CHAPTER 9—SEEDLING QUALITY, GRADING, CULLING AND COUNTING

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SEEDLING QUALITY

Quality in the context of this handbook means the seedling's fitness for planting in the forest. Two of the major attributes of seedling quality are:

1. sturdiness, i.e., the ratio of height to the diameter of the root collar, and
2. shoot-root ratio (with consideration for root structure).

Given equal treatments, good quality seedlings have a better chance to become established and to make good early growth than do seedlings of poor quality.

Nearly all survival studies during the past 50 years show that balanced, medium-sized seedlings (7 to 13 inch stem height) with sturdy stems and well-developed, fibrous root systems have a higher survival rate and make better initial growth than do either larger or smaller seedlings (Scarbrough and Allen 1954, Wakeley 1954, Silker 1960, Shoulders 1960, Swearingen 1963, Meekins 1964, Hermann 1964, Hunt and Gilmore 1967, Carmean 1971, O'Gwynn 1972, Williston 1974, Blair and Cech 1974). Several studies of field planting and survival identify optimum or ideal morphological characteristics shown in table 9-1.

Table 9-1. — Optimum characteristics of southern pine seedlings.

	Species		
Characteristics	Longleaf	Loblolly and slash	Shortleaf
Stem length - inches	--	10	8
Root collar diameter - inches	9/16	7/32	3/16
Root length - inches	6+	6+	6+
Laterals - number	15+ first order laterals	30+ first order laterals	30+ first order laterals
Winter buds	present	present	present
Nature of stem	--	stiff, woody, with bark	stiff, woody with bark
Mycorrhizae	Present	Abundant	Abundant
Shoot/root ratio - Vol.	1:1	2 1/2:1	2 1/2:1

Shoot-root Ratio

The most useful criterion of the quality of seedlings is the relationship between shoot and root sizes. Size is most conveniently expressed as the ratio of the weight of the top to that of the root after the root has been pruned for field planting. The best quality stock is that which has a relatively small top and a large, fibrous root system. The balance between top and roots is of the utmost importance to survival of seedlings because a top-heavy seedling has a transpiring surface out of proportion to the absorbing capacity of the roots.

In the calculation of shoot-root ratios oven-dry weights and cubic volumes have special limits that are mainly associated with root system morphology. Oven-dry weights often are used even though dry-weight analysis requires a drying oven, a balance, and an elapsed time of nearly 2 days for accurate determination.

Field foresters seldom determine optimum shoot-root ratios for planting stock. The optimum range of these ratios for loblolly, slash and shortleaf pine seedlings, based on plantability, survival and cost of production is from 2:1 to 3:1 (table 9-1.). The basic requirements for planting stock have been planting ease and good survival. The quality of the planting operation depends to a high degree on the morphology and mass of the root systems and the sturdiness of the stem. Uniformity of root length and mass is essential to the proper placement of the seedling root in the planting slit or hole. Control of the shoot-root ratio, the mass of the root system and the sturdiness of the stem is a function of the nursery operation, and essential for a successful seedling planting program. Cultural techniques designed to improve seedling quality are discussed in chapter 7.

Seedling Quality Indices

Single parameters such as stem length, stem diameter, root length, dry weight, bud formation, etc., have a limited value in predicting seedling survival and growth after field planting. The concept of bringing together a series of measurements into one value that could be used as an index of seedling quality has been proposed by several researchers. Dickson et al (1960a) suggested the following:

$$\text{Quality index: } \frac{\text{Seedling dry weight (g)}}{\dfrac{\text{Height (cm)}}{\text{diameter (mm)}} + \dfrac{\text{Shoot weight (g)}}{\text{root weight (g)}}}$$

Another seedling index has been suggested as a measure of quality by Armson and Sadreika (1979).

$$\text{Seedling Index (S.I.)} = \frac{\text{Height (cm)}}{\text{Root area index (cm}^2)} \times \text{diameter}^2(\text{mm}^2)$$

Wilde et al (1972) suggest that the ratio of the titration value of roots to the transpirational loss by crowns, or adsorption-transpiration quotient, is a measure of nursery stock succulence and the relative ability of the seedling to cope with unfavorable environmental influences of the planting site.

