A SYSTEMATIC SAMPLING NURSERY INVENTORY PROCEDURE

William Warren Barton and
Charles M. Clements, Foresters
Division of State & Private Forestry, U. S. Forest Service
Upper Darby, Pa.

Need

Many nurserymen at one time or another have experienced embarrassment in some measure from an inventory that either did not come close to the actual number of trees or substantially overran the estimate. To be faced with either one of these conditions during a busy shipping period is demoralizing and unnecessary. When a reliable inventory of shipping stock is at hand, it gives the nursery time to:

1. Locate a supply of the species and age class for which demand exceeds the supply.
2. Initiate a promotional program to merchandise or otherwise handle any over supply.

There is considerable advantage to be gained by taking a careful inventory of 1-0 and 2-0 stock even though the seedlings will not be shipped until they are 3-0. An inventory rather than an ocular estimate taken of seedbeds not ready for shipment is of real value to the nurseryman in the determination of future seeding as well as seedbed management practices.

Background

In 1954 William Warren Barton and Gordon G. Mark developed a statistical procedure for taking seedbed inventories. The inventory is based upon sample plots taken at intervals across the seedbeds. This method has been used for 6 years in the northeastern States and found to be reliable.

The Amplified System

This method, like that in use for the past 6 years, is based upon sample plots taken at intervals across the width of the seedbeds. In addition, so that the number of shippable plants may be known, a sample within the sample is taken to determine the number of plants that meet shipping standards.

Procedure

The number of sample plot counts will depend principally upon the variation within the sample area. Separate sample counts must be made of each group of seedlings for which it is important to have a separate inventory such as each species, age class, and geographic source of seed. Separate sample counts should be made within those groups because of time of seeding, quality of the seed, seed sources, maturity of the seedbeds, type of irrigation, differences in soil management or other controlled or uncontrolled factors which have caused certain beds or groups of beds to be significantly different from the others from the standpoint of seedling density, size, uniformity, or condition.

The sample plots are 6 inches wide and as long as the width of the bed, which is usually 4 feet. This will take care of bed width variations and include border trees in the samples. The use of a counting frame similar to that shown in figure 1 is suggested for this purpose. (Also see Tree Planters' Notes No. 38.)

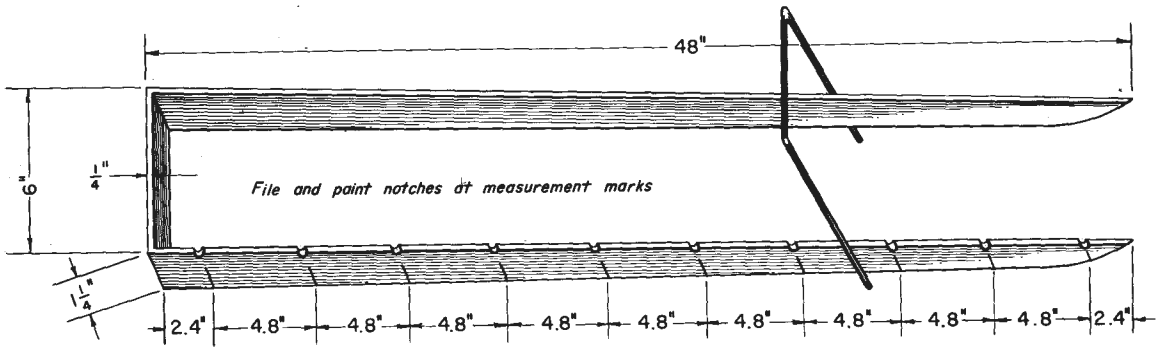

Figure 1.--Nursery inventory counting frame.

When the inventory also includes determination of the number of plantable trees, it will be necessary to take counts of trees that meet plantable standards. This requires that there be established minimum and maximum sizes and other quality standards for plantable trees. To obtain the percentage of shippable trees in the sample, 10 equally spaced and clearly visible marks are placed inside one side of the counting frame, and the tree nearest each of the marks is measured and graded. The number which meets plantable standards is recorded.

Adequacy of the samples for total tree count and plantable percent are separately tested against chosen statistical standards. The initial 20 samples are augmented as necessary. There is no recognized statistical method for testing the degree of accuracy of the systematic sampling discussed in this article. However, the method used to determine the accuracy of results from random sampling to a limit of error of ± 10 percent 95 percent of the time can be applied to the results obtained from this systematic method to indicate the need to take additional samples to obtain the degree of accuracy found adequate for the northeastern States. Since 1954 this method has proven to be sufficiently reliable in the northeastern States for total seedbed count estimates. Therefore, this degree of testing is used as the basis of the system presented here.

