SELECTION FOR PRECOCIOUS FLOWERING IN PINUS SYLVESTRIS

by Henry D. Gerhold'

The reproductive systems of forest trees that have evolved in wild habitats are usually characterized by delayed flowering age, cyclic seed years, and possibly an optimum, rather than a maximum, number of seeds per tree. Presumably these characteristics are favored by natural selection, though not necessarily in all species or in all situations.

During the development of a cultivated variety from wild populations, man may drastically change the reproductive system of a species, and the environment in which it grows. The new forces in man's scheme of selection — controlled mating and artificial regeneration — will tend to multiply genes that favor seed production at an earlier age, at more regular intervals, and in larger amounts, unless counter measures are taken. This raises questions about the effectiveness of these forces in altering features of seed production, as well as the desirability of any change they may bring about.

Earlier and increased fruitfulness has some obvious potential advantages for genetic experiments, for breeding improved varieties, and for mass-producing improved seed (see Green & Porterfield 1962; Matthews 1963; Schrock 1949; Wright 1964). The advantages increase as rotations become shorter, as growth rates improve, and as juvenile selection becomes more feasible. They must be weighed against any adverse effects on yield or quality that accompany increased seed productivity.

This paper reports on flowering characteristics of young Scotch pines, and attempts to organize our present knowledge about precocious flowering in *Pinus sylvestris,* with reference to breeding improved Christmas tree varieties. In such a program, both selection and breeding can start by age 7. While this is not typical of tree breeding programs in general, it may serve as a useful example to give us some insight into a problem that we may face in the future with other species.

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Materials and Methods

Two categories of trees were studied. The largest group consists of 34 open-pollinated families, most of which are progenies of plantation or ornamental trees selected for Christmas tree properties. Many of the seed parents were less than 30 years old, and thus there may have been some mild, but not intentional, selection favoring precocious flowering. Unfortunately there is no provenance information for these trees, but it is likely that countries such as Scotland, France, Germany, and Poland may be represented. Two-year-old seedlings grown at Washington Crossing, N.J., were planted in 1959 in 30 randomized blocks at each of 3 locations in Pennsylvania (also at 3 locations in New Jersey and 3 in New York). They are now 8 years old from seed.

The second category consists of a commercial variety named "Nye Branch", which was included in the same experiment. The only difference in handling was that these seedlings were raised at the Nye Branch Nursery, Porter, Penn. The variety has been derived from a single plantation of unknown origin. In three subsequent generations seed has been collected from the numerous young trees that flowered in Christmas tree plantations, so that a type of mass selection for precocious flowering has been practiced inadvertently. The seedlings in the experiment probably came primarily from the second generation, and may have contained admixtures from the first and/or third generations, although this cannot be stated with complete certainty. The original plantation was crowded and its seed production was low. The first generation may have flowered less than the second or third generations (according to the recollections of the present nursery owner), and these flower abundantly while still very young; but there have been no definitive measurements of any increase in flowering. Currently reverse selection is being practiced, and this may in time yield some interesting comparisons.

In the three Pennsylvania progeny test plantations, every individual was inspected periodically for the presence of ovulate and staminate strobili. Quantitative estimates were made on June 9, 1965, at the University Park plantation. [2]

Discussion of Results

Precocity of flowering may be measured in various ways, including age at which flowering begins, proportion of trees flowering in early years, and abundance of flowers on young trees. The numbers of trees that have flowered at three locations are shown in table 1. Very few flowered by age 4, after which there was a fairly steep increase

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Table 1.--Number of Scotch pine trees flowering at 3 Pennsylvania locations (based on 1050 trees at each)

Age from seed	Univ. Park		Hallston		Akeley	
	Female	Male	Female	Male	Female	Male
3	2	-	-	-	-	-
4	3	-	51	-	17	1
5	41	0	212	1	48	0
6	60	-	144	-	166	-
7	377	13	645	35	230	17
8	790	186	-	-	-	-

in the proportion of trees with ovulate strobili. By age 8, 75 percent of the trees at University Park were flowering, but less than 20 percent produced pollen, and most of these yielded rather small amounts. This pattern is in general agreement with other reports in the literature (Mergen 1961; Righter 1939; Sarvas 1962; Schrock 1949; Wright 1964). However, native Scotch pine in Scandinavian countries is reported to flower only at more advanced ages (Johnsson 1964), and Schrock (1949) has made the same claim for East Prussia, attributing the precocious flowering of certain trees to hybridization with introductions from France. It should be noted that a cyclic pattern appears only in the Hallston data, and that a maximum has not been reached at any of the locations, especially not in male flowering.

