of October from root pieces approximately 1 to 2 mm thick and 5 cm long. The root cuttings are planted upright in flats of mix, covered with moist sphagnum, then stored in a cool greenhouse (15°C). In January, shoots start to show and the sphagnum is removed. The new plants are watered and fertilized with a 20-20-20 formulation at 200 ppm. Cuttings are moved into plugs and later potted on. *Salvia superba* 'East Friesland' is propagated the same as *Phlox*, however, cuttings taken in late August are planted into a cold frame. *Anemone japonica* root cuttings made in February are kept in the greenhouses like *Phlox*. This is one way to prevent freezing of the stock in most years.

Populus 'Tower' is the only tree presently grown at Sheridan's from root cuttings. At one time the nursery also propagated *Gymnocladus dioicus* this way. These cuttings are made similar to those of *Campsis* and *Aralia*.

At Sheridan Nurseries, we have begun to explore the possibility of propagating, both root and hardwood cuttings in "Spencer-Lamaier" rooting trays. The objective is to produce a strong, established plant with a good root ball which can be readily transplanted.

There are, of course, many other shrubs, trees, and perennials which can be easily propagated by root cuttings. The plants discussed here give a brief outline of our root cutting propagation methods. Extensive lists of plants may be found in past IPPS *Proceedings* or most any book on propagation.

PROPER SELECTION OF PROPAGATION MATERIAL CAN BOOST NURSERY PRODUCTIVITY[1]

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Abstract. Three year height data from a *Betula papyrifera* provenance test was used to show the economic benefits of proper selection of propagation material. The best of 8 commercially available seed sources (number 1306, obtained from Musser Forest and Herbst Tree Seed) averaged 8.3 ft in height vs. 7.4 ft for the 8 commercial source average. The shortest source was 6.1 ft. Based on fall 1985 wholesale prices, planting seedlings from

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source 1306 would have grossed an additional $5.60 per plant or an additional $10.00 per plant compared to the 8 commercial seed source average or the shortest commercial source, respectively. Seedling heights within source 1306 ranged form 6.1 to 11.8 ft. Asexual propagation of the tallest individual within source 1306 would have grossed an additional $20.00 per plant compared with the 8 commercial source average and $14.40 per plant compared to the average of source 1306. By recognizing and exploiting variation among and within seed sources, a nursery manager can realize significant increases in nursery productivity (more dollars per acre per year) without changing current production practices.

INTRODUCTION

One goal of nursery production managers is to produce uniform crops. To them variation is undesirable. However, plant-to-plant variation, if exploited, can increase nursery productivity and return more dollars per acre per year to the business. One means of increasing nursery productivity would be to grow the same quality and size plant material in less time. This work will demonstrate how three types of variations: 1) among seed source, 2) within seed source, and 3) within an individual, can be exploited by progressive nursery managers to increase productivity.

Height measurements taken in a 3-year-old *Betula papyrifera* provenance test will be used to demonstrate among and within seed source variation while the importance of within individual variation to nursery productivity will be demonstrated by data from a rooted cutting experiment.

Among Seed Source Variation. The genetic variation in growth potential among seed sources is documented in a provenance test. In a provenance test seed sources (provenances) from different geographical areas are grown in a common environment so that genetic differences can be detected. A *Betula papyrifera* provenance test was planted at Wooster, Ohio in June, 1983, using 3-month old greenhouse grown seedlings from 43 wild seed sources and 8 commercially available seed sources. The planting has eight 4-tree row plots in a randomized complete block design. The planting was measured in September, 1985.

The height data of the 8 commercially available seed sources at year three is presented in Table 1. Average plantation height was 7.4 ft. The tallest commercial seed source (1306) was 36% taller than the shortest commercial seed source (1302), 8.3 vs. 6.1 ft, respectively, and 12% taller than the 8 commercial seed source average. Using prices from the Lake County Nursery Exchange fall, 1985, wholesale catalog (Table 2) the possible per tree gross can be calculated for the various sources. If a nursery had planted seedlings from seed source 1306 instead of 1302 an additional $10.00 per plant

would be realized (Table 3). A similar comparison between source 1306 and the 8 commercial seed source average would have grossed an additional $5.60 per plant. The increased height growth is the result of the genetically superior seed of source 1306. The appealing aspect of selecting genetically superior seed sources is that no modification of production practices needs to be made, except making adjustments for shorter rotation times. Also, the increased gross would represent a close approximation of net profit as it costs no more to purchase seed or raise seedlings from 1306 as it would from any of the other 7 commercial sources.

Table 1. Three year height of *Betula papyrifera* trees raised from 8 commercial seed sources. Plantation site is Wooster, Ohio. Each value is the mean of 32 trees.

