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Yield and quality of seed from YELLOW BIRCH PROGENIES

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KEY WORDS: Provenances, climate catkin dimensions, correlations, pollination, phenology, germination.

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YIELD AND QUALITY OF SEED FROM YELLOW BIRCH PROGENIES

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Seed production in open-grown yellow birch (*Betula alleghaniensis* Britt.) was found to begin at age 7 and to increase with age and size of the trees (Clausen 1977). Although earliness of fruiting and proportion of fruiting trees varies among and within families, the presence and abundance of catkins is mostly determined by the size of the tree crowns (Clausen 1979). However, early and abundant production of fruiting catkins will not necessarily result in a good crop of viable seeds. The purpose of this study was to determine the yield and quality of the seed produced by these young trees and possible relations of catkin size and shape to these characteristics.

METHODS

Yellow birch progenies were planted as 4-year-old seedlings in the spring of 1972 near Lake Tomahawk in Oneida County, north-central Wisconsin. The site is on Padus sandy loam and was clean-cultivated through the summer of 1975 and then mowed (Clausen 1977). Trees were planted at a spacing of 8 x 8 feet (2.4 m) and the plantation contained 155 open-pollinated families in 4-tree square plots and 4 replications (table 1). Fruiting began in the fall of 1974 but the number of fruiting trees and families was not large enough for the study until the following year. Therefore, the data presented here are for catkins and seeds produced in 1975 and 1976.

In each year, fruiting catkins were collected and allowed to dry for several weeks before length and diameter of from 1 to 20 catkins per tree were measured. Each catkin was then broken apart and the number of seeds counted and recorded. In 1975, all seeds from a tree were mixed and a sample of 100 seeds drawn for use in a germination test. Four 100-seed samples per tree were counted out from the 1976 seed crop, placed on type M film, and exposed to soft X-rays (15 kV, 1mA, 80 sec.). The radiographs were examined and the number of seeds with normal-appearing ovules, small or faintly opaque ovules (probably inviable), and empty seeds recorded. Both the 1975 and 1976 seedlots were tested for germination during the following winter by placing the seed on moist perlite in Petri dishes, which were kept under 20-hr photoperiod in a greenhouse at 24C for 30 days.

The catkin data were subjected to analysis of variance using tree means and a one-way nested classification with unequal sample sizes. Catkin diameter/length and catkin volume were calculated because the number of seeds per catkin may be related to catkin shape and volume as well as to catkin dimensions. Catkin volume was determined as that of an ellipsoid. Simple correlations based on individual catkins were calculated in order to establish possible relations between catkin size, catkin shape, number of seeds per catkin, percent filled seeds, and percent germination. Exceptions were those involving 1975 germination data where only tree averages were available. All percentage values used in the calculations were first converted by arcsin transformation.

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

Stand No.	State or Province	Origin code	Location		Number of families
			Lat.	Long.	
			---------- *Degree* ----------		
3241	Nova Scotia	NS	44.6	60.5	8
3063	Nova Scotia	NS	44.1	65.8	7
3066	New Brunswick	NB	47.4	65.2	6
2998	Quebec	PQ	48.2	70.2	8
3000	Quebec	PQ	47.5	75.0	9
3004	Ontario	ON	46.7	79.6	8
3309	Ontario	ON	47.5	84.8	10
2977	Maine	ME	44.8	68.6	8
2986	New Hampshire	NH	43.5	71.4	4
2971	Massachusetts	MA	42.7	73.2	5
3312	Pennsylvania	PA	41.6	78.7	6
3299	Virginia	VA	37.8	79.1	5
2959	North Carolina	NC	35.7	82.3	4
2973	Georgia	GA	34.8	83.8	5
2983	Illinois	IL	41.9	89.4	9
2962	Wisconsin	WI	44.9	87.2	8
4340	Wisconsin	WI	45.6	88.6	8
2968	Wisconsin	WI	46.5	92.1	9
2987	Michigan	MI	47.0	88.7	10
2967	Minnesota	MN	47.8	90.2	9
2964	Minnesota	MN	44.2	94.1	9
Total					155

RESULTS

Seed Yield and Quality

Total seed yield was found to be determined by: (1) geographic origin, (2) number of seed-bearing trees per family, (3) number of fruiting catkins per tree, (4) number of seeds per catkin, and (5) climate. It may, therefore, vary greatly among and within families and from year to year.

