EARLY FLOWERING AND SEED PRODUCTION IN A YELLOW BIRCH PROGENY TEST

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Abstract.--Trees in a yellow birch progeny test began to bear seed when 7 years old and the proportion of fruiting trees increased in the following 2 years. Male catkins were produced at age 8 and the number of trees with males increased greatly the following years. Although there is much variation between and within families in earliness of flowering and in number of flowers and fruiting catkins, about one-third of the families have borne seed and 45 percent have produced males. The number of catkins per tree has ranged up to 429 for females, 196 for fruiting, and 1379 for males. Seed yield varied greatly between and within families, but 49 percent of the trees had between 100 and 200 seeds per catkin. Certain families and trees are more prolific than others and trees of northern origin appear to start flowering earlier and more heavily than those of southern origin. The early and heavy seed production of such early tree ages argues well for seedling seed orchards of this species.

Additional keywords: Variation, seed yield, seed quality.

Early and abundant flowering is a prerequisite for rapid progress in breeding work with any tree species and regular, prolific seed production is essential for mass production of genetically improved material. However, little is known about age of flowering, seed production, and seed yield in yellow birch (*Betula alleghaniensis* Britt.) -- particularly in plantation-grown trees (Clausen 1973b). In this paper I report observations and data taken in our first progeny test with this species.

METHODS

Seedlings were grown in a nursery at Rhinelander, Wisconsin as previously described (Clausen 1973a) using open-pollinated seed of 10 trees from each of 21 stands representing a wide geographic range (table 1). In the spring of 1972, when the seedlings were 4 years old, a plantation was established near Lake Tomahawk in Oneida County, north-central Wisconsin. The site, a former potato field and pasture on Padus sandy loam, was clean-cultivated before planting. It was cultivated through the summer of 1975 and later moved. The plantation originally contained 8 progenies each of 16 stands plus

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Table 1.--Origin of 21 yellow birch stands and number of open-pollinated families included in observations.

Stand No.	Origin	Location		Number of families
		Lat.	Long.	
		deg.	deg.	
3241	Nova Scotia	46.6	60.5	8
3063	Nova Scotia	44.1	65.8	7
3066	New Brunswick	47.4	65.2	6
2998	Quebec	48.2	70.2	8
3000	Quebec	47.5	75.0	9
3004	Ontario	46.7	79.6	8
3309	Ontario	47.5	84.8	10
2977	Maine	44.8	68.6	8
2986	New Hampshire	43.5	71.4	4
2971	Massachusetts	42.7	73.2	5
3312	Pennsylvania	41.6	78.7	6
3299	Virginia	37.8	79.1	5
2959	North Carolina	35.7	82.3	4
2973	Georgia	34.8	83.8	5
2983	Illinois	41.9	89.4	9
2962	Wisconsin	44.9	87.2	8
4340	Wisconsin	45.6	88.6	8
2968	Wisconsin	46.5	92.1	9
2987	Michigan	47.0	88.7	10
2967	Minnesota	47.8	90.2	9
2964	Minnesota	44.2	94.1	9
Total				155

4 progenies each of 4 stands in 8 and 6 replications, respectively. Because many seedlings died the first year due to heat, late frost and disease, the surviving plants were consolidated into 4 blocks and supplemented with replacement plants. Additional families with small numbers of seedlings were used as border trees and are thus unreplicated. At present, the surviving number of families ranges from 4 to 10 per stand and totals 155 (table 1).

The trees were checked for the presence of fruiting catkins in the autumns of 1974, 1975, and 1976 and catkins were collected when present. The number of seeds per catkin was determined in up to 20 catkins per tree for the 1975 seed crop. Germination was tested in seed samples of all trees bearing fruit in 1974 and 1975. Male catkins, which in birch appear in the fall but do not shed pollen until the following spring, were counted on all flowering trees when present. The number of female flowering catkins per tree was counted in the spring of 1976.

