characteristics [e.g., see Anderson (1976)]. However, while modifying regional prices by considering stand characteristics and conditions, these approaches still start with stumpage as the end product and do not consider local conversion costs directly.

In summary, the major advantage of using the residual value approach is that the number of assumptions regarding end products and tree merchantability limits are fewer, and that the quality of the data going into an analysis might be better since it is directly related to the products and conversion technologies and cost associated with a particular plant or firm. Thus, use of residual values has advantages because of their sensitivity to harvested tree diameter as well as their ability to incorporate effects of changes in processing and use. □

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Economic Aspects of Nursery Seed Efficiency[1]

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ABSTRACT. Advancements in forest nursery management practices are directly tied to the value of the seeds used. When seed value is low and seeds are plentiful (as with wild seeds), old nursery practices that produce 5 plantable seedlings for 10 pure live seeds sown may be economically acceptable. However, with genetically improved seeds having a present value of 2 to 10 cents per seed, better nursery practices must be employed to provide optimum seed utilization. At some nurseries that produce 25 million seedlings and with seed costs of 0.5 cents per pure live seed, increasing nursery seed efficiency by 10% could result in saving more than $20,000 annually. Also, if increasing nursery seed efficiency results in planting an additional 3,500 acres with improved seedlings, the increase in present value of future volume gains could easily amount to $90,000 per year. To achieve the goal of producing 8 to 9 seedlings for every 10 pure live seeds sown, forest nurseries must have adequate funding to maintain the best personnel and equipment.

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Forest tree improvement has evolved to the point where many forestry organizations are using first-generation improved seeds, and some are beginning to use seeds from second-generation orchards. A considerable amount of money has been invested in producing the improved seeds. It has been estimated that many organizations in the South invest a quarter of a million dollars or more each year in tree improvement activities (Talbert, Weir, and Arnold 1985). However, few organizations have invested additional money in their nurseries for conserving the seeds produced from the tree improvement effort. Some nurseries are using essentially the same equipment and practices that were employed to grow seedlings from inexpensive wild seeds. These practices often result in wasting 40% or more of the improved genetic resource. The following discussion of the cost and value of improved seeds outlines some economic benefits that can be gained from increasing nursery seed efficiency.

COST OF PRODUCING GENETICALLY IMPROVED SEEDS

The establishment and maintenance of seed orchards are usually the largest costs of a tree improvement program. About 89% of the costs of a seed orchard program are in site preparation, land costs, supervision, fertilization, vegetation control, insecticides, subsoiling, irrigation, harvesting, and seed extraction (Weir and Zobel 1977). The remaining 11% of the costs are expended in selection and progeny testing. These costs have been used to estimate the net investment cost of producing a pound of genetically improved loblolly pine (*Pinus taeda* L.) seeds (Talbert, Weir, and Arnold 1985). A seed orchard size of 60 acres and a 6% real discount rate are assumed. Many tree improvement activities are tax-deductible expenses and the figures reported were after-tax values. The cost of producing improved seeds was found to be highly dependent on seed yield, with the largest costs being associated with poor seed crops. The analysis indicated that seed costs ranged from $56.30 to $181.53 per pound. For seed yields between 40 and 135 pounds per acre, cost of production remained close to $60 per pound. It should be noted that seed orchard seeds of loblolly pine are usually

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larger than wild seeds and often range from 10,000 to 14,000 seeds per pound.[2]

MARKET VALUE

Some organizations produce more seeds than they need and sell the excess. Current market prices for loblolly pine orchard seeds range from $40 to $110 per pound. The price is often set arbitrarily and is usually based on the going rate as well as an attempt to recover some of the cost of production. A few organizations do base the market value on the potential genetic gain of the seeds. At present, the market value is apparently not much greater than the cost of production. Purchasing improved seeds for one-third to one cent per pure live seed is a real bargain even if volume production from plantations is increased by only 10 or 15%.

PRESENT VALUE

The present value of a pound of genetically improved seeds is based on the worth of the extra wood produced at the end of the rotation, discounted to present value. Present net value would take into account cost of production. The present value of improved seeds often greatly exceeds the market value. Some companies calculate the present value of some of their first generation improved loblolly seeds to be more than $1,000 a pound. Factors that influence present value of improved seeds include nursery seed efficiency, establishment density, rotation age, percentage increase in volume production resulting from genetic improvement, stumpage value at time of harvest, real interest rate, percentage of planting chances that successfully reach harvest age, and productivity of the planting sites.

Various management practices will influence nursery seed efficiency, thus enabling the nursery manager to greatly affect the present value of the seeds sown. The "nursery seed efficiency" value is determined by dividing the number of plantable seedlings produced by the number of pure live seeds sown (a pure live seed is a seed with the ability to germinate). This value is similar to "tree percent." However, tree percent has been calculated in different ways in the past and as usually defined does not account for cull seedlings (USDA 1974, Duryea and Landis 1984). By increasing nursery seed efficiency, the nurseryman can reduce seed cost per thousand seedlings and influence future volume gains by conserving a valuable resource. Nursery seed efficiency for southern nurseries can range from 40 to 90% (South and Larsen 1985).