In 9 of the 34 families at University Park, more than 90 percent of their members bore female strobili at age 8, but only 1 family had male strobili on more than half of the trees. In 3 families less than 40 percent of the trees had female strobili. Every Nye Branch tree bore ovulate strobili, and over 90 percent had staminate strobili.

Some differences associated with location are illustrated in table 2. The values reflect not only the tendency to flower at an early age, but also the consistency of flowering during a 4-year period. The number of trees with conelets at Hallston, where the trees were tallest, was over twice

Table 2.--Cumulative number of conelet-bearing trees in Scotch pine families during 4 years at 3 Pennsylvania locations (based on 30 trees per open-pollinated family or variety, 1961-1964)

Family or variety	Location		
	Univ. Park	Hallston	Akeley
Average, 34 families	13	27	12
Range, 34 families	0-36	2-60	0-41
Nye Branch variety	54	76	61
Family number:			
24	6	5	11
11	0	30	12
17	10	34	1
31	17	20	6

as great as at University Park or at Akeley. The Nye Branch variety had 3 to 5 times as many flowering trees as an average family, and 1¼ to 1½ times as many as the most prolific family. Of the 34 families, 23 clearly conformed to the average pattern, that is, they had a high value at Hallston and much smaller, roughly equal values at the other two locations. The four families in table 2 differed most strikingly from the average pattern, indicating considerable interaction between environmental factors associated with locations and flowering precocity measured in this way.

The number of ovulate strobili per flowering tree is also of interest. At University Park in 1965, individual trees bore from 1 to an estimated 270. Of 920 trees, 235 had none, 360 had 1 to 10, 283 had 11 to 100, and 42 trees had over 100 ovulate strobili, 11 of these being Nye Branch. The family averages (number per flowering tree) ranged from 3 to 62, with a grand average of 27, while the comparable value for Nye Branch was 97. Families that bore large numbers of strobili also tended to begin flowering at an early age, but this does not necessarily indicate pleiotrophy or linkage. The association could easily result from similar selection pressures.

Clearly, there is in this species considerable variation in precocity, consistency, and abundance of female flowering upon which selection may operate. The variation can have significant genetic, environmental, and interaction components, and these must be evaluated for any trees that are to be subjected to artificial selection favoring or discriminating against these traits. The experimental design should provide for testing over a period of years, and probably at several locations. The data collection procedure should take into account the initial steep rate of increase in flowering within a few years, and the fact that different families and individuals may pass through this stage at different times. Some of the differences may be rather temporary, and these may be important in some situations but not in others.

The magnitude of the response to selection for precocious flowering is as yet unknown. The extreme values of the Nye Branch variety suggest that it could be very large, for the selection in that case has not been very intensive. However, we have no reference point for comparative purposes. Nevertheless, the startling fact remains that a Scotch pine variety exists, and may have been created with man's help, in which 90 percent or more of the trees at each of three locations have produced unexpectedly large numbers of ovulate strobili by age 7. It is quite possible that similar precocious varieties can be found or created in other species which also do not normally flower at an early age.

Does precocious flowering have adverse effects on yield or quality? No simple answer is possible at the present time. In our material there was a positive, but not close, correlation between height and number of ovulate strobili. This probably does not mean that the more prolific trees are inherently faster growing, but merely that among young flowering trees, those with larger crowns are able to produce more flowers. They may also be too young to show any effect. Schrock (1949) has reported that there was no significant difference in height or diameter between early-flowering Scotch pines 18 to 24 feet high and the non-flowering trees in the same plantation. Among eucalypt species planted in Italy, some of which produced seed at 3 to 5 years of age and at age 10 are up to 60 feet tall, there did not seem to be any correlation between growth rate and age at which flowering began, according to E. Giordano (personal communication). Even if adverse effects on growth are found in the future, they will not necessarily be large or apply to all cases (e.g., see Stern 1963).

Precocious flowering can have undesirable effects on the quality of Scotch pine Christmas trees. Male strobili are formed at the expense of needle fascicles, and when there is a large crop, branches can look rather bare. The presence of cones may have some sales appeal, but when they open at night in a warm living room, the crackling noise can be disturbing to light sleepers. Although these disadvantages are real and not to be dismissed lightly, they probably can be circumvented with some ingenuity.

Conclusion

In my opinion, efforts to exploit precocious flowering could be extremely rewarding, without too great a risk of detracting from yield or quality if reasonable safeguards are incorporated. A small number of such attempts certainly could be justified by producing precociously flowering varieties for use in basic research, for example in theoretical genetic studies requiring several generations, or investigations of the physiology of flowering. They would also have value for tree breeding applications, if deleterious side effects are found to be non-existent, or small enough to be tolerated. The time barrier is one of our chief problems in timber production, especially in tree breeding, and precocious flowering is one promising means of overcoming it.

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