Fruiting was poorest in yellow birch from the Maritime provinces. Trees of New Brunswick origin set no seed in either 1975 or 1976 and those from Nova Scotia stand 3063 did not fruit in 1976 (table 2). The best seed producers were generaly Wisconsin and Minnesota trees that originated within 250 miles of the plantation. Trees of northern origin (latitude 44.5° N or above) began to bear seed at an earlier age than those of southern origin (Clausen 1977). Seed yield followed a similar pattern (table 3). In both years, trees originating east of longitude 80° W averaged more catkins than western trees but had no more seeds per catkin. Geographic origin may thus have an effect on early seed yield in this species.

Fruiting trees accounted for 4 percent of the surviving trees in both 1975 and 1976. Among the seed-bearing families in 1975, the number of fruiting trees per family varied from 1 to 12 or from 2 to 20 percent of the trees (table 2). Families with few survivors had higher but atypical percentages of fruiting trees. In 1976, from 1 to 4 trees per family or from 3 to 12 percent of the trees fruited. Similarly, the number of catkins per tree ranged from 1 to 196 in 1975 and from 1 to 188 in 1976. The total number of fruiting families, trees, and catkins was greater in 1975 than in 1976, possibly due to a severe drought in 1976.

In 1975 the number of seeds per catkin averaged 139 and ranged from 30 to 297 in the 50 families. The 44 families fruiting in 1976 ranged from 9 to 306 seeds per catkin and averaged 151 (table 4). Families from different stands also showed much variation

Table 2.—*Incidence of fruiting in yellow birch trees from 21 origins in 2 years*

Stand No.	Origin	Fruiting in 1975 Families[1]	Trees per family	Catkins per tree	Fruiting in 1976 Families[1]	Trees per family	Catkins per tree
		Percent	*Number*		*Percent*	Number	
3241	NS	13	1	2	22	1	1
3063	NS	43	1-2	1-14	0	—	—
3066	NB	0	—	—	0	—	—
2998	PQ	25	1-2	2-60	12	1	4
3000	PQ	33	1-3	1-12	33	1	2-6
3004	ON	12	1	27	12	1	4
3309	ON	30	1	1-7	20	1	5
2977	ME	25	1-3	5-9	50	1-2	1-23
2986	NH	50	1-3	1-23	50	2	1-40
2971	MA	20	1	30	20	1	1
3312	PA	33	1	1-4	17	2	1-3
3299	VA	40	1-2	11-36	40	1	3-12
2959	NC	25	2	1-4	25	1	10
2973	GA	40	1	6-14	40	1	1-3
2983	IL	33	1-2	2-17	44	1-3	1-65
2962	WI	50	1-4	1-7	62	1-3	1-7
4340	WI	50	1-2	2-27	38	1-2	1-32
2962	WI	33	1-3	2-196	44	1-2	1-188
2987	MI	20	1-12	1-56	10	4	1-10
2967	MN	44	1-2	1-19	33	1-3	1-16
2964	MN	56	1-6	1-16	33	1-2	1-7
Total			85	1,031		65	672

[1]Fifty families fruited in 1975, 44 in 1976.

Table 3.—*Seed yield in yellow birch of northern and southern origin in 2 years*

Fruiting stands	Average number of catkins 1975	Average number of catkins 1976	Average number of seeds/catkin 1975	Average number of seeds/catkin 1976
11 northern	66	39	143	164
9 southern	35	28	134	132

with a range from 28 to 131 percent of the stand means in 1975 and from 8 to 178 percent in 1976. As expected, between- and within-stand variation among the individual trees was even greater (table 4), but neither stand nor family differences were statistically significant in either year. The number of seeds in individual catkins ranged from 4 to 305 in 1975 and from 3 to 399 in 1976. Variation among catkins within a tree was usually less than that among trees.

In contrast to the fair to good seed yield in both years, seed quality was generally poor. Average germination percentage of the 1975 seed ranged from 0 in 5 families and 10 percent or less in 27 families up to 38 in one family (table 5). Among the individual trees it varied from 0 in 8 trees and 10 percent or less

Table 4.—*Total seed yield in 1975 and 1976 seed crops of yellow birch families*

Stand No.	Origin	1975 families Seeds per catkin Mean	1975 families Seeds per catkin Range	1976 families Seeds per catkin Mean	1976 families Seeds per catkin Range
		Number			
3241	NS	112	112	250	250
3063	NS	121	87-165	—	—
2998	PQ	111	52-170	222	222
3000	PQ	85	30-128	196	174-219
3004	ON	190	190	180	180
3309	ON	136	106-152	84	9-160
2977	ME	159	108-209	118	45-211
2986	NH	155	129-181	120	64-175
2971	MA	244	244	59	59
3312	PA	85	59-112	110	110
3299	VA	138	113-163	164	158-170
2959	NC	148	148	171	171
2973	GA	61	45-77	125	125
2983	IL	105	69-131	137	84-189
2962	WI	173	108-297	134	108-166
4340	WI	126	63-228	163	131-222
2968	WI	152	73-220	187	119-283
2987	MI	157	135-179	98	98
2967	MN	182	142-238	177	22-306
2964	MN	156	94-295	168	124-192
Range of trees			18-297		9-314