RESULTS AND DISCUSSION

Age of Flowering and Fruiting.--Female flowering began when the trees were 6 years old from seed (Clausen 1975). At the end of their seventh growing season (fall 1974) 0.5 percent of the surviving trees had fruiting catkins (table 2). Male catkins first appeared in the fall of 1975 when 3.8 percent of the trees produced seed and 0.7 percent had male catkins (table 2). One-half of the trees with males also produced female flowers in the spring of 1976 and in addition, 2.8 percent of the trees had female catkins only (table 2) bringing the proportion of trees with female catkins at this time to 3.2 percent. Eight trees with female flowers in the spring of 1976 failed to develop mature catkins so only 67 trees or 3.8 percent had fruiting catkins the following autumn (table 2). More than one-half of these trees also produced male catkins and an additional 5.0 percent of the trees had males only. At. the most recent count, the proportion of trees with male catkins thus increased to 7.0 percent.

Trees of northern origin began to bear seed at an earlier age than those of southern origin. With the exception of one tree from Illinois and one from southern Minnesota, all fruiting trees in 1974 were of northern origin (latitude 45°N or above). The 12 northern stands produced an average of 4.7 fruiting trees per stand in 1975 compared with 3.8 trees for the 9 southern stands. In 1976 the averages were 3.5 and 2.8 trees, respectively. The difference between the two groups was less pronounced in the spring of 1976 when the northern stands averaged 3.7 trees with female catkins and the southern stands averaged 3.4 trees. The number of trees per stand with male catkins was about equal in the two groups in the fall of 1975 but averaged 6.6 trees in the northern stands and only 4.9 trees in the southern stands in the fall of 1976. Thus, trees of northern origin also appear to produce male catkins at an earlier age than those of southern origin.

Variation among Stands and Families.--In 1974, the first year that seed was produced, only 9 stands were represented but the number of stands with seed-bearing trees increased to 20 the following year (table 3). Thus, by the time the trees were 8 years old from seed (fall 1975), at least one tree from each of the 21 stands had produced seed. In 1976, 67 trees from 19 stands bore seed. Similarly, the number of stands with male catkins increased

Table 2.-- Incidence of flowering and fruiting in trees of different origins by years and seasons.

Stand No.	Origin	Number of Trees with Catkins 1/ Fall 1974 F	Fall 1975 M	Fall 1975 F	Fall 1975 M + F	Spring 1976 M	Spring 1976 F	Spring 1976 M + F	Fall 1976 M	Fall 1976 F	Fall 1976 M + F	No. live trees 1976
3241	NS	2	-	3	-	-	2	-	3	1	-	88
3063	NS	-	-	5	-	-	-	-	3	-	-	75
3066	NB	1	-	-	-	-	-	-	-	-	-	23
2998	PQ	-	-	2	1	-	1	1	5	1	1	109
3000	PQ	-	-	5	-	-	3	-	1	2	1	162
3004	ON	-	-	1	-	-	1	-	8	1	-	86
3309	ON	1	1	3	-	1	2	-	8	-	2	112
2977	ME	-	-	4	-	-	6	-	1	3	3	62
2986	NH	-	-	4	-	-	4	-	-	2	2	22
2971	MA	-	-	1	-	-	1	-	-	-	1	9
3312	PA	-	-	2	-	-	3	-	-	1	1	24
3299	VA	-	-	3	-	-	2	-	4	-	2	36
2959	NC	-	-	2	-	-	1	-	3	1	-	23
2973	GA	-	-	2	-	-	2	-	-	1	1	14
2983	IL	1	3	4	1	2	9	2	5	4	4	129
2962	WI	-	1	7	-	-	8	1	8	6	3	113
4340	WI	1	-	5	-	-	4	-	3	3	1	107
2968	WI	1	-	6	-	-	5	-	6	1	4	82
2987	MI	1	2	10	3	3	3	2	9	1	3	164
2967	MN	4	-	5	1	-	-	1	6	2	3	111
2964	MN	1	2	9	1	2	5	1	15	2	3	167
7077	MI 2/	-	-	-	-	-	-	-	-	-	-	38
Total		13	9	83	7	8	67	8	88	32	35	1756

1/ M - male; F - female
Note that male catkins present in the fall represent next year's crop.

2/ Border trees obtained from Toumey Nursery, Watersmeet, Michigan.

