in a half hour with a crew of 3. Belcher (1) reports a yearly requirement of 2.3 person-hours per plot.

The identification and quantification of preemergence seed losses are the most difficult phase of the history plot procedure for two reasons. First, the exact number of seeds that were sown in the plot must be determined to provide a base against which all subsequent losses can be compared, and second, pre-emergence losses are naturally hidden and, therefore, hard to identify and quantify.

Determining the actual number of sown seeds in a history plot can be established in the following two ways.

Estimates from sowing calculations or seed drill trials. The approximate amount of seed that will be sown in the history plot can be estimated from sowing calculations and seed data. Dividing the seed requirement by the length of seedbed to be sown will provide the average amount of seed for the area of seedbed in the history plot. Another estimation procedure involves test runs with the seed drill. The drill can be run over the top of the soil or on a tarp, and the seed can be directly counted in an area that is equal in size to the history plot. These indirect techniques have the advantage of being quick, easy, and nondestructive, but they only provide approximations of the actual amount of seed that will be sown in the history plot because of the variable distribution patterns of all seed drills.

Actual recovery of sown seed. The only way to really know how many seeds have been sown in a history plot is to count them directly. This is relatively easy for nurseries that sow seed on the surface of the seedbed and cover the seed with a mulch, as the sown seed can be counted before the mulch is applied. Nurseries that drill their seed into the soil, however, must somehow recover and count the sown seed. Because many conifer seeds are small and dark, they are extremely difficult to distinguish from soil particles. One technique to overcome this problem is to color the seed with a material such as aluminum powder or an organic dye (2); seed that is treated with a fungicide or bird repellent prior to sowing will be easier to locate than untreated seed. The seed must still be excavated from the history plot with spatulas or screens and then resown after the counts are completed. Johnson (3) excavated each seed row to a depth of 3.8 cm (1.5 in.) and a width of 5.1 cm (2 in.), and used a screen with 1.98-mm (0.08-in.) openings to recover the seed. These excavations introduce another source of variation, however, because the seed can never be resown in exactly the same manner as an undisturbed plot.

One possible technique to deal with this problem, and the one recommended by the authors, is to use a paired-plot design (fig. 2). The total history plot includes

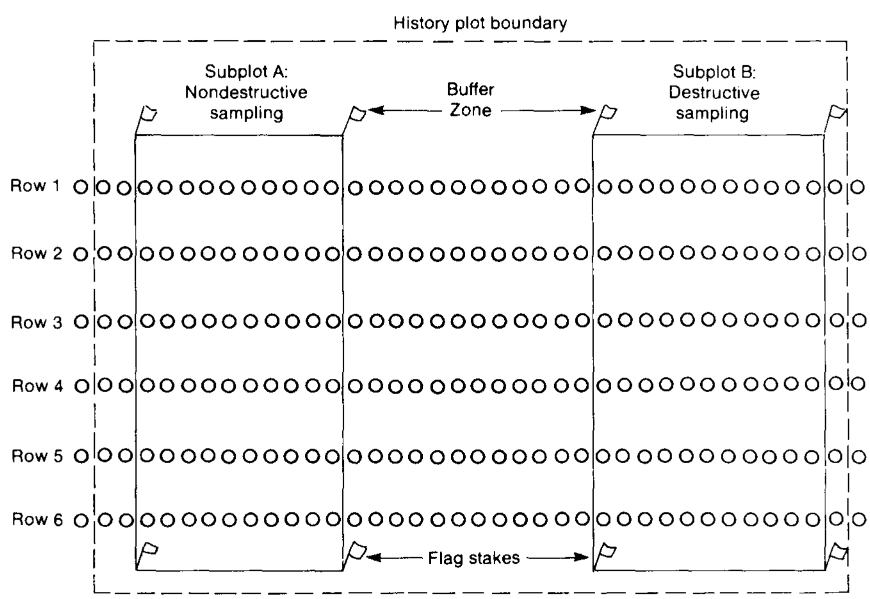

Figure 2—*A paired-plot sampling design is suggested for history plots so that destructive sampling can occur immediately adjacent to, but not disturb, the nondestructive sampling subplot. This example is for a nursery seedbed with 6 seed rows.*

