CHAPTER 16—INVENTORY SYSTEMS

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INTRODUCTION

Each year nursery managers estimate the number of seedlings they can ship from their nurseries. Seedlings produced for sale must be inventoried months in advance as a safeguard against accepting more orders than can be filled. Stock produced for agency use must be inventoried in time to permit detailed preparations for field planting operations such as site preparation, contracts for planting and for adjusting the supply of seedlings by purchase, if necessary.

The inventory should be accurate enough for purposes of nursery cost analysis, and also for distribution of seedlings by seed lots or by specific areas withing the nursery such as blocks, sections or even seedbeds. Final estimates should show numbers of plantable seedlings withing ± 3, 5 or 10 percent, depending on the organization requirements. Less accurate estimates often require correction and adjustments of seedling distribution schedules. Obstacles to meeting the desired accuracy of the inventory are:

1. Variation in seedling density in the seedbeds.
2. The difficulty of detecting some damage, such as root injuries or fusiform rust until late in the growing season or until the stock has been lifted.
3. Failure of a considerable percentage of seedlings to attain plantable size between the final inventory and lifting.

The nursery manager has several options in making an inventory. After selecting a system, the following steps are common to all options:

1. Decide on the number of plots to be used.
2. Locate the plots in which counts are to be made.
3. Count the seedlings and record the data.
4. Calculate the estimated number of plantable seedlings.
5. Calculate the reliability of the estimate.

At least four properties should be present in a good system:

1. The procedures for field data collection must be easily understood so that they can be carried out by nursery workers lacking statistical training.
2. The sampling procedure and analysis should yield objective measures of the reliability of the estimates.
3. The sampling efficiency should be high, i.e., the smallest amount of data should be used to obtain the desired precision of the inventory.
4. The procedures for computation of the estimates should be as efficient as possible (Ware et al 1967).

STATISTICAL TERMINOLOGY

The nursery manager needs to know the total number of seedlings from a seed lot or sub-seed lot. Measures that describe the distribution of some variable or characteristic in a population are called population parameters. The corresponding measures calculated or selected from a set of sample data (observations) from the seed lot are called sample-statistics, such as mean, standard deviation, variance, standard error of the mean, etc. (Freese 1962 Steel and Torrie 1960). The basic justification for this statistical inference is that the distribution which is obtained from a random sample tends to resemble the distribution of the population from which it was drawn. Thus, the mean of a large sample estimates the true mean of its population. Additional statistical terms are defined in appendix 16-1.

NUMBER OF PLOTS NEEDED

Estimating the number of plantable seedlings in a nursery costs money. Errors in this estimate are even more expensive! The aim is to take enough observations to obtain the desired accuracy—no more, no less. The intensity of the sample will be determined by:

1. The accuracy needed.
2. The uniformity of the seedling stand.
3. The experience gained in past years through comparison of sample inventories with the actual count or estimation of the seedlings lifted.
4. The amount of time and money available for the inventory.

The actual number of plots needed may be obtained by several methods:

1. The sample-size formula. See appendix 16-3.
2. Use of tables 16-1 or 16-2.

Table 16-1. — Numbers of samples required to inventory nursery units.[1,2]

Size of nursery unit		Total number of samples required to include following percentages of bed areas						
Number of beds 4 by 400 feet	Number of trees[3/]	20	10	5	2	1	0.5	0.25
1	50,000	80	*40*	20	8	-----	-----	-----
2	100,000	160	80	*40*	16	8	-----	-----
10	500,000	800	400	200	*80*	40	20	-----
20	1,000,000	-----	800	400	160	*80*	40	20
100	5,000,000	-----	-----	2,000	800	400	*200*	100
200	10,000,000	-----	-----	-----	1,600	800	400	*200*

[1] From: Wakeley (1954)

[2] Samples are 1 by 4 feet, across the beds. Bold-faced figures indicate total number of samples suggested for final inventory of uniformly spaced stand or preliminary inventory of very irregular stand. Italic figures indicate total number suggested for final inventory of exceptionally uniform stand or preliminary inventory of ordinary stand. For extremely irregular stands, intensities of sampling should be increased somewhat above those suggested. For numbers of beds intermediate between those shown, numbers of samples should be interpolated.

[3/] Approximate only, assuming a density of slightly more than 31 trees per square foot.

3. A graphic system based on past inventory data (figure 16-1).
4. A standard sampling percentage based on past history.

Method 1:

Obtain an estimate of the variance among plots to determine the number of samples needed to meet the objective. Two alternatives are available:

1. Make a guess at the variance. Base your guess on values obtained from previous inventories or make a rough estimate of the variance by dividing the range (maximum-minimum) by 4 and squaring this result.
2. Make the inventory in two stages. In the first stage, make n_1 random observations and from these compute an estimate of the variance (s^2). This value is then plugged into the sample-size equation. See appendix 16-3.

Method 2

Table 16-1 or 16-2 is used directly. These tables show two methods of determining the number of sample plots required to sample a specified percent of the seedbed area

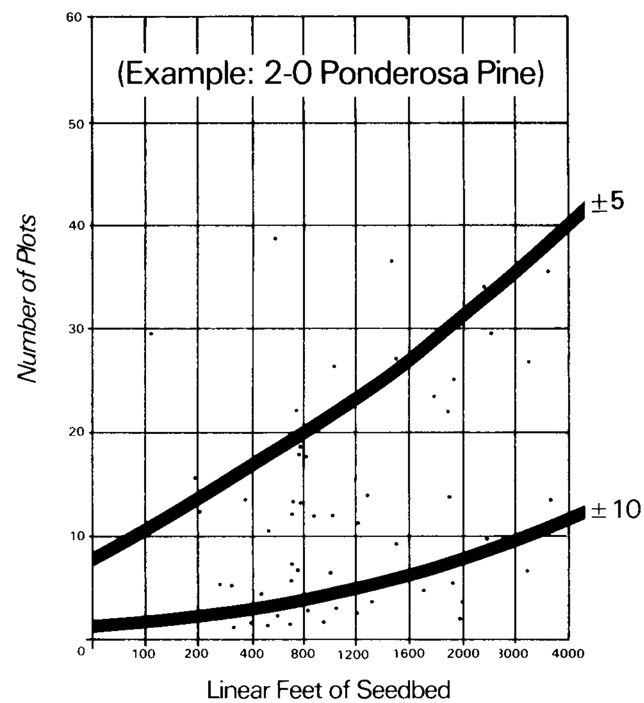

Figure 16-1. — Number of plots needed for sampling errors of ±5% and ±10% (McDonald 1978)

Table 16-2. — Number of inventory plots required for specified error limits.[1,2]