Edgren and Iyer (1979) suggest that volumetric root-top ratios are closely related with drought-resistance index values.

Seedling Morphology

Production of seedlings of a uniform size and quality is impossible without control of seedling growth and development. Any mass-produced product should meet specific standards that can be classified by grades. The concept of seedling grades is based upon the seedling's capacities to survive and grow after being outplanted.

Nursery seedling grades developed so far reflect efforts to judge seedling capacities by visible characteristics. Because these characteristics depend on morphology or external form, they are called morphological grades (Wakeley 1954). Without control of the growth and development of seedlings, nursery production would consist of a very heterogenous mixture of stem sizes and shoot-root ratios, and a high percentage of nonplantable seedlings. As seedbed densities increase above 30 seedlings per square foot, seedlings become more spindly, and have higher shoot-root ratios. With no top pruning, seedling stems may range from 2 to 24 inches in length and from 1/16 to 5/16 inches in root collar diameter. Without root pruning the tap roots may grow 10 to 20 inches long with very few laterals. Their shoot-root ratios may be from 2:1 to 6:1.

Wakeley's morphological grades have been widely accepted as a standard in the South. However, research on planting and field survival since the 1950's indicates that some revision is desirable. Table 9-2 describes grades that are more consistent with current nursery practices and seedling performance after outplanting.

Some nurseries do not count or grade individual seedlings but package the seedlings on the lifting machine in the field (field packing). This type of operation requires a uniform seedbed density, uniform size of seedlings and less than 10 percent culls (chapter 8).

GRADING AND CULLING

Some seedlings in each nursery are often not suitable for field planting because they are too small, damaged or diseased. These seedlings should be removed and discarded. Traditionally, grading and culling have been an integral part of the lifting and packaging operations in southern nurseries. However, reduced seedbed densities, improved insect and disease control, adjustments of fertilization to meet nutrient needs of seedlings during the growing season, root pruning and top clipping, have led to a modification of the old grading and culling practices.

Intensity of grading is an administrative decision. Usually, seedlings are either plantable or nonplantable. However, some industry nurseries plant on a prescription basis whereby different grades of seedlings may be needed for machine planting, for hand planting, for deep droughty sites, or for wet sites. Unfortunately, the intensity of culling is often determined by the degree to which supply meets demand.

Grading and Culling Rules

A general rule is to eliminate grading and culling if the percentage of small, damaged or diseased trees is less than 10 percent in any seed lot.

Culling of undersized trees is done by ocular determination of minimum specifications. Stem diameter or caliper is the chief judgement criterion as it reflects sturdiness and seedling size. Minimum standards for plantable loblolly seedlings are listed in table 9-3.

The minimum tap root length should be 5 inches although some seedlings with 4-inch taproots and adequate laterals are desirable for some difficult planting sites. The number of laterals longer than 1 inch is greatest with stem diameters of 3/16 to 1/4 inch, decreases slowly as stem diameters decrease to 1/8 inch, and decreases rapidly as stem diameters become less than 1/8 inch.

Table 9-2. — Morphological grades of southern pine seedlings.[1]

Grade	Stem or needle length inches	Thickness of stem at ground line inches	Nature of stem	Bark on stem	Needles	Winter buds	Number of first older laterals	Shoot root ratio
			Longleaf					
1	6 - 8 Clipped	11/16	--	--	Abundant Almost all in fasicles	Yes	20 +	1:1
2	6 - 8 Clipped	1/2	--	--	"	Yes	15 +	1 1/2:1
3 - cull		<1/2	--	--	Moderately abundant; some single	No	<10	
			Loblolly and Slash					
1	9 - 12	3/16 - 5/16	Stiff; Woody	Usually on entire stem	Almost all in fasicles	Usually	30 +	2 1/2:1
2	6 - 10	1/8 - 3/16	"	All over lower part of stem	Partly in fasicles	Occasionally	20 +	2 1/2:1 to 3:1
3	3 - 12	<1/8	Weak; often succulent	Often lacking	Some in fasicles	Rarely	<15	>3:1
			Shortleaf[2/]					
1	6 - 10	3/16 - 1/4	Stiff; Woody; usually a crook at ground line	Usually on entire stem	Almost all in fasicles	Usually	25 +	2 1/4:1
2	4 - 8	1/8 - 3/16	"	All over; or on lower part of stem	Partly in fasicles	Occasionally	15 +	2 1/2:1 to 3:1
3	3 - 10	<1/8	Weak, often succulent	Often lacking	Mostly singles	Rarely	<10	>3:1

[1]Adapted from Wakeley (1954)

2/ Sand pine, Virginia pine and white pine are similar to shortleaf pine.