Seed Source	Third year height(ft.)	Percent of 8 seed source (mean)	Percent of seed source 1302 (mean)
1300	7.9	106	129
1302	6.1	82	100
1303	6.9	93	113
1304	7.9	106	129
1305	7.5	101	123
1306[1]	8.3	112	136
1307	7.4	100	121
1308	7.5	101	123
Average	7.4		

[1]Source 1306 was obtained from Musser Forest, Indiana, PA 15701, from seed purchased in fall, 1982, from Herbst Tree Seed, New Fairfield, CT 00812.

Table 2. Costs by height(caliper) of balled and burlapped *Betula papyrifers* plants. Data obtained from 1985 Lake County Nursery Exchange catalog, Perry, OH 44081.

Height (ft)	caliper (in.)	Cost/Plant
6	—	$26.60
7	—	31.00
8	—	36.60
9	1¼	41.00
10	1½	46.50
11	1¾	51.00
12	2	63.75

Within Source Variation. Not all individuals within a seed source were the same height. This tree-to-tree variation is termed, "within source variation" and can also be exploited by nurserymen. Within the tallest source, 1306, individual tree heights ranged from 6.1 to 11.8 ft. If the tallest tree was asexually propagated (thus capturing all of the genetic superiority)

and planted, additional gains could be made. (See "Cautions" section for reason why full phenotypic height might not be achieved.)

If the 11.8 ft individual was asexually propagated (cloned), transferring all of the apparent genetic height superiority to the "offspring", a clonal planting would realize an additional $14.40 per plant compared to planting just seedlings of seed source 1306. An additional $20.00 per plant would be realized if a nursery planted clonal material of the tallest 1306 individual compared to planting seedlings randomly chosen from the 8 commercial seed sources (Table 3).

Table 3. Increased gross return per plant when different constraints are made between propagation sources.

Contrast (seed sources)[1]	Height (ft)	Cost ($)	Differences per plant ($)
1306 vs. 1302	8.3 vs. 61	36.60-26.60	+ 10.00
1306 vs 8 seed source average	8.3 vs. 7.4	35.60-31.00	+ 5.60
Tallest individual within source 1306 vs. 1306 average	11.8 vs. 8.3	51.00-36.60	+ 14.40
Tallest individual within source 1306 vs. 8 seed source average	11.8 vs. 7.4	51.00-31.00	+ 20.00

[1]Seed source 1306 was tallest of 8 commercial seed sources at year three in a Wooster, Ohio, *Betula papyrifera* provenance test; source 1302 was the shortest.

Cautions. Several factors must be considered as every nursery planting seed source 1306 or clonal material from the tallest individual of 1306, might not obtain 8.3 or 11.8 ft tall plants after 3 years.

First the data presented are based on one test site. Seed source by environment interaction may exist. The best source in Wooster, Ohio might not be the best in Wisconsin or Maine. Also, the Wooster planting received excellent care from John Elliot, the farm manager. Less intensive cultural practices would result in reduced growth. Second, the interpretations are based on 3 year results. At the end of 10 years the tallest seed source might not be source 1306. Relative source superiority can shift with time. Third, the genetically best individual within a source might not be the tallest tree in the planting, again due to environmental differences within the Wooster site. The tallest individual in source 1306 might have been in a favorable micro-site and been taller than other individuals within 1306, not for genetic reasons, but for cultural (environmental) reasons.

Finally, significant differences in growth rate and form can occur among individuals within a clone. When long shoots or shoots of *Betula nigra* 'Heritage' are propagated, plants differing in growth rate and form can result, even though they are genetically identical (1). The most likely reason for the difference in appearance can be attributed to plagiotrophic effects, the long term persistance of age, or positional effects.

To realize the full growth potential of the best individual within a source, long shoots must be used as propagation material. Long shoots have been programmed, while on the stock plant, for rapid growth. Long shoots have larger leaves, greater stem caliper, and longer internodes than short shoots.

Propagation of long shoots by stem cuttings can result in plants up to 6 inches taller (28 vs. 22 in.) 125 days after propagation than propagation of short shoots (1). Further, long shoots compared to short shoots need less staking to develop upright growth, produce greater leaf area, and greater root and shoot dry weights.

Stem cutting derived short shoots can be trained into long shoots by vertically staking one shoot and pruning any lateral shoots to a three node length. If done, the transition can be completed within the growing season remaining after propagation, approximately 85 to 125 days. Severe pruning of stock plants will result in the production of long shoot type growth, which can be used for propagation.

In summary, a production manager can increase the return per acre per year by careful selection of propagation material. Selecting the best seed source over the poorest can return up to $10.00 per plant more at the end of three years. Asexual propagation of the best individual within a source can return an additional $10.00 per plant. In order to realize the full growth potential of asexually propagated genotypes long shoots must be selected as propagation material. The increased returns per plant outlined in this paper can be realized without significant changes in present nursery practices.

LITERATURE CITED

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