Number of beds	Total length of bed	Total[3/] number of trees expected	Samples required per bed when specified percent of error												
			In uniform bed is—						In nonuniform bed is—						
			0.5	1	2	3	5	10	1	2	3	5	10	15	20
	Ft.	Thousands	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
1	500	90	---	---	---	46	17	4	---	---	---	58	18	7	4
2	1,000	180	---	---	50	23	8	2	---	---	82	29	8	3	2
5	2,500	450	---	---	20	9	3	---	---	---	35	12	3	1	---
10	5,000	900	---	---	10	5	2	---	---	36	16	6	1	---	---
20	10,000	1,800	---	20	5	2	1	---	---	18	8	3	1	---	---
50	25,000	4,500	---	8	2	1	---	---	---	8	3	1	---	---	---
100	50,000	9,000	17	4	1	---	---	---	14	4	1	---	---	---	---
200	100,000	18,000	8	2	1	---	---	---	8	2	1	---	---	---	---

[1]From: Stoeckler and Jones (1957)

[2]Samples are 4.0 by 0.5 feet taken across the bed. Bold figures represent total numbers of samples suggested as being feasible to take per bed of 500-foot length and still retain fairly good accuracy.

[3/]Approximate only, with plants averaging about 90 per 4.0 by 0.5-foot counting plot, or 45 per square foot.

or to sample within specified limits of error. For a sampling intensity involving 5, 10, 15, or 20 plots per bed, the location of the sampling plots in each 500-foot bed would be at intervals of 100, 50, 30 and 25 feet, respectively, for these sampling densities. The pacing scheme is a departure from strictly random sampling, but because the pace length is likely to vary somewhat the net pattern of the sample distribution would approximate a random placement. Risers or stand pipes are often used as units of spacing.

Method 3

A graphic approach was developed by McDonald (1978) to minimize the time required for repeated sampling (figure 16-1). When sufficient inventory data is available for a given seedlot the curves are constructed for ± 5 and ± 10 percent sampling error rates. The number of plots needed is read directly from the vertical axis at the intersection of the existing linear feet of seedbed with appropriate error rate curve. For this example (2-0 ponderosa pine) the sampling of 1,600 linear feet of seedbeds with an error rate of 5 percent would require 26 to 28 plots.

Method 4

A comparison of the number of plots used and the estimated number of seedlings grown with the actual number of seedlings lifted will provide a measure of the efficiency of past inventories. This relationship can be shown graphically or statistically via regression analysis.

SAMPLING DESIGNS

Four designs are most frequently used in nursery inventories:

1. Random sampling
2. Stratified random sampling
3. Systematic sampling
4. Stratified systematic sampling

In this discussion of inventories, assume that a seed lot is the unit to be inventoried. Large seed lots may be divided into smaller units for the inventory.

Random Sampling

The procedure for obtaining a random sample of a seed lot can be shown by the following illustration:

1. Assume that the beds to be sampled are 400 feet long and the sampling plot to be used is 1 by 4 feet.
2. Assume that a 2-percent sample is desired.
3. Assume that the seed lot covers ten 400-foot seedbeds or 4,000 linear feet. The seed lot will contain 4,000 sampling units, and counts will be made on 80 randomly-selected plots within the seed lot (i.e., $\frac{80}{4000} \times 100 = 2$ percent).

Obtain points for plot locations from a table of random numbers or with an electronic calculator. Determine actual location of the plots by measuring from the beginning of the first seedbed with plots numbered from 1 to 4,000, i.e., the linear distance on the seedbeds. This system provides that all plots or samples for the seed lot are located strictly by random.

In practice, seedbeds are often divided into sampling units of 100 feet. The actual location of sample plots is by a two-digit random number from a table or a calculator. The number of plots corresponds directly to the desired sampling intensity, e.g., a 2 percent sample requires two per 100 foot unit.

An advantage of random sampling is that fewer plots can give acceptable accuracy *if* the plots represent the area involved. This concept is based on the assumption that data collected from the seed lot is distributed in a normal manner throughout the population. The number of seedlings counted on plots distributed randomly throughout the seed lot should follow a normal curve, i.e., 68 percent of the plot means would fall within one standard deviation on either side of the true population mean, 95 percent within two standard deviations, and 99 percent within 2.6 standard deviations (figure 16-2). Although some factors can skew this distribution, for all practical purposes the concept of a normal distribution can be considered acceptable. Thus, with random sampling, probability theory can be applied and valid estimates of error may be obtained (Steele and Torrie 1960).

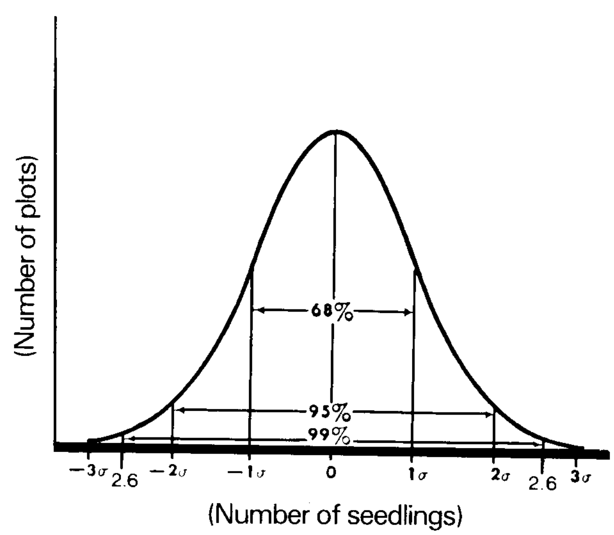

Figure 16-2. — A normal distribution with the area under the curve representing ± 1,2, and 2.6 standard deviations.

Stratified Random Sampling

This sampling design arbitrarily divides the nursery or the sampling unit (a seed lot) into areas that are relatively uniform within, but differ from neighboring areas. Within the sampling unit select areas that have relatively uniform stands of seedlings and relatively uniform quality; map them to fall within one stratum. Areas that seem to differ from this, on either a stand or quality basis, are mapped into another stratum. A particular stratum may contain all or parts of several sections or beds. The number of strata is flexible and may be influenced by sowing dates, differences in soil conditions within the nursery and by cultural treatments. The principle of stratification in the nursery is the same as stratification by timber types when timber cruising.

The illustration for random sampling for a seed lot can easily be converted to stratified random sampling by beds within the seed lot. Each bed will contain 400 sampling units, and counts will be made on eight randomly selected plots. Tags numbered 1 to 400 are mixed thoroughly and eight tags are drawn from the lot. These eight numbers indicate the position of the sample plots on the first beds. The numbers are put back in the box for mixing, after which eight more numbers are drawn. These numbers represent the location of the plots for the second bed. This procedure is repeated for all beds. As an alternative, the points for plot locations can be obtained by selection of numbers from a table of random numbers. All plots or samples within a seedbed are located strictly by random. The actual locations of the plots are determined by measuring from the beginning of the seedbeds with plot numbers from 1 to 400.