Table 3.--Number of families with flowering or fruiting trees by origin, year,, and season.

Stand No.	Origin	Number of Families with Catkins[1/]							
		Fall 1974		Fall 1975		Spring 1976		Fall 1976	
		Female	Male	Female	Male	Female	Male	Female	Male
3241	NS	2	-	2	-	2	-	1	2
3063	NS	-	-	3	-	-	-	-	2
3066	NB	1	-	-	-	-	-	-	-
2998	PQ	-	-	2(1)	1	2(1)	1	2(1)	3
3000	PQ	-	-	3	-	3	-	3(1)	2
3004	ON	-	-	1	-	1	-	1	5
3309	ON	1	-	3	1	2	1	2(2)	5
2977	ME	-	-	2	-	4	-	4(3)	4
2986	NH	-	-	2	-	2	-	2(2)	2
2971	MA	-	-	1	-	1	-	1(1)	1
3312	PA	-	-	2	-	1	-	1(1)	1
3299	VA	-	-	2	-	2	-	2(2)	4
2959	NC	-	-	1	-	1	-	1	2
2973	GA	-	-	2	-	2	-	2(1)	1
2983	IL	1	-	3(1)	4	4(2)	4	4(4)	5
2962	WI	-	-	4	1	5(1)	1	5(3)	6
4340	WI	1	-	4	-	3	-	3(1)	3
2968	WI	1	-	3	-	4	-	4(3)	4
2987	MI	1	-	2(1)	2	2(1)	2	1(1)	5
2967	MN	3	-	4(1)	1	3(1)	1	3(2)	5
2964	MN	1	-	5(1)	3	4(1)	3	3(2)	8
Total		12	-	51(5)	13	48(7)	13	45(30)	70

1/ Figure in parenthesis = number of families with trees having both female and male catkins.

from 1975 to 1976 and those with both female and male catkins also rose from 5 in the fall of 1975 to 15 in the fall of 1976 (table 3).

Variation among the stands in the number of families with flowering or fruiting trees followed the geographic pattern described previously. The average number of families with female catkins was consistently higher in the 12 northern stands than in the 9 southern stands. The number of families with male catkins again differed little among the two groups in the fall of 1975 but showed a similar north-south difference in the fall of 1976.

Almost one-third of the families have borne seed so far (table 3). The number of fruiting families per stand ranged from none to 3 in 1974 and up to 5 in the other two years. Because 8 trees that had female flowers in the spring of 1976 did not set seed, three families with female flowers were not represented among the fruiting families in the fall (table 3). The number of families with male flowers increased from 13 in 1975 to 70 in 1976 or to about 45 percent of the families. Similarly, the highest number of male-flowering families per stand rose from 4 to 8 in the same period (table 3) .

Variation within Families .--The number of flowering or fruiting trees per family has varied with years, stands and families. In 1974, two trees of family 2967-4 from northeastern Minnesota bore seed, while the other 11 families had only one fruiting tree each. The following year most families had either one or two fruiting trees each but 5 families had three (table 4). In addition, family 2962-8 from northeastern Wisconsin had 4 fruiting trees, family 2964-7 from southern Minnesota had 6, and family 2987-4 from Houghton County, Michigan had 12. The last family was also an exception in having 4 trees bearing male catkins that year (table 4). In the spring of 1976, 42 families had one or two trees each with female flowers, 4 had three trees each, and 2 had four trees each. 2987-4 was again in the last group as was family 2983-6 from northern Illinois. Of the families producing seed in the fall of 1976, 91 percent had one or two fruiting trees per family and 3 families had three trees each (table 4). Only 2987-4 had 4 seed-bearing trees. The same family was also the only one that had 7 trees with male catkins. Another prolific family, 2964-7, had 5 trees with males as did family 2968-15 from northwestern Minnesota. Two families had four trees each and 8 families had three trees each but again, the greatest proportion of the families had only 1 or 2 flowering trees (table 4) .

