PROGRESS IN BIRCH GENETICS AND TREE IMPROVEMENT

by KNUD E. CLAUSEN and PETER W. GARRETT, Plant Geneticists, U.S.D.A. Forest Service. Mr. Clausen is at the North Central Forest Experiment Station, Rhinelander, Wis.; Mr. Garrett is at the Northeastern Forest Experiment Station, Durham, N. H.

LITTLE INTEREST has been shown in genetic improvement of our native birches until fairly recently, except for the birch breeding and testing begun by the Northeastern Forest Experiment Station in 1940. Before we can begin improvement of a particular species or genus, we need to know how much genetic variation is present and how various characteristics are inherited. Most of the work with birch at the Institute of Forest Genetics at Rhinelander has sought to provide this kind of information. We will report first on the knowledge of birch genetics acquired so far and relate it to practical applications, then review the practical improvement work in progress, and finally discuss what we might expect from tree-improvement work with the birches in the future.

BIRCH GENETICS

Variation Studies

Since variation in a species is the key to its improvement, several studies of birch variation patterns have been conducted or are in progress. Clausen (*1968a*) found that catkin and fruit characteristics of yellow birch vary in an apparently random manner over the natural range of the species and differ greatly among individual trees within the stands. Although these results have no obvious practical application, they indicate that we might expect similar differences in growth rate or other desirable characteristics.

The observed geographical variation in a species may be due partly to differences in elevation. In a study now in progress, Sharik[1] found the zone of optimal development for yellow birch to occur at lower elevations with increasing latitude. In the Balsam Range of southwestern North Carolina it was at 3,500 to 4,500 feet compared with 1,500 to 2,200 feet in the Green Mountains of Vermont and the White Mountains of New Hampshire. The comparable zone for sweet birch was 500 to 1,000 feet lower, and this species was seldom observed above 500 feet near its northern limit in the Champlain Valley, central New Hampshire, and southwestern Maine. Preliminary observations by Sharik[1] also indicated that yellow birch morphology is much more variable than that of sweet birch. The data collected along these elevational transects should provide much information about local variation, and will be helpful in selection of seed sources for particular localities.

Some of the morphological variation in traits such as size and shape of leaves, catkins, and seeds is due to natural hybridization and introgression (*Clausen 1962, Brayshaw 1966, Dugle 1966, Brittain and Grant 1967a*). Studies of natural hybrids tell us something about which species can be crossed with each other and which characteristics are transmitted to the hybrids. This information is important because natural hybridization between shrubby and tree-size birches is relatively common. Since these hybrids are usually smaller than their tree parents, the presence of shrubby species in or near a birch stand could have a deleterious effect on timber production.

Morphological variation in some species may be due partly to differences in chromosome numbers. Brittain and Grant (*1965, 1966, 1967b, 1968a, 1968b*) have shown that paper birch, a highly variable species, has 56, 70, or 84 chromosomes with 56 and 70 being most prevalent in eastern Canada and 84

[1] Personal communication from T. L. Sharik, University of Michigan, December 1968.

more common in the Rocky Mountains and northwestern Canada. Whether similar chromosomal variation occurs in other birch species has not yet been determined. Paper birch populations with different chromosome numbers could vary not only in morphology but in their adaptation to particular environments. If that should be the case, it might not be enough to use a local seed source that would usually be suitable for the local climate. Instead, the source might have to be selected for the particular site and microclimate.

Growth characteristics appear to vary considerably in the birches. A range-wide study of natural variation in yellow birch initiated by the Institute of Forest Genetics includes 55 seed sources (fig. 1). Second-year height growth in the nursery at Rhinelander, Wisconsin, varied greatly but was essentially random (*Clausen 1968b*). At the end of the third year in the nursery, seedlings from the best source were twice as tall as those from the poorest one, and averaged 59 percent greater in diameter (table 1). Total height was not correlated with latitude, longitude, length of growing season, annual precipitation, average January temperature, or average July temperature (table 2). Although seedlings from the northern sources showed some tendency to be thicker than those from the southern ones, diameter was only weakly correlated with latitude and length of growing season (table 2). Thus the variation in height and diameter of yellow birch appears to be random, at least in the seedling stage. The further growth and development of the seedlings will be studied in 10 test plantings established in the Lake States, New York, and New England, and in three plantings in Canada.