The system of stratified random sampling may involve double or two-phase sampling whereby a specified number of plots are used to obtain the standard error of an estimate. Then the number of plots needed to achieve the desired sampling accuracy is calculated (see appendix 16-3).

Nursery workers rarely sow all of a large seed lot in one block, and small seed lots are frequently interspersed among large seed lots. Thus, there is often an automatic stratification within the nursery.

Systematic Sampling

In the initial inventory a fixed number of 1 by 4 foot plots (e.g. 20) are to be sampled. These are located at fixed intervals along seedbeds. As an illustration, the sampling unit contains nine 600-foot seedbeds, or 5,400 linear feet of beds. Each of the 20 samples will represent

270 linear feet of beds (5,400/20). Start with plot one, 135 feet from the end of the first bed; plot 2 will be 270 feet from plot 1; continue at 270-foot intervals until the 20 sample plots have been located. A formula is then used to compute the number of additional plots required to bring the estimate within ± 1 or 5% of the required accuracy (see appendix 16-3).

The *advantages* of systematic sampling are:

1. It is easier than other methods to apply in the field, saves time and can be done by less skilled workers.
2. It is simpler than other systems and fewer mistakes are likely to be made.
3. The sampling units are widely and evenly distributed and should represent all parts of the population, i.e., the sampling unit.
4. Studies of nursery sampling procedure indicate that systematic sampling has consistently given results as accurate as the fully random system.

The *disadvantages* generally given are:

1. The sample may give a poor estimate of the population mean if irregularities exist in the nursery which are correlated with the spacing of the samples. For example, sample plots may be consistently located on outside or center beds that receive less irrigation water than beds close to the lateral water lines.
2. There is no fully valid, statistical method of computing error (Mullin 1964). However, a systematic sample with a randomly-located starting point does allow a valid estimate of sampling error (Freese 1962).

Systematic sampling is often used when the lot to be inventoried has less than 4,000 linear feet of bed. The number of plots is high because the sample usually runs between 5 and 10 percent of the area. When there are a large number of plots the field counting is time-consuming and the analysis is lengthy.

Stratified Systematic Sampling

This sampling method includes the advantages of the systematic selection of plots and the stratification of the sampling units to obtain homogeneity within the sampling unit. This method is possibly the most frequently used system for large seed lots where stratification is needed to delineate areas of nonuniform seedling density and seedling quality. Sampling units are delineated on seedbed maps, and plot locations are systematically spaced within these sampling units. Computations are similar for all systems, except that there is no valid method of computing error with the systematic systems, unless random starts are used.

TYPES OF INVENTORIES

Several types of inventories can be developed, depending on the needs of the individual nursery and the methods of computation used in processing data.

1. Spring inventories may be made of the total number of seedlings, using only permanent plots. When stand densities are uniform, use permanent (life history) plots if they represent the area close enough to provide a reliable inventory of the total number of seedlings. See appendix 16-2.
2. Spring inventories may be made of the total number of seedlings from temporary plots. Many nursery managers do not establish permanent (life history) plots. The spring inventory of first-year seedlings is made in late June or early July.
3. Spring inventories may be made of the total number of seedlings, using both permanent and temporary plots. This type of inventory can compare permanent and temporary plots of the spring inventory to determine if the permanent plots are representative, tell which plots to use in the fall inventory, and provide inventory figures based on combined data from both types of plots. At the time of the spring inventory, systematically select two to three times the number of the life history plots as temporary plots. If the life history plots do not differ statistically from the temporary plots, they may represent the area well and should be used in the fall inventory.
4. Fall inventories may be made of total seedlings, using only temporary plots.
5. Fall inventories may be made of total seedlings, using permanent plots, or permanent plots plus temporary plots.
6. Fall inventories may be made of plantable seedlings by grades, using temporary plots or a combination of permanent and temporary plots. Grade and cull percentages are usually based on dug seedlings.

LIFE HISTORY PLOTS

Life history plots were used first in the South at the Stuart and Ashe nurseries to learn why the tree percent varied widely among the many seedlots. Tree percent is the percent of the number of clean seed sown which develop into plantable 1-0 seedlings. This factor is based on both expected nursery germination and seedling survival and development in the seedbed. Losses from climatic factors, predators and disease may cause the tree percent to vary from year to year. The plots were, and still are, used to provide the following information:

1. Actual sowing rate, i.e., the number of seeds per square foot or linear foot of drill.
2. Actual field germination.
3. Soil moisture conditions during germination.
4. Reasons for mortality during germination.

5. Survival factor of germinated seed.
6. Morphological development of seedlings.
7. Seedling density.
8. Insect attacks—when and what species.
9. Disease outbreaks.
10. Weed populations.
11. Cull percent.
12. Supplemental spring and fall inventories.

Establishment

Life history plots are randomly or systematically located to serve as permanent plots in the nursery seedbeds. Choose the location of the plots before planting, and list them on tentative-data sheets. Determine the number of plots by tentative planting schedules to minimize biasing the choice of plot locations. The plots may measure 1 by 4 or 1/2 × 4 feet, but more frequently are 1 × 4 feet. Use at least 10 plots per seed lot, or a minimum of about one plot per 1,200 linear feet of seedbeds for each seed lot. For seed lots of more than 20,000 linear feet of seedbeds (fifty 400-foot beds), use one plot per 1,800 linear feet of seedbeds. A more detailed explanation of life history plots is given in appendix 16-2.

Install life history plots directly behind the planter and before mulch is applied. Plots can be established by dropping a 1 by 4 foot frame at the previously chosen spot. Put flexible corners in the soil (venetian blinds or pot stakes are good) and connect opposite pairs with a string. Then count the seeds, and move borderline seeds alternately in and out of the plot to avoid later confusion and biasing of the sowing rate. The count is then tallied by its location, on permanent data sheets (table 16-3). The plots can be installed by the same person who is keeping check on sowing density counts. These counts should also be recorded and can be used to check the representation of the life history plots because the density counts are from a larger percentage sample.

Germination Checks

Make at least five counts at about 7-day intervals between the 10th and the 40th day after sowing, for most species. During these counts, remove dead seedlings and note the probable reasons for death. Those seedlings pulled up will be added to future counts to obtain the total germination. Germination data from life history plots provide a comparison between laboratory and field germination.

Survival Factor

Throughout the summer and fall make three counts to check survival during the growing season (in addition to germination counts). The best times for counts are about July 1, August 15 and October 1. These data will give a survival factor by species and seed lots which, over a

Table 16-3. – Life history plot data sheets.