Table 9-3. — Minimum standards for plantable seedlings (loblolly).

Characteristic	Optimum	Minimum	Maximum
Height (root collar-terminal bud)	8"	5"	12"
Diameter (root collar)	7/32	1/8(4/32)	3/8(12/32)
Root length	6	5	8
Shoot-root ratio (volume)	2 1/2:1	3:1	1 1/2:1

The stem length is of less importance than adequate stem diameter and root system. Stem lengths of 9 to 12 inches are optimum for machine planting. Seedlings with longer stems tend to have an unbalanced shoot-root ratio. Increases in root systems to balance the stem make the plant difficult to package and plant. Sturdy seedlings with stem lengths of 5 to 9 inches can be easily hand planted. Large seedlings often have an advantage where there is competition from weeds and where planting is done by machines. Small seedlings may survive and grow well on moist sites with little or no weed competition.

Seedlings with tap roots cut or broken less than 5 inches below the root collar should be culled unless there are enough laterals to successfully plant the seedling in shallow soils or wet sites. Seedlings with broken stems, stripped foliage, loose bark, split main roots and stripped laterals should be culled. Mechanical damage from belt lifters is often hard to detect, particularly bruised cambium. This type of damage must be carefully evaluated. In general, when any damage is visible the seedlings should be culled.

No general rule is available for culling seedlings with root rot. State plant boards can refuse to permit shipment of seedlings with moderate to severe root rot. Culling of seedlings with visible root rot should be standard practice for nurseries with seedlings that have lost most of the laterals by the black or charcoal root rot, as a precaution against spreading the infection after outplanting. However, a few decayed roots probably are inevitable in any lot of seedlings.

Cull all seedlings infected by fusiform rust as they will seldom produce merchantable wood. However, if the infection is less than 2 or 3 percent and all other seedlings are plantable, grading may be omitted by administrative decision. When fusiform rust infection rates exceed 10 percent, all seedlings from that seed lot or nursery bed area should be graded. Rust infections usually occur after a breakdown in the spraying program. (See chapter 13.) The problem is most serious when infection occurs repeatedly.

Longleaf pine seedlings with excessive brown spot infection, i.e., when a third or more of the needle tissue is involved, should be culled. Seedlings infected with live scale insects should also be culled as their survival percentage will be low.

Photographs, diagrams, or fresh, plainly labeled specimens of plantable seedlings and of seedlings culled because of size, root rot, fusiform rust infection and various types of mechanical or other injury should be mounted on a bulletin board close to the grading tables to guide the graders (Stoeckeler and Jones 1957; Wakeley 1954).

Field Grading

Field grading consists of undercutting the seedbed and removing small seedlings from the seedbed by hand. This work is usually done several months before lifting. When done early, field grading resembles a low thinning because it leaves a little more growing space for the remaining seedlings.

Field grading enables workers to do a more efficient job of field packing. If inventory procedures are accurate, seedlings can be lifted and packed based on bed inventory figures (see chapter 8).

Some nursery workers select seedlings by rows or sections of seedbeds in the nursery with specific morphological characteristics for specific planting sites. This is a seedling-site matching process rather than a grading procedure.

Shed Grading

Most grading, culling and counting is done in packing sheds. The operations must be performed rapidly to keep the roots from drying excessively. The air temperature should be low and the relative humidity high to avoid seedling dessication. The temperature and humidity should be as uniform as possible, to increase the working efficiency of the graders.

Grading tables have been designed to speed up the process of handling seedlings. An endless belt conveyor driven by an electric motor carries seedlings along the table (figure 9-1).