Example

In the following example a lot of beds containing 6,000 square feet of seedbed area is used. This is equivalent to 3 rows each 500 feet long.

Using a counting frame, take 20 sample plots 6 inches wide across the bed. Start with plot one 37 feet from the end of the first bed, plot two at 75 feet from plot one and continue at 75-foot intervals until 20 sample plots have been counted.

For each sample, record in column 2 of Form A the total number of plants counted within the frame. Then, if seedling quality is to be estimated, select the tree nearest each of the 10 marks on the side of the counting frame and grade it. Record the number of these trees that meet plantable standards in column 4 of Form A.

Checking the Adequacy of Sample for Total Count

a. Square the number of trees in column 2 (Form A) and enter in column 3.

b. Total columns 2 and 3.

c. Calculate the number of additional sample plots (Nx) required (see No. (1) Form A).

[1] $$Nx = 421 \left(\frac{20 (\Sigma X^2)}{(\Sigma X)^2} - 1 \right) - 20$$

$$= 421 \left(\frac{20 \text{ (Total of column 3)}}{\text{square of total column 2}} - 1 \right) - 20$$

These additional samples, if any, are placed more or less uniformly between the samples already taken. The total of all samples divided by the total number of samples ($20 + N_x$) is the accepted average sample count.

Checking the Adequacy of Sampling for Plantability Percent

a. Total column 4 on Form A.

b. Calculate the number of additional samples (Ns needed) (see No. (2) on Form A).

[2] $$Ns = 40 \left(\frac{200 - (\Sigma S)}{\Sigma S} \right) - 20$$

$$Ns = 40 \left(\frac{200 - \text{(Total of column 4)}}{\text{total column 4}} \right) - 20$$

These additional samples are taken in connection with additional samples for total count estimate. If more samples are required for grading plantability than for total count, the additional samples for grading may be taken anywhere with consideration given to getting a representative picture of the entire bed situation.

---

[1] Beginning with the standard formula for determining the number of sample observations for a 10% confidence limit (with probability of .95)

$$\frac{t^2_{.05} S^2_{\bar{X}}}{\bar{X}^2} = \frac{t^2_{.05}}{\bar{X}^2} \left(\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n(n-1)} \right) = (.10)^2$$

and substituting 20 for n and an estimated value of $t_{.05}$, algebraic simplification leads to the easily applied formula:

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

for the additional tsu count samples required.

[2] Similarly, if it is assumed that in sampling for shippability the variance of the percentage shippable based on a count of 10 seedlings is:

$$\sigma^2_p = \frac{p(1-p)}{10}$$

and the variance of the mean of 20 counts is

$$\sigma^2_{\bar{p}} = \frac{p(1-p)}{20(10)}$$

we may substitute $\frac{\Sigma S}{200}$ for $\bar{p}$. Substitution in the formula for

$t_{.05} \sigma_{\bar{p}} = (.10) \bar{p}$ and simplifying yields the easily applied formula $N_S = 40 \left(\frac{200 - \Sigma S}{\Sigma S} \right) - 20$ to estimate the additional counts needed.

Calculate the Seedbed Inventory

After the additional counts have been made, calculate the estimate of seedlings per square foot and the estimate of total seedlings in the bed.

a. Calculate the number of seedlings per square foot by dividing the grand total of column 2 by the total number of samples counted (see No. (3) on Form B).

$$\text{Seedlings per square foot} = \frac{\text{grand total of column 2}}{2 \times (\text{total number of samples})}$$

(If other than a 6-inch by 4-foot counting frame was used, a correction factor must be used here.)

b. Calculate the total number of seedlings in the bed by multiplying the result from step a. by the seedbed area in square feet (see No. (4) on Form B).

Total bed estimate = (Seedlings per square foot) x (seedbed area in square feet)

c. Calculate the percent of plantable trees by dividing the grand total of column 4 by 10 times the total number of 10-tree grading counts made (see No. (5) on Form B).

$$\%\ \text{plantable} = \frac{\text{grand total of column 4}}{10 \times \text{number of grading counts}}$$

d. Apply this percentage to both the seedlings per square foot and total bed estimate to get the plantable stock estimate per square foot and total in bed (see Nos. (6) and (7) on Form B).