Table 5.—*Germination of 1975 and 1976 yellow birch seed crops and filled seed percentage of 1976 seed*

Stand No.	Origin	1975 families Germination Mean	1975 families Germination Range	1976 families Filled seeds Mean	1976 families Filled seeds Range	1976 families Germination Mean	1976 families Germination Range
		Percent					
3241	NS	10	10	0	0	0	0
3063	NS	8	4-12	—	—	—	—
2998	PQ	4	0-8	12	12	0.2	0.2
3000	PQ	3	1-6	14	0-24	9	0-17
3004	ON	19	19	11	11	8	8
3309	ON	4	2-7	17	8-26	16	6-26
2977	ME	14	8-20	21	9-27	11	4-17
2986	NH	6	0-13	10	8-12	3	2-4
2971	MA	12	12	8	8	8	8
3312	PA	4	3-4	4	4	4	4
3299	VA	5	0-9	8	6-11	5	3-8
2959	NC	2	2	0	0	0	0
2973	GA	0	0	0.3	0.3	0	0
2983	IL	24	8-38	24	11-44	1	0.4-1.3
2962	WI	13	6-23	12	22	3	7
4340	WI	7	4-9	9	8-18	8	0-16
2968	WI	10	4-16	11	0-28	9	0-23
2987	MI	11	7-14	10	10	5	5
2967	MN	11	0-18	15	2-34	5	0-14
2964	MN	12	1-19	40	24-61	18	4-34
Range of trees			0-62		0-67		0-52

in 44 up to a maximum of 62 percent. As a result, the average germination was only 9 percent compared with 90 percent or better for mature trees in good seed years. The amount of filled seed in the 1976 seed,

as determined by X-radiography, averaged only 10 percent for the 44 families and was extremely variable (table 5). Six families had only empty seed while 34 families had 30 percent or less filled seed and 4 families had more than 30 percent. Twelve trees had no filled seed, 18 had up to 10 percent, 25 had 11-30, 6 had 31-50, and 3 had more than 50 percent filled seed. In contrast, filled seed percentages exceeding 90 percent are common in natural stands in good seed years. Germination percentages were generally lower than filled seed percentages and ranged from 0 in 8 families and less than 10 percent in 26 families up to 34 percent in 1 family (table 5). The best tree had 52 percent germination, but the average for the 1976 seed crop was only 6 percent.

Catkin Characteristics and Relations to Seed Yield and Quality

On the average, catkin length and diameter were greater in 1975 than in 1976 (table 6). The smaller catkin dimensions in 1976 may be due to the drought because moisture availability affects the size of plant parts (Kozlowski 1971). Much variation among stands, families, and trees was recorded in both years but the analysis of variance showed no significant differences among seed origins or families in either year. The 1975 analysis included 74 trees of 43 families from 20 stands while the 1976 analysis included 65 trees of 43 families from 19 stands. As shown previously, the analyses of number of seeds per catkin gave similar results. The lack of significance can probably be ascribed to the fact that unequal numbers of trees per family and of families per stands were used in the analyses with the attendant reduction in degrees of freedom. Because catkin dimensions were greater in 1975 than in 1976, both the diameter/length ratio and catkin volume followed the same pattern (table 6).

Table 6.—*Characteristics of catkins collected from 8- and 9-year-old yellow birch in 1975 and 1976*

Catkin characteristic	1975 families		1976 families	
	Mean	Range	Mean	Range
Length (mm)	24.3	13.3-36.3	21.1	12.3-34.2
Diameter (mm)	15.2	10.0-24.3	10.0	5.5-14.0
Diam./length	.629	.401-.902	.484	.269-.707
Volume (cm^3)	3.23	0.75-6.85	1.27	0.32-2.72

Correlations between catkin characteristics and seed yield were higher in 1975 than in 1976. In both years, number of seeds per catkin showed the closest relation to catkin length and catkin volume (table 7). One might expect a good correlation between catkin diameter and number of seeds because catkin diameter and volume were highly correlated in both years. This was true in 1975 but not in 1976. The apparent reason is that the catkins were proportionately thinner in 1976 as evidenced by the smaller diameter/length ratio in that year (table 6) and also by the poor correlation between catkin length and diameter, which contrasts to the close relation between them in 1976 (table 7). Catkin shape, as measured by the diameter/length ratio, was unrelated to catkin volume and was a fair to poor indicator of seed yield (table 7).