The grading table unit may consist of one or two belts and have a root-pruning device attached at the discharge end of the table. A fine mist sprayer is often placed above the belt to prevent drying of seedling roots (May 1938, Toumey and Korstian 1949, Clifford 1964). Several types of measurement aids have been developed for graders. These consist of various types of calipers to measure stem diameters and a scale for determining stem and root lengths (Mullin 1959, Hertel 1961, Lanquist 1965).

Seedlings may be placed on the grading belt at one end or scattered along the belt as it moves. Graders on either side of the belt remove small, diseased or damaged seedlings as the seedlings pass on the belt. A more common practice is to remove and grade seedlings from seedling holders or containers next to the table. Cull seedlings are dropped to the floor or placed in tubs. Plantable seedlings are placed on the belt and conveyed to the packing area. A three-belt grading system developed by the Forest Service has been used in the West (Cluster 1980) (see figure 9-2). Other grading systems are diagrammed in Appendix 9-1.

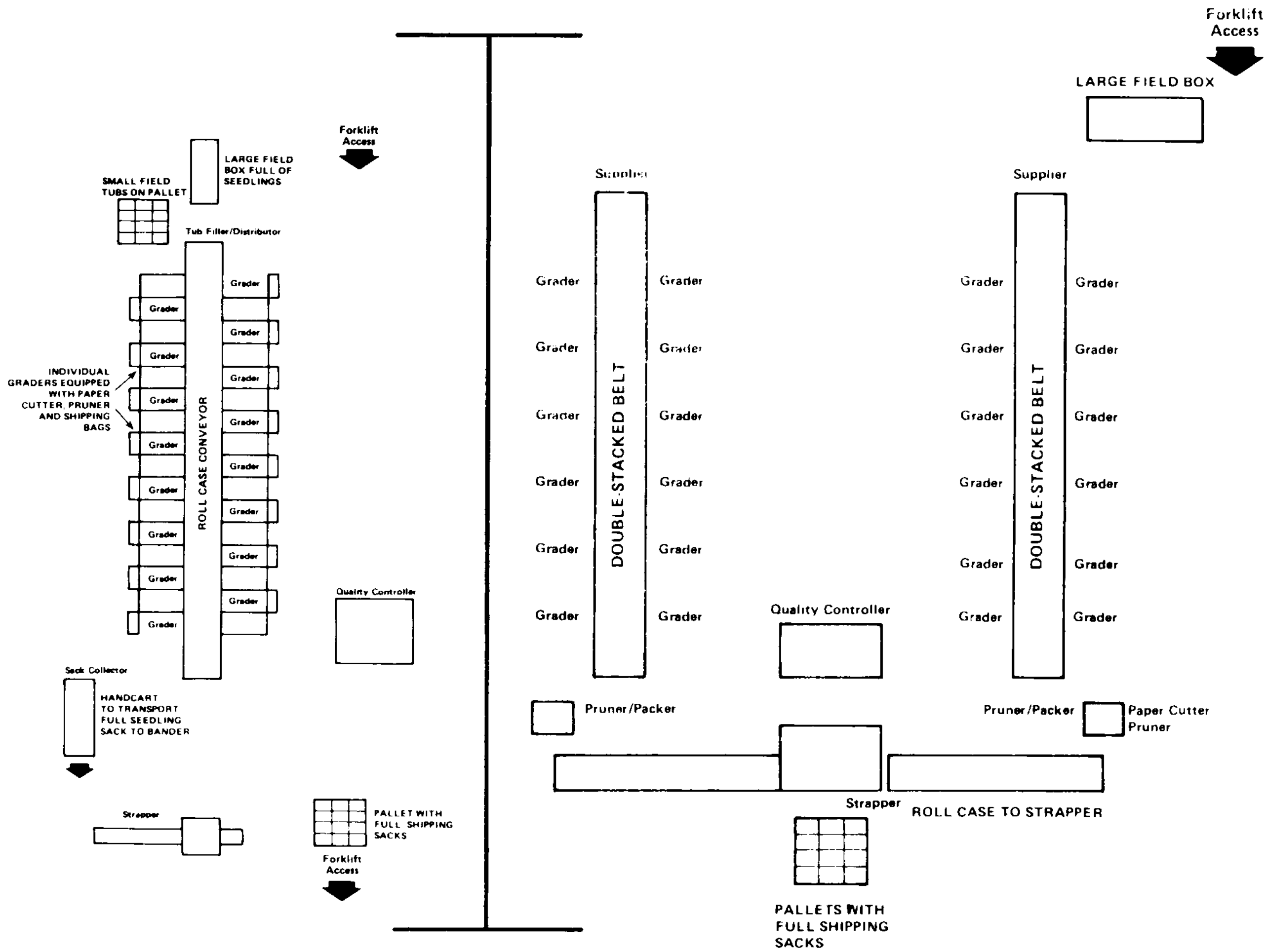

Figure 9-1. — Individual work station grading systems.