As mentioned previously, individual yellow birches growing in the same stand appear to vary widely. To determine whether the great height variability observed in the seed-source

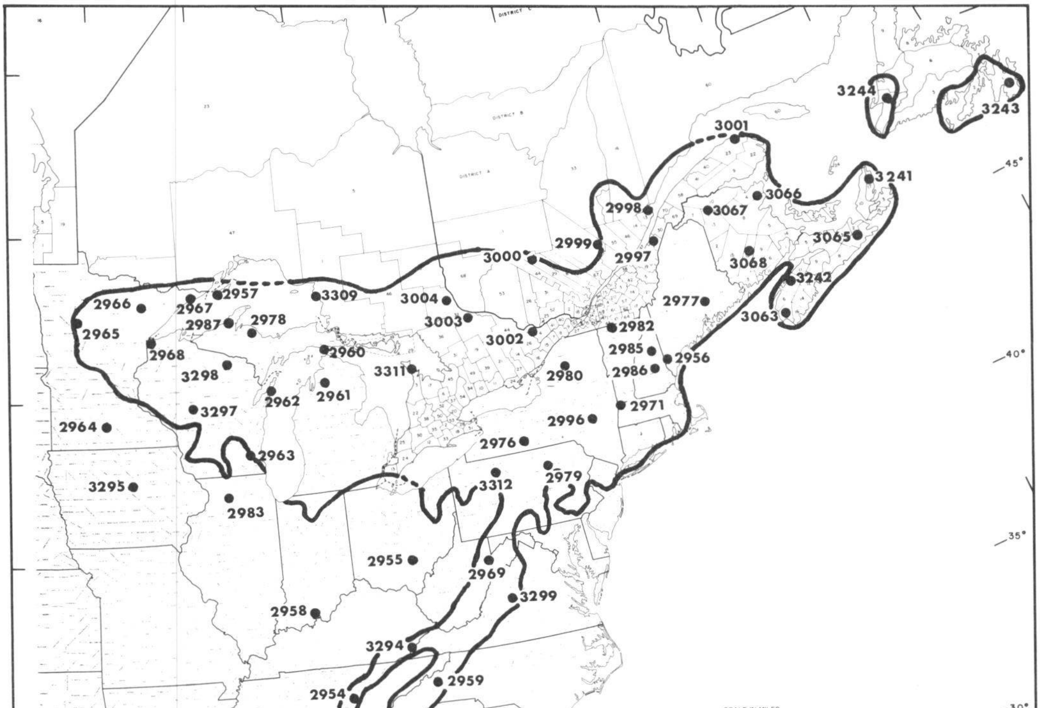

Figure 1.—Natural range of yellow birch, adapted from maps in USDA Forest Service *(1965)* and Dansereau and Pageau *(1966)*, and location of 55 seed sources.

Table 1.—*Origin, mean 3-year height and diameter, growth initiation, and winter injury of seedlings from 55 yellow birch seed sources*