two subplots that are separated by a buffer zone: subplot A for nondestructive sampling, and subplot B for destructive sampling. Nondestructive, repetitive measurements such as live seedling counts and shoot measurements can be made throughout the crop cycle in subplot A, whereas one-time destructive measurements involving seed and seedling excavation can be made in subplot B. The basic premise of this plot design is that the sown seed density will be similar between the two adjacent subplots; this assumption has been verified by actual nursery testing. Subplot B is generally excavated immediately after sowing to determine actual sowing density, and the seed resown to provide seedlings for later destructive sampling.

The subplots are generally 30.5 cm (12 in.) wide and rectangular in shape and extend completely across the seedbed. Plot corners should be marked with flag stakes or slats at all four corners (fig. 2) and referenced to some permanent feature such as an irrigation riser so that they can be precisely relocated at any time during the rotation, should the corner markers be accidentally removed. Flexible markers, such as flag stakes, are preferred because they are less likely to be damaged or pulled out during tractor operations.

The history plots should be revisited at regular intervals to monitor the fate of seed and seedlings and determine the causes of loss. Dead seedlings should be recorded and then removed during each visit to avoid possible confusion as to when the loss occurred (3). Request the assistance of a nursery pathologist during these first visits, particularly during the seed excavation procedure, to help determine the exact cause of mortality. If this is not possible, collect samples of dead seed and seedlings and store them under refrigeration until they can be examined by a trained pathologist.

While the history plots are read during the seedling emergence period, a string can be permanently run around the corner stakes to establish the plot perimeter. Seed located exactly on the boundary line should be alternately placed in or out of the plot to avoid bias and to make a

Table 2—*Specific measurements taken on history plots during a crop rotation*

Measurement	Application to nursery management
Subplot A (nondestructive sampling)	
Standard	
A-1 Live seedling count	Used to compute field germination and seedbed density
A-2 Dead seedling count	Causes, timing, and quantity of seedling losses
A-3 Shippable seedling yield	Determine actual shippable seedling yield
Optional	
A-4 Seedling height and caliper	Develop seedling growth curves
A-5 Shoot phenology observations	Develop seedling growth curves
A-6 Soil pathogen analysis	Determine if regular fumigation is necessary and establish the relationship between pathogen levels and seedling losses
Subplot B (destructive sampling)	
Standard	
B-1 Seed density	Seed drill calibration and performance; needed for computing survival percentage
B-2 Sowing depth	Seed drill performance and adjustment
B-3 Ungerminated seed examination	Causes of preemergence mortality
Optional	
B-4 Relative root growth measurements	Development of seedling growth curves
B-5 Root phenology observations	Development of seedling growth curves
B-6 Ovendry seedling weight	Determining shoot/root ratios
B-7 Soil nutrient analysis	Determines mineral nutrient availability
B-8 Seedling nutrient analysis	Determines mineral nutrient uptake
B-9 Root growth capacity	Measures seedling performance potential
B-10 Frost hardiness	Measures ability to tolerate frost and storability

clear decision about which seeds are in the plot and which are not (1). Once the seedlings have become established, rods or a counting frame can be placed across the seedbed to mark the across-bed sides of the plot.

Monitoring History Plots

Standard and optional measurements that can be made with history plots are listed in table 2. Standard measurements are those needed to determine nursery sowing factors, whereas optional measurements provided other information about seedling growth and phenology that can be used in many phases of nursery management. Table 3 is a time schedule for taking the measurements listed in table 2.

History plots can be incorporated into other nursery sampling processes, such as seedbed inventory (1), because history plot data provide an intensive look at seedling growth and development. If the history plots are excavated at the end of the crop cycle, the seedlings can be measured and graded to provide information on seedling grading specifications, cull rates, and net seedling yield per area of seedbed.