COUNTING SEEDLINGS

When seedlings must be counted, grading and counting are combined into one operation. Plantable seedlings are counted and separated into bundles of 10 to 50 seedlings. Painted lines can divide the belt into sections. A specific number of seedlings can be placed in each section. A seedling handler at the end of the table gathers seedlings from the belts and combines them into larger bundles of 100 to 500, which in turn are conveyed to the packing section.

Care is needed during the grading and counting process to:

1. Prevent drying of roots.
2. Prevent heating of seedlings while in temporary storage or in transit.
3. Retain the maximum number of short, fibrous roots and mycorrhizae.
4. Avoid stripping the bark from roots.
5. Avoid breaking of roots and tops, and any other mechanical damage.

The older practice of counting and tying seedlings into bundles of 25, 50 or 100 has been discontinued except for special small orders in some of the State nurseries. Small bundles of seedlings can be kept separate by binding with twine, tape or rubber bands.

Weighing Vs Counting

During the first 2 years of operation of the W.W. Ashe nursery (1936-7), all seedlings were counted as they were graded. Check counts of seedlings in bales showed an average of ± 5 percent error in count for nearly all bales. Many of the graders apparently did not count accurately enough to justify the expense of counting all seedlings.

In 1976, a report (King 1976) indicated that only two southern nurseries were still counting seedlings. In other nurseries, counting was not considered necessary. Estimates of seedling numbers are commonly obtained by determining the approximate weight of a specific number of seedlings and then using this weight to pack approximately 1,000 seedlings. Volume can be used in lieu of weight by determining the approximate volume of the number of seedlings desired per package. The volume method is usually less accurate than the weight method, however.

The technique of weighing seedlings varies among nurseries, but is usually similar to the following pattern described by Wynens (1964):

> The plant layout within the packing shed consists of a receiving area, a weight-control station operated by one person, two weighing stations and six packing stations operated by two men each, with one person furnishing packing supplies. The three sets of scales are laundry-type with platform pan and dial graduated from 0 to 100 pounds in 1/4 pound increments. The weight control scales have 11 containers (cans), 10 on the platform and one off. Seedlings from the field are brought into the packing shed in tubs. The operator randomly samples each load of trees by taking samples from each tub until a 500 count sample is taken, i.e., all 10 containers are filled with 50 trees each. The weight is reported to weighers who in turn weigh by this factor. The weight controller takes another sample to 50, filling the empty can and removing the oldest can on the scale. This is replaced by the new sample. Any variation in weight is reported to the weighers. This removal of the oldest can and refilling with a new sample is continuous through the operation. Counting of the 50 seedling samples is done over a sheet of paper so that soil from roots can be caught and added back to the sample to be weighed. This continuous sampling gives a moving average and reflects any variation due to environment.

Another variation of the weighing process is the use of a balance scale with a low-high beam-to-platform ratio. A counted sample is placed on the beam and trees are placed on the platform until a balance is obtained. The number by weight is instantly given this way by multiplying the number in the sample by the ratio of beam to platform. The beam sample is constantly being replaced to prevent seedling roots from drying out. Other modifications of the weight-count method have been made to adjust for handling of seedling from the grading table, or to fit any nursery's needs.

The most important prerequisites to accurate weight-counting are uniform bed density and seedling size. Counting samples of seedlings packaged by weight in two nurseries indicated a variation of ±5 percent. This is comparable to the accuracy for actual seedling counts.