Nursery Seed Efficiency Benefits Both Public and Industrial Organizations

There are distinct financial differences in the way forest nurseries are operated. Some organizations run their nurseries somewhat independently of the rest of the forestry enterprise and, therefore, usually operate with the short-term goal of reducing seedling costs. Other organizations view their nursery operation as an integrated part of their entire forestry enterprise. These nurseries usually operate with the goal of maximizing future profits. Both types of organizations benefit from increasing nursery seed efficiency.

Short-Term Benefits—Reduced Seed Costs

For many established nurseries in the South, seed cost can easily be the most expensive item in producing improved seedlings. For example, at 8,000 plantable seedlings per pound, seed cost could range from $7 to $23 per thousand seedlings (Table 1). Seed cost can easily account for more than 50% of the total seedling cost, and could be reduced by 27% if the number of plantable seedlings could be increased to 11,000 per pound. It is apparent that if seed costs are included in the cost of producing genetically improved seedlings, spending money on methods that will increase nursery seed efficiency will help keep seedling costs to a minimum.

If just seed costs are considered, management practices to increase nursery seed efficiency are economically justified. For example, if a nursery producing 30 million seedlings has a nursery seed efficiency of 60% and seed costs of $60 per 12,000 pure live seed, $22,700 annually could be saved by increasing the nursery seed efficiency to 66%. Put another way, up to $22,700 could be spent annually on management practices to increase nursery seed efficiency from 60 to 66%.

Unfortunately, some organizations (public organizations in particular) do not include seed costs in the cost of producing seedlings. As a result, the same nursery practices used with inexpensive wild seeds are used with valuable improved seeds. This leads to wasting a valuable resource, because improvements in certain nursery practices are difficult to justify economically when seeds

Table 1. Seed cost per thousand plantable loblolly pine seedlings per several seed orchard and nursery yield experiences.

Orchard yield	Net investment (cost/lb of seeds[1])	Plantable seedlings produced per pound of seeds[2]				
		7,000	8,000	9,000	10,000	11,000
lb/ac	($)	Seed cost per thousand seedlings ($)				
10	$181.53	25.93	22.69	20.19	18.15	16.50
20	99.51	14.21	12.43	11.05	9.95	9.05
30	76.20	10.88	9.52	8.47	7.62	6.92
40	63.91	9.13	7.98	7.10	6.39	5.81
75	56.30	8.04	7.03	6.25	5.63	5.12
95	60.88	8.69	7.61	6.76	6.08	5.53
150	69.54	9.93	8.69	7.72	6.95	6.32
% Decrease in cost of seeds		<—14%—><—12%—><—11%—><—10%—>				

[1] Talbert, Weir, and Arnold (1985).
[2] 12,000 pure live seeds per pound.

[2] Wayne Bell, personal communication.

are provided to the nursery free of cost.

Long-Term Benefits—Increased Volume Gains in Plantations

The profitability of a tree improvement program corresponds directly to seedling yields from the nursery. The value of genetically improved seeds is not realized until planting stock is produced. When more seedlings are produced from improved seeds, more acres can be planted with improved seedlings. Any acre reforested with seedlings of low genetic potential represents a lost investment opportunity. Therefore, practices that affect nursery seed efficiency directly affect the profitability of tree improvement programs. This is true whether an organization has a limited or an excess supply of improved seeds.

The additional acreage outplanted per nursery acre is a function of seedling density in the nursery as well as outplanting density in the field. For example, if a nursery with a 65% nursery seed efficiency produces 700,000 plantable seedlings per acre, and seedlings are outplanted at a density of 700 per acre, then for every acre of improved seedlings in the nursery, an additional 77 acres could be outplanted with improved seedlings if the nursery seed efficiency could be increased to 70%.

The present value of the additional wood obtained by the use of genetically improved seedlings is affected by rotation age, the real interest rate, stumpage value at time of harvest, and site quality. Discounted values of one cord of wood under several rotations, stumpage values, and interest rates are presented in Table 2. By using Table 2 and knowing the base growth rate (cords per acre per year from unimproved stock), the rotation age, and the percent genetic gain, one can calculate how much increased value can be obtained by increasing nursery seed efficiency. The present value is derived with the following formula:

$$PV = (PSN/PSO) \times ((NNSE/ONSE) - 1) \times (PV1C) \times (RA) \times (BGR) \times (VGHS - VGLS)$$

where

- PV = present value of additional wood obtained by increasing the nursery seed efficiency on one acre of improved seedlings in the nursery
- PSN = number of plantable seedlings produced per nursery acre
- PSO = number of plantable seedlings outplanted per acre
- $ONSE$ = old nursery seed efficiency (expressed as a decimal value)
- $NNSE$ = new nursery seed efficiency (expressed as a decimal value)
- $PV1C$ = present value of 1 cord of wood harvested at the rotation age (value from Table 2)
- RA = rotation age
- BGR = base growth rate in cords/acre/year
- $VGHS$ = average volume gain of higher performing seedlings (at rotation age)
- $VGLS$ = average volume gain of lower performing seedlings

Table 2. Present value of one cord of wood at various rotation ages, harvest values, and interest rates.