Source No.	State or province	Location		Elevation	3-year—		Growth initia-tion[2]	Seedlings winter damaged
		Lat.	Long.		Height	Diam.[1]		
		Degrees	*Degrees*	*Feet*	*Cm.*	*Mm.*		*Percent*
3243	Newfoundland	47.2	53.4	50	46.0	6.3	2.89	18.6
3244	Newfoundland	48.6	58.2	400	51.9	6.5	3.57	14.3
3241	Nova Scotia	46.6	60.5	100	56.0	6.9	3.89	19.0
3065	Nova Scotia	45.4	61.8	450	38.9	5.6	3.86	10.5
3242	Nova Scotia	44.8	65.2	650	48.5	6.0	3.75	32.2
3063	Nova Scotia	44.1	65.8	350	44.8	6.1	3.38	23.4
3068	New Brunswick	46.0	66.4	300	47.9	6.3	4.00	47.0
3066	New Brunswick	47.4	65.2	300	46.9	6.5	3.56	20.4
3067	New Brunswick	47.5	67.4	925	46.2	6.7	4.00	28.1
3001	Quebec	49.2	65.1	300	41.8	5.8	4.14	6.2
2998	Quebec	48.2	70.2	1,000	36.5	5.8	4.56	17.8
2997	Quebec	47.0	70.3	400	39.7	6.0	4.00	23.7
2999	Quebec	47.4	72.6	1,000	46.9	6.4	3.75	11.6
3000	Quebec	47.5	75.0	1,500	41.8	5.9	3.71	17.5
3002	Ontario	45.1	76.9	1,000	50.3	6.2	3.33	25.2
3003	Ontario	46.1	79.0	1,000	46.6	6.0	3.50	28.5
3004	Ontario	46.7	79.6	1,000	51.2	6.6	3.33	14.2
3311	Ontario	45.0	81.4	625	52.8	7.1	3.88	20.3
3309	Ontario	47.5	84.8	1,000	45.8	6.0	3.38	9.8
2977	Maine	44.8	68.6	250	40.0	5.9	3.67	36.1
2956	Maine	43.7	70.9	1,000	46.1	6.2	3.56	19.6
2985	New Hampshire	44.0	71.4	1,900	44.1	5.5	3.22	18.4
2986	New Hampshire	43.5	71.4	1,300	52.4	6.6	3.71	23.2
2982	Vermont	44.7	72.6	1,250	54.7	6.8	2.88	30.2
2971	Massachusetts	42.7	73.2	1,610	47.6	6.1	3.25	25.8
2980	New York	49.2	74.9	1,620	52.8	6.3	3.78	13.4
2996	New York	42.5	74.2	2,100	54.0	6.5	3.44	17.5
2976	New York	42.3	77.3	1,300	52.4	6.3	2.33	40.0
2979	Pennsylvania	41.3	76.3	2,300	53.9	6.4	2.86	31.0
3312	Pennsylvania	41.6	78.7	1,800	57.4	6.6	2.44	47.2
2969	West Virginia	39.0	79.7	2,200	58.5	6.6	2.22	43.8
3299	Virginia	37.8	79.1	3,000	38.6	5.4	1.62	50.6
2959	North Carolina	35.7	82.3	5,160	52.2	6.3	2.00	18.7
2973	Georgia	34.8	83.8	4,700	44.1	5.7	1.78	24.1
2953	Tennessee	35.2	85.7	1,740	32.1	4.7	1.50	91.4
2954	Tennessee	35.7	85.3	1,420	29.3	4.2	2.00	82.7
3294	Kentucky	36.9	82.9	3,600	54.3	6.1	1.62	53.7
2955	Ohio	39.5	82.5	830	49.8	6.1	2.44	74.6
2958	Indiana	38.3	86.5	700	44.0	6.2	2.33	52.7
2983	Illinois	41.9	89.4	680	42.4	5.6	3.75	28.0
3295	Iowa	42.4	93.1	1,050	59.9	6.6	2.89	24.2
2961	Michigan	45.0	85.0	1,000	63.6	7.1	3.38	34.4
2960	Michigan	45.9	84.8	625	49.4	6.3	3.33	21.6
2978	Michigan	46.7	87.9	1,675	41.1	6.1	3.44	17.0
2987	Michigan	47.0	88.7	1,250	45.6	6.1	3.62	6.7
2968	Wisconsin	46.5	92.1	1,150	45.7	6.1	3.67	9.9
3298	Wisconsin	45.7	89.0	1,710	42.1	5.5	3.86	17.6
3297	Wisconsin	44.5	90.4	1,100	49.6	6.2	2.22	17.8
2962	Wisconsin	44.9	87.2	600	55.5	6.7	3.88	27.9
2963	Wisconsin	43.1	88.4	900	49.2	6.2	2.78	19.0
2964	Minnesota	44.2	94.1	800	49.6	6.4	3.28	12.7
2965	Minnesota	47.2	95.2	1,480	50.7	6.8	3.60	23.2
2966	Minnesota	47.6	92.5	1,700	54.5	6.7	3.25	26.8
2967	Minnesota	47.8	90.2	1,400	49.7	6.6	3.50	18.7
2957	Isle Royale, Michigan	47.9	89.1	750	41.8	6.0	4.00	29.6