Chart 1

Location				Species and lot No.	No. seed planted	Date planted	Soil and weather conditions
Comp.	Line	Bed	Post				

Chart 2

Species and lot No.	No. plots desired	No. plots obtained	Desired seed/ft.	Av. seed/ft. on plots	Av. seed/ft. on check	Adjustments

Chart 3

Species and lot No.	Lab. germ.	Field germ.	No. days	Diff. from lab. germ.	Remarks

Chart 4

Species and lot No.	Location				No. seed planted	Date planted	Germ. checks by days after planted				Remarks
	Comp.	Line	Bed	Post							

Chart 5

Species and lot No.	Location				Inventory checks				Grading				Diseased	Av. height
	Comp.	Line	Bed	Post	June	Aug.	Sept.	Oct.	Total	#1	#2	#3		

Chart 6

Species and lot No.	No. plots	Total plot count	Av./foot on plots	M seedlings per bed	No. beds	M seedlings total	Adjustments	Less cull

5-year period, should give an accurate representation for the nursery. Without this information, the survival factor is often an educated guess. The survival factor can be influenced by location within the nursery, nursery cultural practices and environmental factors. If the nursery practice was varied within a species, the value of a particular cultural operation could be assessed by use of the survival factor.

Seedling Grades

Seedlings in the life history plots can be graded in the field or lifted before operational lifting to determine the cull percent or the percentages of Grades 1 and 2 seedlings.

Inventories

An advanced use of the life history plots is for the shipping inventory. Studies at the [illegible] Nursery indicated that life history plots were reasonable and accurate on uniform seed lots of 30,000 square feet or more, using three plots per 14,400 square feet. The larger the seed lot to be sampled, the smaller the percentage of samples needed (Belcher 1964a,b).

FIELD PROCEDURE FOR INVENTORIES

Nursery inventory work tends to become a tedious task. Assign this duty to workers who can read and record data accurately. Plot locations of permanent (life history) plots are already listed on the data sheets. List the locations of temporary plots on data sheets before the inventory begins. Irrigation risers can serve as markers or points of reference for measuring distances. Seedbed plot counts can be made most advantageously by two persons, each working on one-half of the plot. Large nurseries may have self-propelled inventory carts (weeding carts) which straddle the bed and take workers from plot to plot.

Plot Counts

The standard plot size in most southern nurseries is 1 by 4 feet. Other sizes that have been used are: 3 inches by 4 feet, 6 inches by 4 feet, 21 × 41 inches and 41 × 40 inches. The 1 by 4 foot plot is easy to use, requires less field time than larger plots and gives results that are statistically as accurate as plots of other sizes.

The sampling frame is eased down among the seedlings at right angles to the length of the bed and at exactly the predetermined location. Do not move the frame to either side to include or exclude better- or poorer-looking portions of the seedling stand. Moving the frame almost invariably reduces the accuracy of the inventory. Count the living seedlings with their base within the frame and record the number on a prepared form in the column headed "Number of living seedlings". Plots in drainage channels and at the ends of beds should be so designated and analyzed separately.

Number of Plantable Seedlings

The number of plantable seedlings can be determined by several methods. There must first be established maximum and minimum sizes and other quality standards. Count all plantable seedlings or all culls on all samples on the basis of top development alone, i.e., stem diameter, stem length and needle development. The percentage of plantable seedlings in a sample plot can be determined by counting part of the sample, for example every fifth or tenth seedling. One technique is to make 10 equally spaced and clearly visible marks on the inside of one side of the frame. The seedling nearest each of the marks is measured and graded.

The most reliable estimate of the percentage of plantable seedlings can be obtained only from sampling seedlings actually dug from the seedbeds and graded by a regular-season grader. This percentage can be compared with the percent obtained by visual examination of tops alone.

The maximum variation of grades and cull percentages can be accounted for by increasing the number of dug samples. If one half of the bed is a mirror image of the other half of the bed, dig only a 1 by 2 foot sample from the edge of the bed toward the center. However, the side of the bed from which the plot begins should be randomly chosen or at least alternated so that all variation within the bed can be measured (Belcher 1972).

A cull percent is sometimes estimated for the spring inventory, when seedling estimates are needed to determine if additional sowing is needed. A typical estimate falls between 10 and 20 percent.

DATA PROCESSING

Processing of nursery stock inventories from sample-plot data can be handled by office calculators or by computers. Automated processing of inventory data:

1. Provides a high degree of accuracy at low cost.
2. Relieves nursery workers of the time-consuming job of calculating the inventories by hand.
3. Provides an estimate of numbers of total seedlings and plantable seedlings, according to the desired categories for each sampling unit.
4. Gives the standard error for these units.
5. Can show the number of plots to sample in each sampling unit for two different levels of sampling errors.

Hand Calculations

Five steps are involved in the calculation of the inventory by office calculation equipment.

1. Check the adequacy of the sample for total count.
2. Check the adequacy of sampling for plantability percent.
3. Calculate the estimates for total number of seedlings.
4. Calculate the estimates of the number of plantable seedlings.
5. Calculate the variances and standard deviations.

You may also wish to compute the standard error, the standard error percent and the coefficient of variation for each sampling unit. See Appendix 16-3 for the procedure described by Barton and Clements (1961).

Computer Processing

The Forest Service has developed two computerized inventory procedures: NURINV (Space and Belcher 1972) and NMIS (Thatcher 1982).

NURINV.—This program is designed for efficient batch-processing of several types of inventories. The program can calculate total seedlings, plantable seedlings by grades, the number of additional plots needed to reduce the sampling error to an acceptable level, average number of seedlings per square foot, sample error and the amount of variation in each seed lot.

A printout sheet (table 16-4) can show the following information for a sampling unit:

- date of inventory
- species
- date of sowing
- total linear feet of seedbed or total bed area
- sample size (square feet)
- number of samples taken
- number of samples required for 5- or 1-percent accuracy
- average number of trees per square foot
- standard deviation
- lot number
- seed source
- sampling error
- gross number of seedlings
- expected losses and net plantable seedlings

NMIS.—The Nursery Management Information System (acronym NMIS) is designed to store, manipulate and summarize data on seed and seedlings in Forest Service nurseries. See figure 16-3. NMIS is designed for the TI 990 microcomputer. Programming is in BASIC. NMIS will store and summarize nursery inventory data and calculate sample statistics. See figure 16-4.

A system handbook is in preparation.

Table 16-4. — Example of a NURINV printout.