Plantable stock per square foot = (seedlings per square foot) x (% plantable)

Plantable stock in beds = (total seedling estimate) x (% plantable)

e. To determine the total number of trees available for sale of distribution, subtract the anticipated loss resulting from digging injury from the total obtained in d. This may be a percentage or a number of trees. It may run about 5 percent, depending on the stock (see No. (8) on Form B).

Salable stock = Plantable stock x (1 - loss %) or Salable

stock = Plantable stock - (estimated tree loss).

FOREST TREE NURSERY INVENTORY RECORD FORM A Sheet No. 1 of 2

Nursery _____ Address _____

Species _____ Age Class _____ Block _____

Seed Lot _____ Rows _____

Col. 1 Sample Number	Col. 2 Tree Count	Col. 3 Tree Count Squared	Col. 4 Trees in Shippable Grade
(#)	(X)	(X^2)	(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
Totals	ΣX 1,518	ΣX^2 121,460	ΣS 129
	$(\Sigma X)^2$ 2,304,324		

(1) Additional tree count samples required

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

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

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

$$= 22.734 - 20$$

= 3 additional plots needed

(2) Additional 10-tree grading samples required

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

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

$$= 40\ (.551) - 20$$

$$= 22.040 - 20$$

= 2 additional plots required

Notes on last sheet of Form A:

Width of sample _____ in.

Area of bed _____ sq. ft.

Grand totals:

No. count samples _____

No. grade samples _____

Column 2 _____

Column 4 _____

Date _____

Estimator _____

FOREST TREE NURSERY INVENTORY RECORD FORM A Sheet No. 2 of 2

Nursery _____ Address _____

Species _____ Age Class _____ Block _____

Seed Lot _____ Rows _____

Col. 1 Sample Number	Col. 2 Tree Count	Col. 3 Tree Count Squared	Col. 4 Trees in Shippable Grade
(#)	(X)	(X^2)	(S)
21	62		7
22	84		6
23	72		
4			
5			
6			
7			
8			
9			
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
0			
Totals	ΣX 218	ΣX^2	ΣS 13
	$(\Sigma X)^2$		

(1) Additional tree count samples required

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

$$= 421\left(\frac{20\ (\quad)}{(\quad)} - 1\right) - 20$$

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

$$= \qquad - 20$$

= ____ additional plots needed

(2) Additional 10-tree grading samples required

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

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

$$= 40\ (\quad) - 20$$

$$= \qquad - 20$$

= _____ additional plots needed

Notes on last sheet of Form A:

Width of sample 6 in.

Area of bed 6,000 sq.ft.

Grand totals:

No. count samples 23

No. grade samples 22

Column 2 1,736

Column 4 142

Date _____

Estimator _____

FOREST TREE NURSERY INVENTORY RECORD FORM B Sheet No._____

Nursery_____ Address _____

Species_____ Age Class _____ Block _____

Seed Lot _____ Rows _____

GROSS ESTIMATE

Estimated seedlings

(3) Per sq. ft. = $\frac{\text{Grand total Col. 2}}{\text{Two X No. Samples}}$

or $\frac{1736}{46} = 38$

(4) In bed = (Seedlings per sq. ft.) X (bed area)

or 38 X 6000 = 228,000

SHIPPABLE GRADE ESTIMATE

Shippable seedlings

(5) % shippable = $\frac{\text{Grand total Col. 4}}{\text{10 X (no. grading samples)}}$

or $\frac{142}{10 \text{ X } 22} = 65\%$

(6) Per sq. ft. = (Gross seedlings per sq. ft.) X (Plantable %)

or 38 X .65 = 25

(7) In bed = (Shippable seedlings per sq. ft.) X (bed area)

or 25 X 6000 = 150 M

NET SALABLE ESTIMATE

Available for sale and distribution

(8) Lifting loss 5 %, or _____ trees

Shippable trees in bed	150 M
- loss (.05)	7 M
Salable trees	143 M

References

Nursery Inventory Counting Frame. Tree Planters' Notes #38

Forest Tree Nursery Seedbed Inventory. Region 7 - U.S. Forest Service 1954

Region 7 Committee Report on Grading Standards for Forest Planting Stock - August 1, 1960