SELECTION AND SEED ORCHARD ESTABLISHMENT OF SUPERIOR GREEN ASH

Richard A. Cunningham

Rocky Mountain Forest and
Range Experiment Station
Bottineau, North Dakota

Of the many tree species that have been planted in the Northern Great Plains shelterbelts, the majority have been deciduous, broadleafed species. Green ash *(Fraxinus pennsylvanica* Marsh.) was often used as the intermediate-height component of a multiple-species shelterbelt. Survival of green ash has been outstanding on practically all sites throughout the Great Plains region. Read (1958) reported that a survey of Great Plains shelterbelts in 1954 revealed over-all survival of green ash average to be 77 percent at an average age of 16 years after planting. Read (1958) suggested that green ash is probably one of the best medium- to slow-growing windbreak species from the standpoints of survival and adaptation to difficult sites.

Because of its excellent record of survival, green ash has continued to be a fairly popular choice for windbreak plantings. Some resistance to its use has been met, with the primary objections being susceptibility to wood boring insects, and its relatively slow growth rate compared to fast growing hardwood species such as Siberian elm (*Ulmus pumila* L.).

In order to make green ash a more useful species for shelterbelt plantings, a selection and breeding program was initiated at the USDA—Forest Service Shelterbelt Laboratory in Bottineau, North Dakota.

Briefly stated, the selection and breeding program for the genetic improvement of green ash will involve:

(1) Selection of superior phenotypes of green ash from existing shelterbelts in the northern Great Plains.
(2) Vegetative propagation of the superior phenotypes and establishment of a clonal seed orchard for research purposes.
(3) Development of techniques for seed orchard establishment, management, and evaluation that are suitable for a dioecious species such as green ash.
(4) Providing nurserymen, or others, with technical assistance in establishing production seed orchards.
(5) Progeny testing the selected phenotypes at several locations.
(6) Development of recurrent selection procedures for incorporation of increased genetic gains in subsequent generation seed orchards.

METHODS

Selection of Superior Phenotypes

Green ash is the most widely distributed of all American ashes (Wright, 1962). Its range extends from Cape Breton Island and Nova Scotia to southeastern Alberta and Montana, and southward to central Texas and northern Florida. In the northern Great Plains most of the natural populations of green ash occur on alluvial soils of river and creek bottoms. Upland sites are generally too droughty to permit natural regeneration of this species. At least three different ecotypes have been identified in the Great Plains (Mueli and Shirley, 1937)..

Populations from the arid, northwestern part of the green ash range were found to be more drought resistant than those from the central Great Plains where the annual rainfall is higher. A marked decrease in the size of both parent trees and their progeny was noted from south to north and east to west. A provenance study of green ash (Bagley, 1970), utilizing seed collections from nine locations in the Great Plains, has provided evidence that a green ash provenance may be safely planted as much as three degrees latitude north of its native site. Northern provenances grew more slowly than local sources when grown south of their native origins. Natural variation also is evident in morphological characters such as crown length and density, autumnal coloration, leaf initiation, and abcission. To utilize this natural variation, selections were made in existing shelterbelts planted throughout the northern Great Plains. Probably most of the seed used to produce seedlings for shelterbelt plantings has come from natural populations occurring along river and creek drainages or from windbreak, block, or ornamental plantings derived from these natural populations.

Selecting within shelterbelts presents a favorable opportunity to compare trees of identical age growing on fairly uniform sites. Phenotypic variation due to environment or age effects should be considerably reduced thus increasing the probability that the variation observed is largely genotypic in origin.

The area surveyed for superior phenotypes has included both North Dakota and South Dakota. Future selections may be made in Nebraska, Montana and Minnesota.

Selection Criteria

Traits considered desirable in hardwood species used for shelterbelt plantings include the following (Dawson and Read, 1964):

(1) moderately fast growth
(2) moderately broad crown of uniformly high density
(3) single straight stem

(4) tolerant of unfavorable soil conditions
(5) resistant to drought injury
(6) resistant to winter injury
(7) resistant to herbicide injury
(8) resistant to insect attacks
(9) resistant to diseases
(10) compatible with farming operations
(11) non-competitive with adjacent crops
(12) aesthetically appealing

It is unlikely that a single candidate tree will possess all of these characteristics or even a majority; however, inclusion of candidates possessing one or more favorable traits in a breeding program will provide the genetic basis for combining all of these traits into one superior phenotype.