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PAGE 1                                                            NURSERY INVENTORY

LOT  1        DATE  JUL 5, 1979
LOB SOWN 5/6/79
SAMPLE SIZE   .5  SQFT       TOTAL LINEAR FT OF BEDS    2790      SAMPLES TAKEN = 120      SAMPLES REQUIRED FOR 5 o/o = 115
AVG TREES PER SQFT = 37.5       SAMPLING ERROR = 4.9       STD DEV = 5.04       COEF OF VAR = 26.8
GROSS SEEDLINGS   418500       PLUS OR MINUS   20494       EXPECTED LOSSES = 41013       NET PLANTABLE SEEDLINGS = 377487

LOT  2        DATE  JUL 5, 1979
LOB I-61-70 SOWN 5/7/79
SAMPLE SIZE   .5  SQFT       TOTAL LINEAR FT OF BEDS    7935      SAMPLES TAKEN = 128      SAMPLES REQUIRED FOR 5 o/o = 124
AVG TREES PER SQFT = 32.5       SAMPLING ERROR = 4.9       STD DEV = 4.54       COEF OF VAR = 27.9
GROSS SEEDLINGS   1031550      PLUS OR MINUS   50929    EXPECTED LOSSES = 101091       NET PLANTABLE SEEDLINGS = 930459

LOT  3        DATE  JUL 5, 1979
LOB SO NORTH SOWN 5/7,18/79
SAMPLE SIZE   .5  SQFT       TOTAL LINEAR FT OF BEDS    3005      SAMPLES TAKEN = 140      SAMPLES REQUIRED FOR 5 o/o= 135
AVG TREES PER SQFT = 32.5       SAMPLING ERROR = 4.9       STD DEV = 4.73       COEF OF VAR = 29.1
GROSS SEEDLINGS   390650       PLUS OR MINUS   19188       EXPECTED LOSSES = 38283       NET PLANTABLE SEEDLINGS = 352367

LOT  4        DATE  JUL 5, 1979
LOB 7804 L SOWN 5/21,25/79
SAMPLE SIZE   .5  SQFT       TOTAL LINEAR FT OF BEDS    9195      SAMPLES TAKEN = 140      SAMPLES REQUIRED FOR 5 o/o = 127
AVG TREES PER SQFT = 28.9       SAMPLING ERROR = 4.8       STD DEV = 4.09       COEF OF VAR = 28.2
GROSS SEEDLINGS   1062942      PLUS OR MINUS   50746       EXPECTED LOSSES = 104168       NET PLANTABLE SEEDLINGS = 958774

LOT  5        DATE  JUL 5, 1979
LOB 1840 SOWN 5/7/79
SAMPLE SIZE   .5  SQFT       TOTAL LINEAR FT OF BEDS    23135     SAMPLES TAKEN = 160      SAMPLES REQUIRED FOR 5 o/o = 15C
AVG TREES PER SQFT = 28.5       SAMPLING ERROR = 4.8       STD DEV = 4.38       COEF OF VAR = 30.6
GROSS SEEDLINGS   2637390      PLUS OR MINUS   127806      EXPECTED LOSSES = 258464       NET PLANTABLE SEEDLINGS = 2378926

LOT  6        DATE JUL 5, 1979
LOB 76 MD SOWN 5/7/79
SAMPLE SIZE   .5  SQFT       TOTAL LINEAR FT OF BEDS    7945      SAMPLES TAKEN = 200      SAMPLES REQUIRED FOR 5 o/o = 198
AVG TREES PER SQFT = 22.5       SAMPLING ERROR = 5         STD DEV = 3.96       COEF OF VAR = 35.2
GROSS SEEDLINGS   715050       PLUS OR MINUS   35586       EXPECTED LOSSES = 70074       NET PLANTABLE SEEDLINGS = 644976

LOT  7        DATE  JUL 5, 1979
LOB ACC-1 M SOWN 5/18/79
SAMPLE SIZE   .5  SQFT       TOTAL LINEAR FT OF BEDS    16470     SAMPLES TAKEN = 140      SAMPLES REQUIRED FOR 5 o/o = 143
AVG TREES PER SQFT = 29.7       SAMPLING ERROR = 5.1       STD DEV = 4.45       COEF OF VAR = 29.9
GROSS SEEDLINGS   1956636      PLUS OR MINUS   99024       EXPECTED LOSSES = 191750       NET PLANTABLE SEEDLINGS = 1764886
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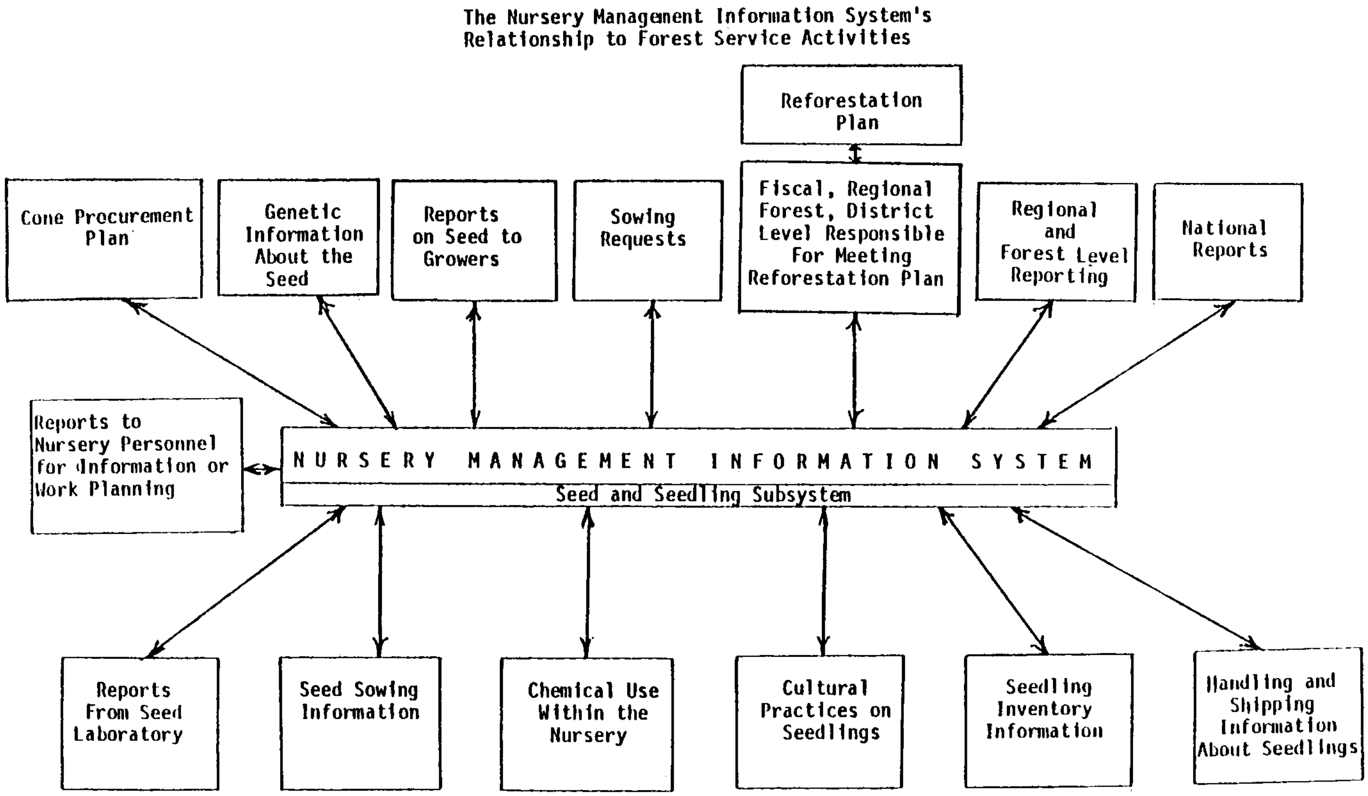