Table 3—*Time schedule for specific measurements on history plots*[1]

Sampling event	Sampling interval	Time after sowing (wks)	Specific measurements taken	
			Subplot A	Subplot B
1. Prefumigation	Once	—	A-6	—
2. Postfumigation	Once	—	A-6	—
3. Postsowing	Once	0	—	B-1 B-2
4. During emergence	Weekly	1 to 6	A-1 A-2 A-5	—
5. Postemergence	Once	6	A-6	B-3
6. During 1 + 0 season	Twice/mon.	6 to end	A-1 A-2 A-4 A-5	B-4 B-5
7. End of 1 + 0 season	Once	—	A-1	B-6 B-7 B-8
8. During 2 + 0 season	Twice/mon.	—	A-1 A-2 A-4 A-5	B-4 B-5
9. End of 2 + 0 season	Once	—	A-1	B-6 B-7 B-8 B-9 B-10
10. Prelifting	Once	—	A-1 A-2	B-9 B-10
11. Lifting, grading, and packing	Once	—	A-3	—

[1]Plot designations are those listed in table 2.

Using History Plot Data in Nursery Management

Seed-use efficiency. The numerical data on seed and seedling losses have obvious applications in the determination and refining of nursery factors (fig. 1) that can be used in sowing rate calculations. As the specific causes of the losses are identified, corrective actions can be taken to reduce or eliminate them completely. Although not often recognized, improving seed-use efficiency can have significant economic impacts, particularly for genetically improved seed. South (5) estimates that a southern forest nursery with an annual production of 30 million seedlings could realize a yearly savings of $15,000 by increasing seed-use efficiency from 50 to 55 %.

Scheduling and evaluating cultural practices. The effort of nursery cultural operations, such as seedbed fumigation, can also be critically examined through history plots. When history plot data from Mt. Sopris Nursery were analyzed, it was obvious that the greatest seed and seedling loss occurred during the germination and emergence period (fig. 3). Direct observations during checks of the history plots and associated soil testing for pathogenic fungi identified the cause of the losses as damping-off and seed predation by birds. Consequently, regular seedbed fumigation was prescribed to reduce damping-off fungal populations, and early morning bird patrols were established to discourage bird predation.

Other cultural practices, like root pruning or top mowing, have extremely narrow operational windows that must be carefully scheduled. Many nursery managers try to prune the roots of pine seedlings in the fall of the 1 + 0 year to sever the dominant tap root and stimulate a more fibrous root system. The timing of this operation is critical, however. If it is done too early, it may reduce shoot growth, but if it is done too late, the seedlings will not have time to reestablish a good root system and may undergo frost-heaving during the winter. The best time for root pruning, as determined from the history plot data, is a narrow time period after budset but before the fall root growth period (fig. 4).