Number of fruiting catkins per tree has varied greatly but shows some increase with time. Although most trees had less than 10 catkins the first year, one tree each had 14, 21, 44, and 51 catkins (table 5). In 1975 most trees had 25 or less catkins but 9 trees had greater numbers with a maximum of 196. Although 10 trees had more than 25 female catkins in the spring of 1976, abortion of catkins reduced the number of trees in this group to 5 by next autumn. Thus, the tree that had 429 female catkins in the spring produced only 188 mature catkins. Number of male catkins per tree has increased markedly from one year to the next. In 1975 the maximum number of male catkins found on one tree was 57 but in 1976, 27 percent of the trees had over 100 catkins and one tree had as many as 1379 (table 5). Certain stands and

Table 4.--Frequency distribution of families with flowering or fruiting trees.

Season	Number of Trees per Family								Total
	1	2	3	4	5	6	7	12	
	Number of Families								
Female catkins									
Fall 1974	11	1							12
Fall 1975	33	10	5	1	-	1	-	1	51
Spring 1976	29	13	4	2					48
Fall 1976	28	13	3	1					45
Male catkins									
Fall 1975	12	-	-	1					13
Fall 1976	40	17	8	2	2	-	1		70

Table 5.--Frequency distribution of flowering or fruiting trees.

Season	Number of Catkins per Tree									Total	Range
	1-10	11-25	26-50	51-100	101-200	201-300	301-400	401-500	500+		
	Number of Trees										
Female catkins											
Fall 1974	9	2	1	1						13	1-51
Fall 1975	61	20	5	3	1					90	1-196
Spring 1976	55	10	5	4	-	-	-	1		75	1-429
Fall 1976	55	7	3	1	1					67	1-188
Male catkins											
Fall 1975	9	3	3	1						16	1-57
Fall 1976	30	19	25	16	16	8	4	4	1	123	1-1379

families appear to contain more prolific trees than others. For example, the tree that had 429 female catkins and 188 fruiting catkins in 1976 belongs to family 2968-1 from northeastern Wisconsin, while the tree with 196 fruiting catkins in 1975 and the one with 1379 male catkins in 1976 both belong to family 2968-15.

Transplanting tends to increase flowering in many plants. The replacement and moving of trees that took place in this plantation could, therefore, have influenced earliness of flowering. Of the 13 trees that fruited in 1974, 11 had been replaced in 1973 and 2 were transplanted in 1974. However, in the following years the flowering and fruiting trees from different years of planting were in about equal proportions. Thus, 14, 12 and 11 percent of the trees planted in 1972, 1973, and 1974, respectively, have flowered or fruited. Transplanting, therefore, seems to have had little effect on earliness of flowering in this plantation.

Seed Yield and Seed Quality .--Effective seed yield depends not only on the number of seeds per fruiting catkin but also on seed quality. The number of seeds per catkin in the 1975 seed crop varied among stands, families, and trees (table 6). Thirteen families averaged less than 100 seeds per catkins, 30 families had between 100 and 200, and 7 families had more than 200. Because 34 families were represented by only one tree each, information on within-family variation is limited. However, among the 9 families with 2 trees per family, the difference between trees ranged from 2 to 121 percent of the mean, or in the latter case from 44 to 238 seeds per catkin. Within the 4 families with 3 trees each, the difference among trees ranged from 97 to 121 percent of the mean and in the families with 6 and 11 trees each, the difference amounted to 132 and 194 percent, respectively. Thus, the within-family variation appears, not unexpectedly, to increase with family size. Of the 85 individual trees sampled, 33 percent had less than 100 seeds per catkin, 49 percent had between 100 and 200, and 18 percent had more than 200. The extreme tree averages were 18 and 297 seeds per catkin. Variation among catkins within a tree was noted but appears to be less than that among trees. The highest number of seeds found in a catkin was 305.

Seed quality has so far been rather poor and could be a serious problem unless it improves in the future. Due to heavy-metal poisoned perlite, germination tests of the 1974 seed collections had to be repeated, but there was not enough seed of 4 trees for the second test. Seed of the remaining 9 trees had from 10 to 61 percent germination with only one tree having less than 30 percent.