Figure 16-3. — NMIS Capabilities.

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BED INVENTORY

SEEDLING ID IS:  8402675004
FIELD IS:        11
COMPARTMENT IS:  5
BED IS:          5
BED LENGTH IS:    402
CULL % IS:        .18
PLOT COUNT ( 1 ) IS:     109
PLOT COUNT ( 2 ) IS:     140
PLOT COUNT ( 3 ) IS:     135
PLOT COUNT ( 4 ) IS:     125
PLOT COUNT ( 5 ) IS:     128
PLOT COUNT ( 6 ) IS:     139
PLOT COUNT ( 7 ) IS:     136
PLOT COUNT ( 8 ) IS:     135

FOR THE ABOVE SET OF DATA:
     GROSS MEAN =          130.88
     GROSS BED COUNT =     52613.76
     NET BED VOLUME =      43143.28
     NET MEAN =            107.32
     DENSITY =             37.39
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Figure 16-4. — NMIS inventory printout.

SUMMARY

An inventory of planting stock must be available months in advance of lifting as a safeguard against accepting more orders than can be filled, and to permit detailed preparations for planting. The inventory must be tailored to the particular nursery and the information needed for its management. Characteristics of a good inventory are simplicity, reliability and efficiency in terms of data collection and data processing.

Inventories can be based on permanent life history plots, temporary plots or a combination of both. Sample-plot locations can be selected at random or systematically. Random placement of plots provides better statistical control and interpretation, but is more difficult to use in the field than systematic placement of plots. The plot size is usually 1 by 4 feet. The number of plots needed depends on the variability of stocking and the degree of accuracy desired. An estimate of the variation in seedling density can be obtained from past inventories or determined by a preliminary sample.

Sample accuracy of ±5 percent is adequate for many nurseries. A few nurseries will accept an accuracy of ±10 percent, while others require closer estimates.

Computations can be handled by hand calculators at the nursery or by computer programs. The Forest Service has developed NURINV and NMIS programs for nursery inventory use.

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APPENDIX 16-1.—STATISTICAL TERMS USED IN NURSERY INVENTORIES

Coefficient of variation.—The sample standard deviation expressed as a percentage of the mean.

Confidence interval or interval estimate.—Because $\bar{x}$ is only an estimate of the true population mean, we would like to establish an interval around the mean and state that we are reasonably confident that the true mean is contained within this interval.

Confidence limits.—The two statistics that determine the limits of the interval.

Distribution.—A distribution refers to the frequency of a specified variable in the population. A variable may be distributed in many ways within a population. Thus, we have binomial, Poisson and normal distributions. Fortunately most large-sample means approach a normal distribution and therefore probability theory is valid in their statistical treatment (Freese 1962).

Mean.—An arithmetic mean is the sum of all seedlings counted on n number of plots divided by the number (n) of plots.

Standard deviation.—The square root of the variance. This characterizes the dispersion of individuals about the mean.

Standard error of the mean.—A measure of variation among sample means.

"t".—A term used to represent the "t" or Student's distribution or a symmetrical distribution with a mean of zero. Its form differs for different values of n. "t" tables are given in statistics books.

Variance.—A very important measurement concerning the distribution of population. Although numerous measures of variability exist, the sample variance is probably the most common measure of variability.

APPENDIX 16-2.—ESTABLISHMENT AND USE OF LIFE HISTORY PLOTS (Belcher 1964b)

Establish 1 by 4 foot plots at the time of planting and maintain them throughout the growth of the seedlings in the nursery. Locate the plots randomly on a copy of form I in table 16-5.

The number of plots is predicted by table 16-6. The plots should be listed 2 weeks before installation or as soon as the number of beds of each lot is known.

Number of plots required for given sampling percentages.[1]

Total no. sq. ft.	No. 400 ft. beds[2]	% Sampling	No. of plots required	No. plots between riser lines
775,000	500+	0.02	39	1
400,000	258+	0.03	30	1
240,000	155+	0.04	24	2
90,000	58+	0.05	11	2
80,000	52+	0.06	12	2
65,000	42+	0.07	11	3
55,000	35+	0.08	11	3
40,000	36+	0.09	9	3
30,000	19+	0.10	7	3
20,000	13+	0.20	10	7
20,000	Less than 13	1.00	50	33
14,000	Less than 9	2.00	70	70

[1]Source: Belcher (1964b).

[2]Less than 19 beds would not be as accurate nor as economical as random sampling counts.

The limitations on sampling are:

1. The required number of plots from Table 16-6 must be located between each pair of riser lines for that lot.
2. The random sampling from random number tables allows the plots to fall on beds one through nine.
3. The post location must be between the second and next-to-last post on the riser line. Any plot falling in a ditch or point of seed drill adjustment should be moved one post in either direction without any particular reference. Use a suitable media to mark the boundary at the time of installation so that the 30- to 40-day germination count may be made accurately.

To install the plots, spot the location as soon after planting as possible. Drop a 1 × 4 foot frame on the bed with no particular preference to place, but at right angles to the bed. The slats are fitted into the corners, the frame removed and cord tied to connect the slats opposite one another. All borderline seeds are moved in or out so there will be no discrepancy during germination counts. Count the seed with a pointed instrument to ensure that all seeds are counted. The number is listed and then the plot will receive the same mulching as the rest of the bed, and at the same time.

The benefits in using permanent plots are many, but to be most beneficial they must be representative, i.e., a plot falling in a bad sowing area should not be relocated as it will represent that type of planting. It is not wise to put a plot in a place where seeding adjustments were made, as it would represent an adequate sample and would be apt to distort estimates derived from the sample.