[1] Diameter measured 1 inch above the ground.
[2] Average flushing score on 5 May, 1967 (1 = late, 5 = early).

study might be due to the fact that the seed lots used were a mixture from an average of 10 trees per stand, a study of 199 individual tree progenies is now in progress. At the end of the first growing season there were highly significant differences in seedling height, not only among the 21 sources but also among the trees within each source. The results also showed that certain sources were much more variable than others (fig. 2).

For example, seedlings from Nova Scotia source 3063 had the greatest average height but the least height variation (the best progeny was only 23 percent taller than the poorest one). In contrast, the seedlings from Pennsylvania source 3312 ranked second in average height, and the best progency was twice as tall as the poorest one. The greatest difference between progenies within a source, 127 percent, was in New Brunswick source 3066. Thus, which tree is selected as crop tree or superior tree would be less important in a tall and relatively uniform source such as 3063 than it would be in a variable source like 3066 or in a poor source like 2973 (Georgia).

The large amount of individual tree variation present in yellow birch indicates that a selection program in this species should focus on selection and testing of individual trees.

Yellow birch, in contrast to its random variation in height and diameter, exhibits a gradual north-south trend or clinal variation in growth initiation and cessation. Flushing of seedlings from the 55 sources was scored in the nursery every 3 days between 21 April and 1 June, 1967. The best separation among the sources was on 5 May, when the northern sources were generally farther advanced than the southern sources (table 1). Growth initiation showed a high correlation with latitude, average January temperature, and length of growing season (table 2). Similarly, seedlings from the northern sources stopped growing earlier than those from the southern sources at the end of their second year in the nursery; growth cessation was also closely correlated with latitude (*Clausen 1968b*). However, growth initiation and cessation did not appear to be related to height.

Since seedlings from northern sources start growing early in the spring, they are more likely to be damaged by late spring frosts than seedlings from southern sources. On the other hand, seedlings from the southern sources, which continue growing until fall, are more susceptible to injury from early fall frosts.

The importance of frost resistance is illustrated by the seed-source study. The seedlings were scored for light, medium, and heavy winter injury after their second winter in the nursery. No attempt was made to distinguish damage caused by fall frosts from that caused by winter cold. Surprisingly enough, seedlings from all 55 seed sources showed some degree of winter injury (table 1). Although the percentage of injured trees often was high, the damage was normally light in most of the

Table 2.—*Correlation between 3-year height, diameter, and flushing of seedlings from 55 yellow birch seed sources and environmental variables of the seed sources*

Environmental variable	3-Year height	3-Year diameter	Flushing 5 May, 1967
Latitude	0.0678	0.4048**	0.8461**
Longitude	.0900	–.0469	–.2898
Length of growing season	–.1486	–.4139**	–.6536**
Annual precipitation	–.0672	–.2382	–.5166**
Average January temperature	–.0305	–.3300	–.7571**
Average July temperature	–.0439	–.3153	–.5751**

** Significant at the 1-percent level.

northern and eastern sources. Most severely damaged were seedlings from the Ohio, Indiana, Virginia, Kentucky, and Tennessee sources. Of the southern group, only the North Carolina and Georgia seedlings were relatively frost resistant; but these sources were from high elevations (table 1).

These results demonstrate that in yellow birch, as in other species, it is extremely important to choose the right seed source for a particular location. While seedlings originating farther south may have good growth, they may not be winter-hardy. On the other hand, if they come from too far north they may be susceptible to late spring frosts. Therefore, seed or seedlings should not be moved too far north or south of their origin.