Seedling growth and phenology. The seedling measure

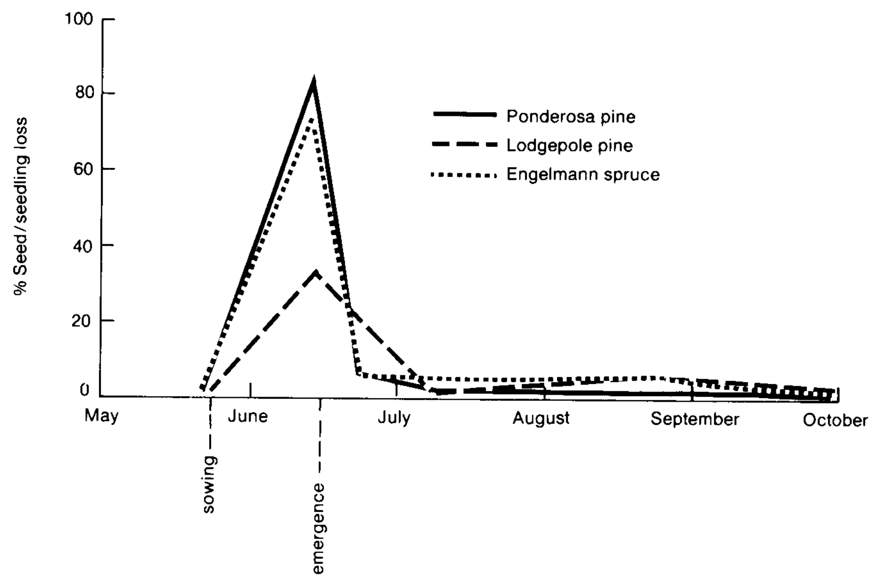

Figure 3—*History plots at Mt. Sopris Nursery, CO, revealed that the majority of seed and seedling losses were occurring during the germination and emergence period (4).*

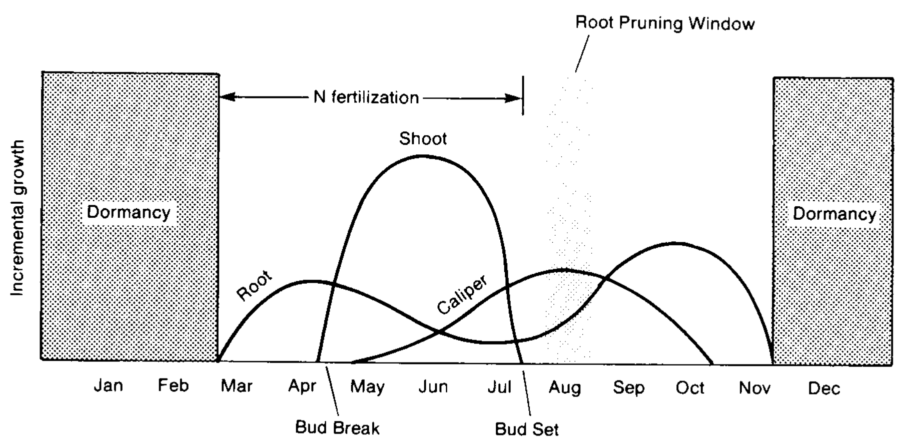

Figure 4—*Seedling growth curves from history plot data can be used to schedule nursery cultural practices such as fertilization and root pruning. This graph represents the second year of a 2 + 0 seedling production cycle.*

ments made in history plots can be used to generate seedling growth curves that illustrate the annual cycle of seedling growth (fig. 4). Not only do these growth curves provide an excellent visual representation of the timing of significant events such as budbreak and budset, but they can be used to help schedule cultural practices such as fertilizer applications. Nitrogen (N) fertilizer should be applied early in the growing season, so that sufficient N is available during the rapid shoot growth period, but not so late that it could interfere with the onset of dormancy (fig. 4).

Problem solving. One of the most useful applications of the history plot procedure is for nursery problem-solving. Installations of history plots in seedbeds of a particularly troublesome species or seed lot can provide invaluable information on the fate of the seed and seedlings during the crop cycle. Without the focused perspective provided by history plots, nursery managers often are unable to determine the specific causes of seed and seedling losses.

Conclusions and Recommendations

History plots offer the nursery manager a technique to accurately monitor the fate of seed and seedlings throughout the nursery crop cycle. One of the principal uses of history plot information is to establish or refine nursery sowing factors. The causes of seed and seedling losses can be identified during the regularly scheduled plot visits, and this information can then be used to schedule or modify nursery cultural practices to reduce or eliminate these losses. Information on seedling growth and phenology can be used to generate seedling growth curves that give the nursery manager a valuable tool for timing cultural practices. The history plot procedure is also useful as a nursery problem-solving technique.

In summary, the history plot procedure brings the nursery manager into close contact with the growing seedlings at regular intervals throughout the crop cycle, providing the indepth understanding necessary to scientifically manage a forest tree seedling nursery.

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