When plots are being installed, the person who checks the accuracy of the seed distribution with the amount desired (check count) should make at least five counts between each pair of water lines. These counts will provide larger samples that will be used to check the history plots to be sure they are representative. An adjustment percent will be used with any plots differing from the check count by 2 or more seedlings per foot. To simplify record-keeping, use form II in table 16-5. Columns five and six should not vary more than 2 seedlings per foot.

PARTICULAR USES OF PLOTS

Germination

After installation of plots, make at least five counts in the first 40-day period. Germination is usually complete between 20 and 40 days. Germination requires a minimum of 20 days for longleaf and 30 for shortleaf, slash, and loblolly pines. The counts should fall between the 10th and 30th day with a final close examination at the end of germination. At the end of this germination period fill out form III in table 16-5 for the annual report.

During counts any dead seedlings will be counted, pulled up and noted as to cause. These dead seedlings should be added to all subsequent counts so that total germination may be known. Use chart IV in table 16-5 during counts.

Inventory

The larger the amount to be sampled the smaller the percent of sample. With this in mind and the fact that you are making an intensive check, use a much smaller sample than would normally be acceptable. Table 16-6 lists the necessary number of plots for the number of beds in that lot to be acceptable for inventory purposes. Although it would not be practical to go below the listed number for the 19+ beds, it would be wise to have one or two plots in a small lot for germination purposes. Although their use is limited, they can be used for spring inventory where culls are not accounted for and precision is not so refined.

After germination counts are finished, make inventory counts in June (spring inventory), August, first of September (optional), and October (fall inventory). Record the inventory counts on form V and summarize them on form VI, table 16-5. As the string for the boundary will have nearly disintegrated, use a small-gauge metal rod to find the boundaries. Push the rod across the bed from one slat to the other. Two rods will be required to count a plot.

Dug Samples

The cull factor must be determined in the fall inventory. Dig one plot per riser line and grade it with a wedge cut according to Wakeley's specifications in *Planting the Southern Pines*, page 103. In grading, only borderline cases are upgraded. You will then have a slight margin for error as more growth is possible than appears in your figures. Record your figures on form V, as collected. These figures will be computed by species and not by lots, as only a general knowledge is needed and it would not be practical to tie the grading into the density on the basis of this small sample.

Collect all slats or stakes during the fall inventory and when dug samples are obtained. You can then use them again and, in the process, keep trash out of the field.

These sampling programs can be used to get additional information beside that collected for germination and inventory checks. In the same process, you can check on the condition of the soil, insect attacks (when to spray), disease outbreaks and seedling density.

Work Involved

Task	*Hours per Plot**
Plan and install of plots (1 person)	0.6
Germination counts (2 persons)	0.4
Inventory counts (2 persons)	0.2
Compute and analyze data on all counts (1 person)	0.7
Dug samples: dig, grade and record (3 persons)	0.4
Total	2.3

Based on 1962 and 1963 plots.

SUMMARY OF OPERATIONS

1. Two weeks before planting: Randomly locate plots on chart I, table 16-5 by use of table 16-6.
2. One to two weeks before planting: Prepare adequate stakes and boundary string.
3. At planting time: One person completes chart I, table 16-5 as plots are installed. Another person makes check counts and adjusts the planter.
4. After planting: Within 1 week complete chart II, table 16-5.
5. Tenth to the 30th day after planting: Make germination checks on chart IV, table 16-5.
6. Immediately after the 40th day from planting: Complete chart III, table 16-5. Also, begin chart V (summer checks for survival).
7. Use chart VI for spring inventory (without culls column) and fall inventory for lots meeting the requirements for inventory on table I.
8. During the October inventory the slats will be taken up at time of dug samples. List the data on dug samples on chart V, table 16-5.

APPENDIX 16-3
Examples of the calculation of sample statistics.

Based on 5 plots from a 4 × 100 foot seedbed.

No. i	No. of seedlings per plot (1′ × 4′) Xi	Xi − $\overline{X}$	(Xi − $\overline{X}$)²
1	100	0	0
2	110	10	100
3	95	−5	25
4	90	−10	100
5	105	5	25
	500	0	250

N = total number of plots in the population = 100
n = number of plots sampled = 5
n_1 = plot 1; n_2 = plot 2; etc.
X_i = number of seedlings on plot n_i

1. Mean (arithmetic) = the sum of all seedlings counted on all plots divided by n number of plots.

$$\bar{x} = \frac{\Sigma X}{n} = \frac{(X_1 + X_2 + X_3 + X_4 + X_5)}{5} = \frac{500}{5} = 100$$

2. Estimated number of seedlings = total number of plots in the population x the mean number of seedlings per plot.

$$= N \text{ times } \bar{x} = 100 \times 100 = 10{,}000$$

3. Variance: the arithmetic sum of the deviations from the mean is always zero no matter how great or small the variability. If every plot contained the same number of seedlings, there is no variability.

$$\text{Sample variance} = s^2 = \frac{\Sigma(X_1 - X)^2}{n - 1} = \frac{250}{4} = 62.5$$

4. Standard deviation = s = $\sqrt{s^2}$ = 7.9
On the average about 2/3s of the unit values of a normal population will be within one standard deviation of the mean. About 95 percent will be within two standard deviations of the mean and 99 percent within 2.6 standard deviations.

5. Coefficient of variation (C) is the standard deviation expressed as a percentage of the mean.

$$C = \frac{s}{\bar{x}} \text{ times } 100 = \frac{7.9}{100} \times 100 = 7.9 \text{ percent}$$

The coefficient of variation facilitates comparison of variability about different size means. A standard deviation of 2 for a mean of 10 indicated the same relative variability as a standard deviation of 16 for a mean of 80. C would be 20 percent in each case.

6. Standard error of the mean is a measure of variation among sample means. If one could visualize the drawing of several different samples of size n from a population and computing the mean for each sample, the sample means would vary but would all estimate the true mean of the population.

$$s_{\bar{x}} = \sqrt{\frac{s^2}{n}} \times (- \frac{n}{N}) = \sqrt{\frac{62.5}{5}} \times (1 - \frac{5}{100})$$

$$= \sqrt{12.5 \times (1 - .05)} = \sqrt{11.875} = 3.4$$

If the sampling fraction, $\frac{n}{N}$, is small, i.e. below 1:20

$$s_{\bar{x}} = \sqrt{\frac{s^2}{n}} = \sqrt{\frac{62.5}{5}} = 3.5$$

7. Variance of the sample mean is simply the square of the standard error of the mean

$$s_x{}^2 - 3.4^2 = 11.56$$

8. Determine number of sample plots needed. (Freese 1967)
   (a) For an infinite number of plots or when N is large. The sample size can be computed by

$$n = \frac{t^2 (s^2)}{E^2}$$

"t" value is obtained from a "t" or probability table

Probability

n	0.1	0.05	0.01
5	2.132	2.776	4.604
10	1.833	2.262	3.250
20	1.729	2.093	2.861
40	1.684	2.021	2.704
60	1.671	2.000	2.660

If we want to say that the true mean falls within certain limits unless a one-in-twenty chance has occurred, use the t-value in the column headed 0.05. If we want to say that the true value lies within a set of limits unless a one-in-100 chance has occurred, select t from the column headed 0.01.