The importance of seed origin was apparent in the great differences in performance of seedlings from different sources in the same state or province (table 1). For example, the height differences between seedlings from the best and poorest seed sources amounted to 32 percent for Wisconsin, 55 percent for Michigan, 28 percent for Quebec and 44 percent for Nova Scotia. Even the two New Hampshire sources, which came from areas within about 40 miles of each other, were different. Seedlings from the southernmost source (2986) were 19 percent taller than those from nearby source 2985, and more comparable in height to seedlings from the much more distant sources from northern Vermont (2982) and northern New York (2980). Granted, these are only heights after 3 years in the nursery; but it has been shown that the seedlings of two European species (*Betula pendula* Roth and *B. pubescens* Ehrh.) that were tallest in the nursery maintained their superiority for at least 9 years in the field (*Clausen 1963*).

Crossability Studies and Tests of Hybrids

Before beginning a practical breeding program, it is important to know which trees can be selfed, crossed with other trees of the same species, or crossed with members of

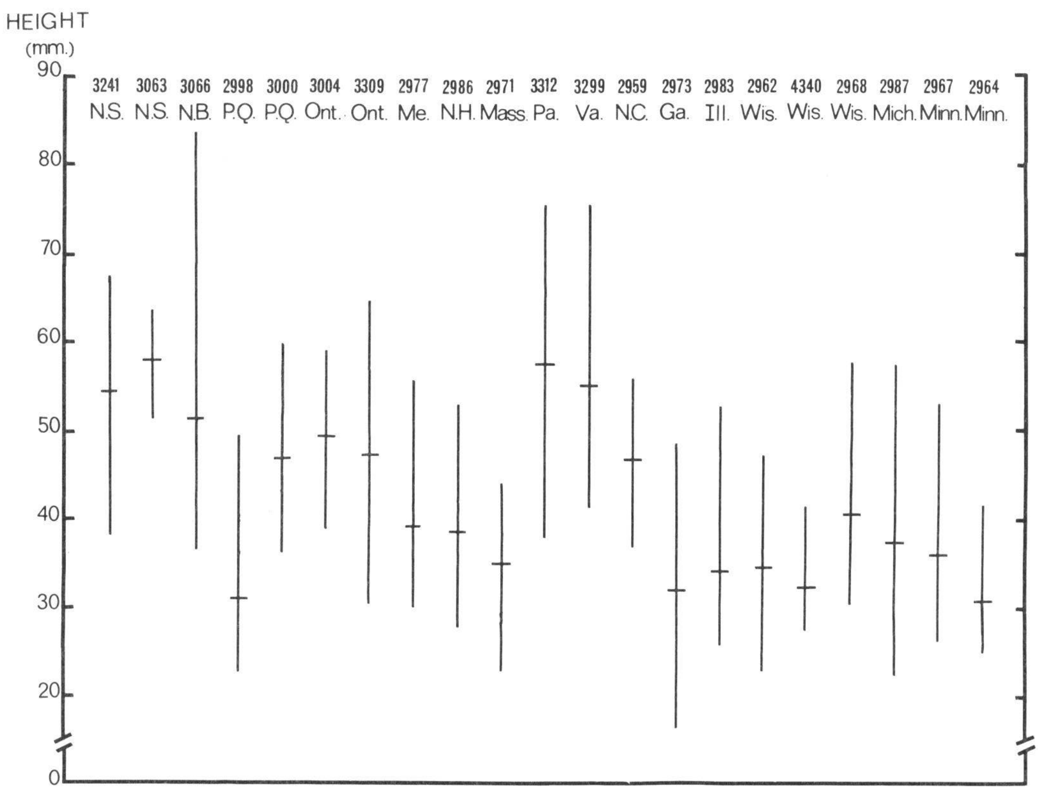

Figure 2.—Range of 1-year-old seedling heights (progeny means) and average height for each of 21 yellow birch seed sources.

other species. So far we know that self-compatibility is very low in most birches and only certain individuals will produce viable seed after selfing (*Clausen 1966*). Surprisingly enough, certain trees will not cross with other trees of the same species, and thus would be of limited use in a breeding program or a seed orchard. Hence compatibility tests of superior trees are important in birch. Interspecific crosses, which are aimed primarily at increasing understanding of species relationships, have shown that certain species can be crossed successfully, others only with difficulty, and some not at all. Certain crosses are successful only in one direction, often depending on the chromosome numbers of the parent species involved in the cross.