Stumpage value ($/cord at time of harvest)	Rotation age	Real interest rate 4%	6%	8%
			($)	
15	20	6.39	4.68	3.22
	25	5.63	3.49	2.19
	30	4.62	2.61	1.49
20	20	9.13	6.24	4.29
	25	7.50	4.66	2.92
	30	6.16	3.48	1.99
25	20	11.41	7.79	5.36
	25	9.38	5.82	3.65
	30	7.70	4.35	2.48

As an example, Nursery A produces 700,000 plantable seedlings per acre with a nursery seed efficiency of 0.6 and grows 30 acres of seedlings of which 20 acres are improved. The company outplants 700 trees per acre, on a 25-year rotation, and plants on land that produces 1.5 cords/ac/yr. The company's economist uses a 6% real interest rate and predicts that stumpage values in 25 years will be $20/cord. Progeny tests from the first generation seed orchard indicate a 12% gain in volume production. The nursery manager has collected data to show that improving early seedling establishment can increase nursery seed efficiency from 0.6 to 0.66. The nursery manager uses the following calculations to justify purchasing new equipment and supplies necessary to improve nursery seed efficiency.

$$\$2{,}097 = (700{,}000/700) \times ((0.66/0.6) - 1) \times (\$4.66) \times (25) \times (1.5) \times (0.12 - 0)$$

Under these conditions, increasing nursery seed efficiency from 0.6 to 0.66 would increase the present value of each acre in the nursery (that would have been sown with improved seed using the old nursery seed efficiency value) by $2,097. This means that for 20 acres of improved seedlings, the company could justify spending up to $41,940 annually on nursery management practices that would increase nursery seed efficiency from 0.6 to 0.66.

The above example is for an organization that is not planting all improved seedlings. However, the analysis can also apply to organizations that produce an excess of improved seeds. Examples of two hypothetical cases of nurseries using improved seeds from differing stages of tree improvement are presented below.

Nursery B has just enough seed

to sow the entire nursery with orchard seeds that have an average of 12% genetic gain. The seeds however, have been collected into two performance groups (the practice of collecting seeds by family or other genetic group is increasing). The genetic gain from the best performing families averages 18% ($VGHS$ = 0.18) while the group containing the other families averages 8% gain ($VGLS$ = 0.08). The nursery has enough seeds to sow 20 acres with seeds from the better families while the remaining 20 acres are sown with seeds from the lower group. An increase of 4% in nursery seed efficiency would increase the area sown with seeds from the better families by 0.8 acre. As a result, more seedlings from the higher performance seed group will be produced while fewer seedlings from the lower performance group will be needed for outplanting. Under the economic assumptions outlined for Nursery A, this would result in an increase in present value of seedlings produced by $34,940 ($1,747 × 20 ac).

Nursery C has enough seeds to sow 20 acres of the nursery with seeds from a second generation orchard that averages 32% genetic gain ($VGHS$ = 0.32). The remaining 20 acres are sown with first generation orchard seeds that average 12% gain ($VGLS$ = 0.12). The increase in present value due to increasing nursery seed efficiency by 4% is twice as great ($69,880 = $3,494 × 20 ac) as that for Nursery B because the difference in potential volume gains ($VGHS$-$VGLS$) between the seed lots is twice as great. As long as a limited supply of highly improved genetic seeds for producing seedlings exists, keeping nursery seed efficiencies high will be economically important for many years to come.

Nursery Management Practices that Affect Nursery Seed Efficiency

There are various management practices that influence nursery seed efficiency. Important seed management techniques include seed-orchard management practices, seed extraction, seed cleaning, seed sizing, seed storage, seed stratification, and seed treatments. Sowing practices that affect nursery seed efficiency include sowing date, sowing by family, sowing density, sowing pattern, precision sowing, sowing depth, seedbed stabilization, and seedbed mulching. Other management practices that affect nursery seed efficiency include fertilization, irrigation, pest management, root-pruning, harvesting, and seedling storage. Poor management practices in any of these areas can decrease nursery seed efficiency. Therefore, it is economically important to determine where improvements are needed in order to optimize nursery seed efficiency.

SUMMARY

Optimum volume gains cannot be realized solely by increasing the genetic potential of the seeds produced. The process of converting the genetic material into seedlings or plantlets must also be optimized. Efficient conversion of seeds into seedlings is dependent on funding that is adequate to provide the nursery with the best managers, equipment, and research. Present value analysis can easily demonstrate large benefits are possible by increasing nursery seed efficiency.

However, some individuals do not fully understand the concept of present value economics and subsequently believe that the market value is all the seeds are worth. This lack of understanding of present value can directly affect the amount of resources provided to the nursery in order to produce the maximum number of plantable seedlings per unit of seeds. This helps explain why some organizations can afford to spend millions in developing new nurseries while others are not allowed to spend $35,000 per year to retain an experienced nursery manager. Once it is realized how much can be gained by improving nursery seed efficiency, funds to conduct research and improve nursery management practices are easy to justify. □

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