"t" = probability − from table
s^2 = variance
E = a specified value (say 2 seedlings per square foot or 8 seedlings per plot (1′ × 4′))

For a 95% confidence level with a value of E as ±8 seedlings per plot:

$$n = \frac{(2.775^2)(62.5)}{8^2} = \frac{481}{64} = 7.5 \text{ plots}$$

For a 99% confidence level:

$$n = \frac{(4.604^2)(62.5)}{8^2} = \frac{21.2 \times 62.5}{64} = \frac{1325}{64} = 20.7 \text{ plots}$$

(b) When variance is a none too reliable guess, the number of samples needed to estimate the mean to within ± E units can be computed as follows:

For the 95% confidence level:

$$n = \frac{4(2 \times s^2)}{E^2} = \frac{4 \times 2 \times 62.5}{64} = 7.8 \text{ plots}$$

For the 99% confidence level:

$$n = \frac{20(2 \times s^2)}{3E^2} = \frac{20 \times 2 \times 62.5}{3 \times 64} = \frac{2500}{192} = 13 \text{ plots}$$

Other formulas may be used to compute values for n.

9. Confidence limits: For the example being used.
   - $n = 5$
   - $\bar{x} = 100$
   - $s_{\bar{x}} = 3.4$
   - (a) 95 percent
     - (1) For the sample plots
       $= \bar{x} \pm (t)(s_x) = 100 \pm 2.776 \times 3.4$
       $= 100 \pm 9.4 = 90.6$ to 109.4
     - (2) For the total population
       $= 10.000 \pm 2.776 \times 340 = 10.000 \pm 944$
       $= 9056$ to 10994
   - (b) 99 percent
     - (1) For the sample plots
       $\bar{x} \pm 4.606 \times 3.4 = 100 \pm 15.6$
       $= 84.4$ to 115.6
     - (2) For the total population
       $10,000 \pm 4.606 \times 340 = 10,000 \pm 1565$
       $= 8435$ to 11565

APPENDIX 16-4

OFFICE CALCULATION OF A SEED LOT INVENTORY (Adapted from Barton and Clements 1961)

Data based on a sampling unit of one seed lot on 6000 square feet of seedbeds or three beds 500 feet long. The initial sampling consists of twenty 1 × 4 foot plots.

A. Check the adequacy of sampling for total seedling count.

1. The number of seedlings in each sample (observation) is recorded in column 2 of the Nursery Inventory Record form.
2. Square the number of seedlings for each sample in column 2 and enter in column 3.
3. Total columns 2 and 3.
4. Calculate the number of additional sample plots (n_x) required for a 10% confidence limit (with a probablity of .95). The formula by Barton and Clements (1961) is:

$$n_x = 421\left(\frac{20 \times (\Sigma X^2)}{(\Sigma X)^2} - 1\right) - 20$$

This formula is applicable only when 20 samples are obtained initially. 421 is a constant representing an estimated value of $t_{.05}$.

$$n_x = 421\left(\frac{20 \times 121460)}{2304324} - 1\right) - 20$$

$$= 421\ (1.054 - 1) - 20$$

$$= 22.734 - 20 = 3 \text{ additional plots needed.}$$

(See appendix 16-3 for other formulas for determining the number of observations needed for different levels of probability).

B. Additional sampling

1. Take three additional samples placed more or less uniformly between the samples already taken.
2. The number of seedlings in each of the additional plots are recorded in column 2 of the inventory record.

C. Calculate the seed lot or sampling unit inventory.

1. Calculate the mean number of seedlings per square foot by dividing the grand total of column 2 by the total number of square feet in the sampled area.

Mean number of seedlings per square foot $= \frac{1736}{4 \times 23} = 19$

2. Calculate the total number of estimated seedlings in the seed lot or the sampling unit.
Total number of seedlings = 19 × 6000 = 114,000

D. Check the adequacy of sampling for plantability percent.

Seedling quality or plantability is estimated when seedling counts are made. To obtain the percentage of plantable seedlings in a sample, 10 equally spaced and clearly visible marks are made inside one side of the inventory counting frame. The tree nearest each of the marks is measured and graded. The number of seedlings which meet plantable standards is recorded in column 4 of the inventory record.

$$n_s = 40\left(\frac{200 - S}{S}\right) - 20$$

Where S is the sum of column 4

$$n_s = 40\left(\frac{200 - 129}{129}\right) - 20 = 40\ (.551) - 20$$

$$= 22.04 - 20 = 2 \text{ additional plots required.}$$

The formula for plantability percent is applicable only when 20 samples and 10 seedlings per plot are used; and with an estimated value of $t_{.05}$.

E. Determine the percent of plantable seedlings

1. Determine number of plantable seedlings on two additional plots and enter values in column 4.
2. Percent of plantable seedlings

$$\frac{\text{Grand total col. 4}}{10 \times \text{number of grading samples}} =$$

$$\frac{142}{10 \times 22} \times 100 = 65 \text{ percent.}$$

F. Calculate the estimated number of plantable seedlings.

1. Plantable seedlings per square foot = total number per square foot × plantable % = 19 × .65 – 12.
2. Estimated number of plantable seedlings in the seed lot = Number of plantable seedlings per square foot × number of square feet in the seed lot – 12 × 6000 = 72,000

Forest Tree Nursery Inventory Record (Barton and Clements 1961)

Nursery ______________________ Address ______________________

Species ______________________ Seed lot ______________________

Block ______________________ Row ______________________

Col. 1 Sample number II	Col. 2 Tree count (X_1)	Col. 3 Tree count squared (X^2)	Col. 4 Trees in shippable grades (S)
1	36	1,296	6
2	50	2,500	7
3	98	9,604	7
4	96	9,216	6
5	88	7,744	9
6	78	6,084	8
7	82	6,724	6
8	68	4,624	4
9	60	3,600	8
10	58	3,364	8
11	70	4,900	7
12	76	5,776	3
13	84	7,056	10
14	90	8,100	9
15	102	10,404	4
16	96	9,216	5
17	92	8,464	1
18	76	5,776	8
19	64	4,096	7
20	54	2,916	6
Subtotal (Σ)	1,518	121,460	129
$(\Sigma X)^2$	2,304,324		
21	62		7
22	84		6
23	72		
24			
25			
Subtotal (Σ)	218		142
Totals	1,736		