The first controlled birch crosses made in this country were carried out at the Northeastern Forest Experiment Station in 1940; the progenies from these crosses were planted at Standing Stone, Pennsylvania, in 1946. In 1963 the sweet birch x paper birch hybrids averaged 37.2 feet in height and 5.0 inches in diameter compared with 27.8 feet and 3.4 inches for open-pollinated paper birch. The reciprocal cross (paper x sweet birch) had slightly better form but was otherwise comparable to paper birch. The hybrids between gray birch (*B. populifolia* Marsh.) and paper birch were 10 feet taller and 1.8 inches thicker than the paper x gray hybrids, but both crosses were inferior to both paper birch and gray birch. The sweet birch x yellow birch hybrids that were taller than both parents at age five (*Schreiner 1949*) had fallen behind both parents when measured by Sharik[1] in 1968. The average height and diameter of the hybrid were 32.4 feet and 3.2 inches, respectively, compared with 36.1 feet and 4.2 inches for yellow birch, and 37.3 feet and 4.3 inches for sweet birch.

Other hybrid progenies planted at Williamstown, Massachusetts, in 1954 were measured in 1967 at age 17 years from seed. The *B. papyrifera* x *pubescens* hybrid was superior to its reciprocal but inferior to both parent species. The hybrids *B. papyrifera* x *maximowicziana* Reg. and *B. pubescens* x *maximowicziana* were as tall as progenies of their respective female parents. In the work at the Institute of Forest Genetics we have also noted large differences between reciprocal crosses, but the progenies are too young to draw any conclusions from. Crosses made in Sweden involving paper birch showed that at 24 years of age the hybrids *B. pubescens* x *papyrifera* and *B. pendula* x *papyrifera* performed no better than pure paper birch, and were inferior to the two Swedish species (*Johnsson 1967*).

Although certain interspecific hybrids between the native birches thus far have shown better growth than the pure species, we need to do more crossing and testing before we can judge the value of interspecific hybridization as a means of increasing growth. Interspecific hybrids may, however, be of value in developing resistance to insects or disease. An example is the *B. populifolia* x *papyrifera* hybrid, which should be tested for possible resistance to birch dieback. Some hybrids appear to be resistant to birch leaf miner (*Fenusa pusilla* Lep.) and deserve further testing.

We have made crosses between trees of the same species, but since the progenies are still young about all we can say at present is that a lot depends on the individual trees used as parents. Older work in Sweden with *B. pendula* and *B. pubescens* also demonstrated that certain crosses were much more vigorous than others at age 20 to 24 (*Johnsson 1967*). The best results were obtained with parents located within a few degrees latitude of each other; progenies from crosses between northern and southern parents tested in the south showed decreased growth as latitude of the northern parents increased. Unfortunately, these crosses were not tested near the northern parents where they possibly could show superior growth.

Intraspecific hybrids, on the basis of our limited experience, appear to offer much promise. Crosses between different provenances should receive particular attention, but should probably be limited to provenances within relatively close latitude of each other. Thus far, the trees used in most crosses have been selected more for convenience than for particular attributes. If future crosses are made with trees selected for fast growth or other desirable characteristics, significant improvements should be possible.

Exotics

Although the genus *Betula* contains about 50 species, few exotic birches have been tested in this country so far. In 1954 the Northeastern Forest Experiment Station established a planting at Williamstown, Massachusetts, that included two European species, *B. pendula* and *B. pubescens,* three Asiatic species and varieties, *B. davurica* Pall., *B. platyphylla* var. *japonica* (Miq.) Hara and *B. platyphylla* var. *szechuanica* (Schneid.) Rehd., and native paper birch for comparison. When measured in 1967, 17 years from seed, the two European species were slightly taller, the Korean variety of *B. platyphylla* was equal to, and the Chinese variety of *B. platyphylla* slightly taller than the paper birch lots (table 3). One lot of Japanese *B. davurica* was 33 percent taller than the paper birch, and one lot of the Japanese variety of *B. platyphylla* was 48 percent taller (table 3).