Advantages of the weight-counting method are:

- Increased daily output
- Lower cost
- Fewer line workers
- Higher morale among workers
- Root exposure is minimized
- Less handling of seedlings and less chance of injury to seedlings
- About as accurate as counting

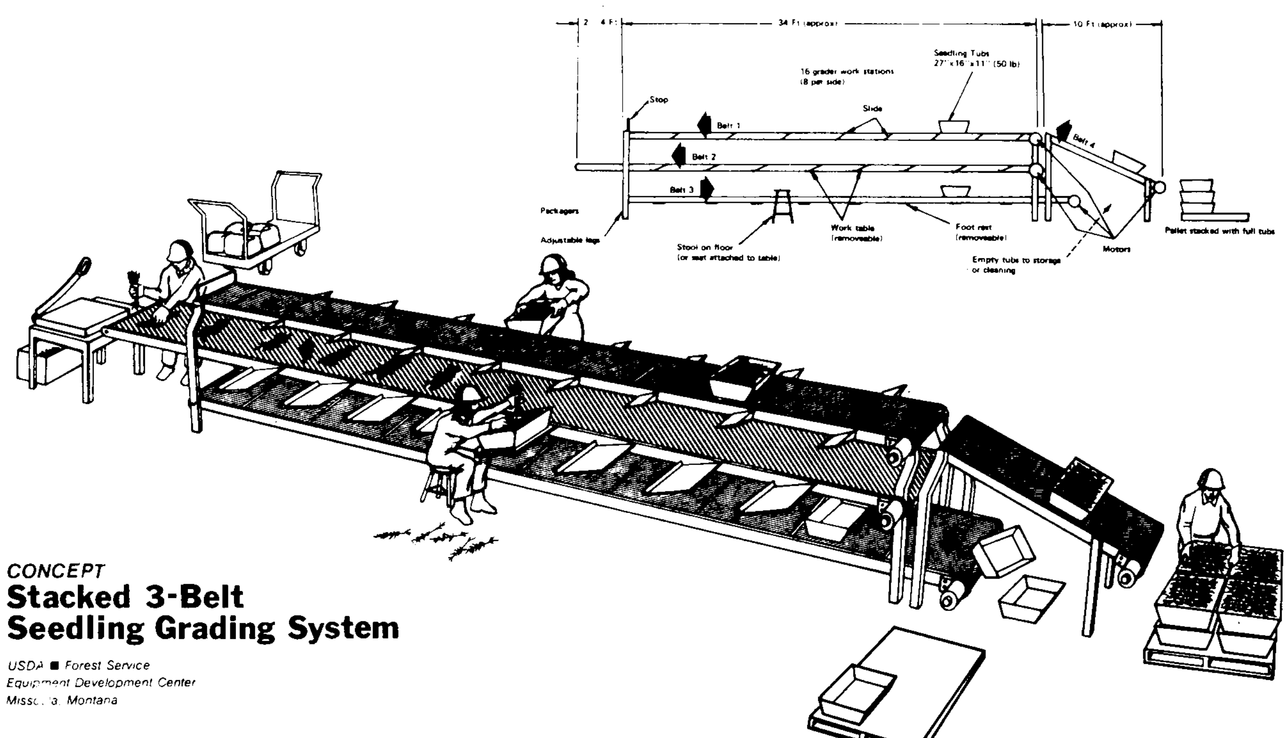

Figure 9-2. — Stacked 3-belt seedling grading system.

Major disadvantages of weighing seedlings include a high variation among packages when seedlings are not uniform in size and weight, and a tendency to avoid the careful examination of individual seedlings.

Package Volume vs Counting

Most nurseries pack seedlings in standard size bales or bags. The numbers of seedlings per bale or bag can be estimated by counting the number of seedlings in every tenth package or other sampling system. These values are about as accurate as counts by weights as long as seedlings are from beds of uniform seedling density and size.

Root Pruning

The practice of pruning or trimming roots is sometimes included in the grading-packing procedure. Seedlings that have extra long, coarse roots are hard to pack, and hard to plant. Roots can be trimmed by pruning blades on the grading table, circular or band saws, or with a hatchet and chopping block. Although this procedure is not as efficient as mechanical root pruning in the seedbed, it is preferable to mutilation by planting crews.

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APPENDIX 9-1.

GRADING SYSTEMS (Cluster 1980)