In general, germination of the 1975 seed crop was poorer than it was the previous year. The average germination percentage ranged from 0 in 5 families and less than 10 percent in 26 families up to 38 percent in family 2983-6. Of the 85 trees, 8 had no germination, 44 had 10 percent or less and 31 had between 11 and 30 percent. Only two trees with 31 and 62 percent germination, respectively, exceeded the 30 percent level. In contrast, germination percentages exceeding 90 percent are common in yellow birch in good seed years (Clausen 1973b).

Table 6.--Average number of seeds per catkin in 1975 seed crop.

Stand		Number of Samples			Mean no. seeds per catkin	
No.	Origin	Families	Trees	Catkins	Families	Trees
3241	NS	1	1	2	112	112
3063	NS	3	4	21	87-166	87-166
3066	NB	-	-	-	-	-
2998	PQ	2	3	70	52-174	52-174
3000	PQ	3	5	22	30-128	18-168
3004	ON	1	1	10	190	190
3309	ON	3	3	10	106-152	106-152
2977	ME	2	4	24	95-208	43-208
2986	NH	2	4	34	129-181	71-218
2971	MA	1	1	10	235	235
3312	PA	2	2	5	59-112	59-112
3299	VA	2	3	31	112-163	94-163
2959	NC	1	2	5	116-181	116-181
2973	GA	2	2	20	45-77	45-77
2983	IL	3	5	49	69-131	51-131
2962	WI	4	7	16	92-297	58-297
4340	WI	4	5	37	63-228	44-238
2968	WI	3	6	58	79-220	62-244
2987	MI	2	12	146	116-179	64-289
2967	MN	4	5	49	142-238	142-240
2964	MN	5	10	51	94-295	50-295
Total		50	85	670		
Range					30-297	18-297

Some of the poor seed quality may be due to phenological problems. For example, the lack of germination in the seed of the two trees from Georgia (stand 2973) is probably due to the fact that these trees flower later than most of the other trees in the plantation and thus are likely not to be pollinated. Trees of other southern origins such as North Carolina stand 2959 and Virginia stand 3299, tend to be late-flowering and may also be out of phase with the majority of the trees. They have, in fact, only produced seed of very poor quality so far.

Poor germination may simply reflect a lack of filled seed. How much of the seed was filled in the two years is unknown but we intend to check on that in the coming years by means of X-ray photography. The relatively poor seed quality is possibly due to a lack of pollen. None of the test trees produced male catkins in the spring of 1975 so the pollen had to come from the surrounding area where yellow birch is neither very close nor very common. Similarly, the number of male catkins present in the spring of 1976 was too small to ensure adequate pollination. The quality of the current seed crop, which has not yet been tested, may, therefore, also be poor. The large number of male catkins present this fall should, however, produce an abundance of pollen next spring. Assuming that we also have a good crop of female flowers, which seems likely after last summer's drought, and also escape inclement weather during the flowering period, the quality of next year's seed crop should improve. If it does not, we will have to look for other causes of low seed quality.

CONCLUSION

The fact that yellow birch is capable of producing viable seed at age 7 and male flowers at age 8 is an encouraging indication that seedling seed orchards should work well with this species. It also means that we should be able to start two-parent progeny tests fairly quickly and move on to second generation selection and testing without a long delay in time.

Another encouraging finding is that we can expect substantial seed crops on trees less than 10 years old. Since almost one-half of the trees studied had between 100 and 200 seeds per catkin, it would seem safe to use these as average figures. Thus, a tree with 100 catkins can easily produce between 10,000 and 20,000 seeds. Although catkin size is known to vary greatly among individual yellow birch trees (Clausen 1968), we don't know whether the number of seeds per catkin depends on catkin size. If we can demonstrate such a relationship as this study continues, we might be able to increase seed yield by selecting trees with larger catkins.

Effective seed yield remains a problem due to the poor seed quality but that may improve with the expected increase in pollen production in future years. At the Lake Tomahawk test location, it is apparent that trees of northern origin tend to flower earlier and more profusely than those of southern origin. It is also clear that certain families and certain trees are more prolific than others. We will continue to study the trees in this progeny test in order to see whether these variation patterns will change with time.

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