Each superior tree candidate was measured or scored for the following characteristics:

(1) total height (nearest 10 cm.)
(2) d.b.h. (nearest 0.1 inch)
(3) age at breast height (from increment borings)
(4) crown length (nearest 10 cm.)
(5) crown density (1—sparse, 2—moderate, 3—dense)
(6) apical dominance (ratio unforked ht. to total ht.)
(7) insect damage
(8) disease damage
(9) sex
(10) seed crop if female

In order to judge relative superiority of a superior tree candidate, the five tallest trees of the same species, located within a radius of 66 feet from the selected tree, were also measured for the same characteristics as the candidate tree. Any superiority of a candidate tree in relation to the comparison trees was calculated, when applicable, for each trait as follows:

$$\text{percent superiority} = 100 \frac{s}{c} - 100 \text{ where:}$$

s = value of selected tree
c = average value of comparison trees

A total of 63 superior phenotypes, located within North Dakota and South Dakota, have been selected to date.

Selection for insect resistance has not yet been possible due to the difficulties in identifying and testing resistant trees. The two primary insect pests are woodborers: the ash borer *(Podosesia syringae fraxini* Lugger); and the carpenterworm *(Prionoxystus robiniae* [Peck]). Natural infestations of these insects have generally been of insufficient intensity to insure a valid expression of tolerance or resistance.

Artificial infestations are difficult to handle because of the large minimum-tree diameter necessary for infestation. The ash borer seldom infests trees under 1.5 inches in diameter, and the carpenterworm is seldom found in trees less than 3 inches in diameter (Tagestad, 1972).

Entomologists at the Shelterbelt Laboratory are cooperating in attempts to develop testing programs for evaluating insect resistance.

RESULTS

Selected Phenotypes

Table 1 lists the mean values for each trait calculated on an over-all basis and broken down by states. Also listed are the population means and standard deviations for each of the five traits. These population values were derived from the combined data of both selected and check trees. The "average" standard deviation gives some indication of the variability encountered in selecting for each trait. These estimates of variability are likely to be on the low side, because check trees were limited to codominant or dominant trees, thereby excluding trees in lower crown classes.

Table 1. Mean values for selection traits

Trait	North Dakota		South Dakota		Combined		Population	
	Select Trees	*Check Trees*	*Select Trees*	*Check Trees*	*Select Trees*	*Check Trees*	$\bar{x}$	S.D.[4]
Total Ht. (m.)	11.9	9.2	11.7	9.2	11.79	9.2	9.5	2.75
D.b.h. (in.)	7.4	5.3	7.6	5.4	7.5	5.3	5.6	1.80
Crown density[1] (score)	2.2	1.9	2.8	2.1	2.5	1.9	2.1	0.61
Live crown[2] (percent)	54.0	40.0	50.9	29.0	52.8	35.4	68.4	18.00
Apical dom.[3] (percent)	73.2	71.4	70.7	62.2	72.2	67.6	38.3	27.64

[1] Visual score: 1 = sparse, 2 = moderate, 3 = dense.
[2] Percentage of total stem height occupied by live branches.
[3] (Ratio of height to first fork to total tree height) x 100.
[4] Standard deviation. Average of standard deviations calculated for each group of 5 check trees plus select tree (63 groups).

Table 2 shows the relative superiority of the selected phenotypes over the check trees for each trait. The data were broken down by states to determine if regional differences existed. Selected trees had advantages of 28 percent in height and 41 percent in diameter at breast height. Crown density averaged 30 percent better for the selected trees, but their percentage of live crown was only marginally better. The degree of apical dominance was substantially better among the selected trees. This is due in large part to our policy of generally rejecting candidate trees that were forked below one-quarter of their height.

The primary criterion for selection was superior total height. Any superiority evidenced in other traits can be considered "gravy." We are fortunate in that most of the other traits were, at least phenotypically, rather strongly correlated with height.

Regional differences were not evident for height **and** diameter, but large between-state differences existed for the crown characteristics. The selected trees from South Dakota were considerably more superior to their check trees than were those from North Dakota in terms of crown density, live branch **retention, and apical dominance.** Climatic differences **between the two states, such** a the frequency of ice storms or wet snows, may be causal factors of these crown differences.

Table 2. Percent superiority[1] of selected trees over check trees for five traits by states

Trait	North Dakota	South Dakota	Mean
Total height	29.15	27.30	28.35
D.b.h.	40.66	40.65	40.65
Crown density	21.00[2]	39.82[2]	29.19
Live crown	2.22[3]	15.17[3]	7.61
Apical dominance	68.89	155.93	104.90

[1] Percent superiority = $100 \frac{s}{c} \cdot 100$ where:

s = value of selected tree
c = average value of comparison trees

[2] Means for states signficantly different at the .05 level of significance
[3] Means for states significantly different at the .01 level of significance

Since green ash is a dioecious species, it was of interest to determine if any of the selection criteria was correlated with tree sex. In order to reduce the influence of the differential ages represented among the selected trees, the ratio of total height to age was calculated for each selected tree. An analysis of variance indicated there were no significant differences in the ht. /age ratio due to sex of the selected trees.