Of the characteristics measured, catkin length was the best indicator of potential seed yield but not of seed quality. Catkin length was poorly correlated with percent filled seed in 1976 and with seed germination in both 1975 and 1976 (table 7). The correlation between catkin length and percent germination was closer in 1975 than in 1976 as a result of the slightly better germination in 1976. The relation between seed yield and seed quality was poor. Number of seeds was uncorrelated with both percent filled seeds and percent germination in 1976 and only poorly correlated with germination percentage in

Table 7.—*Correlations between catkin characteristics, seed yield, and seed quality for 2 years*

Variables correlated	r[1]	
	[2]1975	[3]1976
Catkin length-catkin diameter	0.668**	0.117*
Catkin length-catkin volume	.820**	.522**
Catkin diameter-catkin volume	.944**	.868**
Catkin diameter/length-catkin volume	−.253	.131
Catkin length-No. seeds/catkin	.621**	.533**
Catkin diameter-No. seeds/catkin	.529**	.254**
Catkin volume-No. seeds/catkin	.574**	.422**
Catkin diameter/length-No. seeds/catkin	−.316**	−.273**
Catkin length-percent filled seeds	—	.280**
Catkin length-percent germination	.329**	.294**
No. seeds/catkin-percent filled seeds	—	−.042
No. seeds/catkin-percent germination	.271*	.041
Percent filled seeds-percent germination	—	.550**

[1]** = significant at 0.01 level; * = significant at 0.05 level.

[2]First 8 correlations based on 237 individual catkins; last 2 on 74-tree averages.

[3]First 8 correlations based on 307 individual catkins; last 5 on 155 catkins.

1975 (table 7). The correlation between percent filled seed and percent germination (0.55) was only fair, indicating that a portion of the filled seeds was not viable. Although most of the correlations are statistically significant, few of them show biologically significant relations.

DISCUSSION

These yellow birch trees were beginning to produce substantial amounts of seed by the time they were 8 and 9 years old. Total yield of an average tree was more than 1,500 seeds in both 1975 and 1976. Trees with high numbers of catkins produced correspondingly greater numbers of seeds. Seed yield will, of course, increase with time as the number of catkins per tree goes up and with further increases in the average number of seeds per catkin. In 1975, 18 percent of the trees had more than 200 seeds per catkin compared with 22 percent in 1976. Of the latter, 3 percent had more than 300 seeds per catkin.

Variation between and within families in seed yield was substantial but not statistically significant. The lack of significance appears to be due to the plant material and the nature of the data. Unequal sample sizes were used in the analyses because the number of fruiting trees per family and the number of fruiting families per stand varied so much in both years. Therefore, the degrees of freedom were reduced accordingly and even large differences were not significant.

The correlation analyses indicate that catkin length, and, to a lesser degree, catkin volume have a fairly good positive relation with number of seeds per catkin. Catkin diameter, however, appears to vary more from year to year than other catkin variables and thus is a less reliable estimator of potential seed yield.

Seed quality so far has not been as good as seed yield. Amount of filled seed was generally low, and seed germination in both years was less than 10 percent compared with percentages above 90 percent for mature yellow birch in good seed years (Clausen 1973). As a result, effective seed yield is still disappointingly low.

The poor seed quality noted in these young trees may be due to a lack of pollen. No male catkins were produced in the plantation in the spring of 1975 and of the 16 trees with male catkins in the spring of 1976 more than one-half had less than 10 catkins per tree (Clausen 1977). Thus, in both years most of the pollen had to come from the surrounding area where yellow birch is not common. Filled seed and germination percentages should improve as more trees begin to bear male catkins.

In addition, the flowering phenology of some of the trees may be a problem. Trees of southern origin flowered later and may, therefore, be out of phase with the other trees in the plantation. The lack of seed germination in the trees from Georgia and the poorly filled and poorly germinating seed of trees from North Carolina stand 2959 and Virginia stand 3299 suggest that these trees flower too late to be pollinated by trees of northern origin. On the other hand, the Wisconsin and Minnesota trees flower in synchrony with local pollen shed, and therefore, produced more and better seed.

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