A height of 30 feet in 17 years is an impressive demonstration of the growth potential of certain exotics, but much more extensive tests are required before we can say much about the relative merits of various species. The success of an exotic depends largely on finding the right provenance for a particular locality, and the same provenance will seldom do equally well in all areas.

BIRCH TREE IMPROVEMENT

Selection and Progeny Testing

Clausen and Godman *(1967)* published a guide to selection of superior yellow birch trees. Recently we demonstrated that smooth-barked or heavily peeling yellow birches are younger and faster-growing than rough-barked trees.[2] This finding should make it easier to identify potentially fast-growing trees that should be selected as crop trees or superior trees.

Table 3.—*Height in 1967 of Betula species and varieties planted at Williamstown, Mass., in 1954*

Species or variety	Origin	Height
		Feet
B. pendula	Sweden	23.0
B. pubescens	N. Europe	21.6
B. davurica	Japan	26.9
B. platyphylla var. *japonica*	Korea	20.3
B. platyphylla var. *japonica*	Japan	30.0
B. platyphylla var. *szechuanica*	W. China	23.0
B. papyrifera		20.2

Region 9 of the Forest Service is selecting superior yellow and paper birches as part of its tree-improvement program. So far about 30 superior yellow birches have been selected on the National Forests in Michigan and Wisconsin, and work with paper birch has been scheduled for Wisconsin and Minnesota. In Vermont and New Hampshire, about 20 superior yellow birches and 30 paper birches have been selected. Plans call for progeny testing of all selected trees before seedling seed orchards are established.[3]

The importance of progeny testing should be emphasized. As mentioned previously, certain yellow birches seem to produce much faster-growing progeny than others. Swedish studies of *B. pendula* and *B. pubescens* have shown that significant differences between individual tree progenies persist for at least 20 years after planting, and in some cases become more pronounced with time *(Johnsson 1967).*

EXPECTATIONS

Although much basic work on variation, inheritance patterns, characteristics to breed for, and crossing compatibilities remains to be done in *Betula,* the information accumulated so far justifies practical improvement efforts with the two most important commercial species, yellow birch and paper birch. We apparently have ample geographic variation to work with and, at least in yellow birch, much local variation. Since we know that intraspecific incompatibilities exist in these species, selected trees should be tested for compatibility as well as for transmittance of desired characteristics to their progeny. Until further tests have been conducted, we cannot say whether or not exotics will be important in birch improvement, either as species or as parents in interspecific hybrids.

We are naturally interested in increasing the growth rate and hence the wood produc-

[2] Clausen, K. E., and Godman, R. M. Bark characteristics as indicators of age and growth rate in yellow birch. USDA Forest Serv. Res. Note. North Central Forest Exp. Sta. (In press).

[3] Personal communication from J. A. Pitcher, USDA Forest Service, Milwaukee, Wis. January 1969.

tion of the birches, but the greatest benefit from genetic improvement will probably come from improved tree quality. The importance of improvement in tree quality can be illustrated by the latest Wisconsin sawtimber prices shown below (medium price per thousand board feet):[4]

Species	*Veneer log*	*No. 1 sawlog*	*No. 2 sawlog*
Paper birch . .	$150	$100	$55
Yellow birch. .	$227	$150	$62

Thus, an improvement in quality from No. 2 to No. 1 would almost double the price of a paper birch saw log and more than double the price of a yellow birch log. And improvement from No. 2 to veneer quality would almost triple the price of a paper birch saw log and more than triple the price of a yellow birch log. The difference in financial returns would be even greater if the growth rates were concomitantly improved by as little as 10 percent. Only through better quality will an investment in developing and planting genetically improved hardwoods pay off.

Tree-improvement work can be conducted on a less intensive scale than through an actual breeding program. Much improvement in tree quality can be accomplished through better silvicultural practices. Thus, if the forester will learn how to recognize high-quality and fast-growing birch trees and leave these as crop trees when making timber-stand-improvement cuttings or as seed trees when making regeneration cuttings, future tree crops will almost certainly be improved. However, this type of tree improvement does require that the forester look at individual trees rather than at the stand in general.

[4] Data from Wisconsin Forest Products Price Review, Fall 1968, Forestry Department, University of Wisconsin.

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