Seed Orchard Establishment

Type of Seed Orchard

The first generation seed orchards will be established with clonally propagated material for several reasons. The great distances between the locations of the superior trees would make controlled pollinations among them time consuming and costly. It would be more efficient to "package" the genotypes of such trees vegetatively rather than sexually. Secondly, there is an immediate demand for genetically improved green ash seed in North Dakota (Hinds, 1970). A grafted seed orchard often produces commercial quantities of seed several years before a seedling seed orchard of comparable age would do so. For these reasons and because green ash is easily propagated by grafting,the first generation seed orchards will be of clonal origin.

Geographic Locations

A research seed orchard will be established in cooperation with North Dakota State University-Bottineau Branch. The planting site will be on a portion of the North Dakota Forest Service nursery at Bottineau. This orchard will be used to develop techniques for seed orchard establishment and Maintenance.

The manager of the State Association of Soil Conservation Districts tree nursery at Bismarck, North Dakota has plans to establish a production seed orchard using scion material provided by the Shelterbelt Laboratory in Bottineau. Technical advice related to seed orchard establishment and maintenance will also be provided to nurserymen requesting such assistance.

Orchard Design

Since green ash is a dioecious species, the positioning of clones within the seed orchard requires different techniques than those commonly used for monoecious species. No **selfing can occur, thus the problem of inbreeding** is practically eliminated. Crosses between individuals of common descent could occur if the selection of superior trees included a male and female from the same geographic area where there was a chance they could be related. The probability of such an occurrence is extremely small, and for that reason the effects of inbreeding in the seed orchard can be safely ignored.

To achieve a high degree of cross-fertilization within the seed orchard, its design will be such that each male tree will be surrounded by a maximum number of females of dissimilar genotypes. To achieve maximum seed production, the seed orchard should contain the minimum number of males necessary for adequate pollination of all females. This requirement will be counter-balanced by the desirability of including in the orchard all those males exhibiting superior phenotypes,

Figure 1 illustrates the basic orchard design that will be used. An isolation zone of randomly positioned male clones surrounds the orchard. Within the orchard itself, male clones are randomly alternated in every other row with female clones. All of the female clones are positioned randomly. This random arrangement of female trees around each male tree should promote maximal cross-fertilization between each male and a group of eight females. Since there will be fewer males than females within the orchard proper, there will be the opportunity to position different ramets of each female clone with several different male clones.

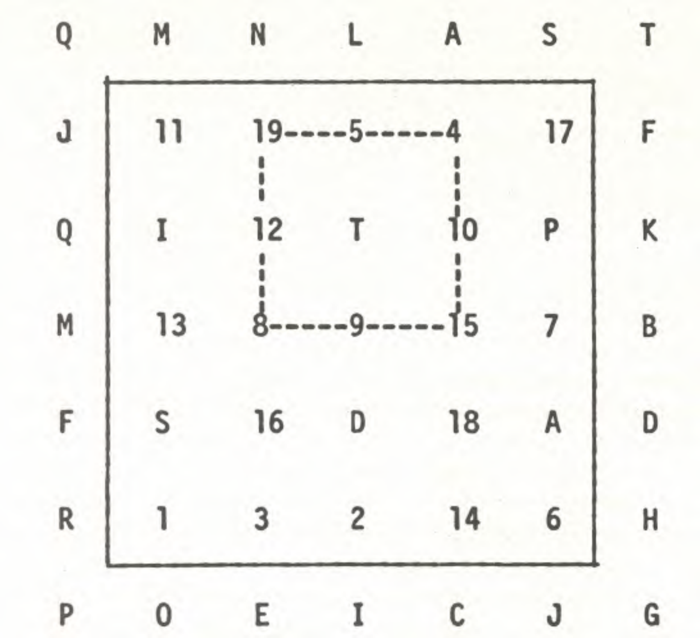

Figure 1. Green ash seed orchard design: letters identify male clones (A-T); numbers identify female clones (1-19); dotted line denotes primary crossing cell.

SUMMARY

A program for selection and seed orchard establishment of a dioecious hardwood species (green ash) has been outlined. Selection of 63 superior phenotypes resulted in a selected population height advantage of 28 percent over the population of check trees. Even larger differences resulted between the selected and check populations for diameter, crown density and apical dominance. Selection for insect resistance has not yet been possible due to the apparent lack of variation in susceptibility to primary insect pests.

Proposals were made for seed orchard design and establishment, especially suited for the requirements of a dioecious tree species.

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