# POTENTIAL SEED PRODUCTION FROM A WHITE SPRUCE CLONAL SEED ORCHARD

HANS NIENSTAEDT and RICHARD M. JEFFERS 1

One objective of tree improvement programs is mass production of genetically superior seed. Such seed is usually collected in grafted or in seedling seed orchards from selected trees. White spruce *(Picea glauca* (Moench) Voss) is widely planted in the Lake States, and seed orchards are now being established to produce genetically superior seed. What will these orchards yield? We present here some early answers to this question. Our results are limited to clonal orchards.

Wright (1964) reported that moderate numbers of cones can be found occasionally on 6- to 10-year-old white spruce and that most trees produce cones in quantity by the time they are 10 to 15 years old. Planted white spruce in northeastern Wisconsin apparently do not produce moderate cone crops until they are much older. For example, in an unfertilized planting of trees 21 years old from seed, only 10 out of 23 selected trees could be included in a pollination program requiring a minimum of 10 pollination bags per tree .2

There are several reports in the literature on the potential seed production from grafted material of other species. Among these are cone and seed production of 12-year-old grafted Scotch pine (Hadders and Ahgren 1958), cone and seed yields from pine seed orchards (Johnsson 1961), and production of Norway spruce seed in orchards (Ruden 1961). Johnsson reported considerable variation among clones of Scotch pine in the number of cones and seed produced per clone. Van Buijtenen (1966) reported on the effect of spacing, fertilization, and cultivation on flowering and seed production in loblolly pine. To our knowledge there are no reports on potential seed production from white spruce clonal orchards.

## Material and Methods

Twelve white spruce trees were selected from a 1926 plantation near Keshena in Menominee County, Wis. Scion material was collected from the upper third of the crowns of the four tallest trees (which had poor form), four dominant trees, and four intermediate or suppressed trees (table 1). Grafts were made in the greenhouse on potted white spruce root stock in April 1959. The grafts (ramets) were transferred to the nursery in 1960 and were used in establishing a small planting near Rhinelander, Wis., in 1963. A randomized block design with four replications was used. Each clone was represented by a 4-ramet line plot; the spacing was 8 feet between ramets and 10 feet between rows. Each graft was fertilized with approximately 4 ounces of 10-10-10 in July 1963 and again in 1964. On June 15, 1964, weeds were killed with a herbicide.

The number of cones produced by each ramet was counted 6 and 9 years after grafting. Analysis of variance was used to determine if significant differences were present among replications and clones.

In 1967 the fast-growing and dominant clones were

TABLE 1.—*Ortet description and cone production of white spruce clones 6 and 9 years after grafting.*

| Class [1] | Clones | Ortet description | | Average number of cones per ramet[2] | |
|---|---|---|---|---|---|
| | | D.b.h. | Height | 1964 | 1967 |
| | *Number* | *Inches* | *Feet* | *Number* | *Number* |
| F | 1885 | 9.30 | 48.6 | 18 | 122 |
| F | 1887 | 9.48 | 50.4 | 5 | 49 |
| F | 1889 | 7.32 | 46.0 | 11 | 50 |
| F | 1890 | 8.72 | 46.0 | 9 | 128 |
| D | 1886 | 7.89 | 39.0 | 23 | 53 |
| D | 1888 | 8.33 | 45.0 | 17 | 92 |
| D | 2517 | 7.18 | 43.0 | 21 | 115 |
| D | 2518 | 8.09 | 45.0 | 1 | 44 |
| I | 2519 | 4.22 | 32.5 | 34 | 147 |
| I | 2520 | 4.26 | 31.5 | 45 | 183 |
| I | 2521 | 4.43 | 35.0 | 25 | 90 |
| I | 2522 | 4.30 | 32.0 | 35 | 108 |

[1] Class F = fastest growing, poor form; D = dominant, good form; I = intermediate.

[2] Average of 16 ramets.

1 The authors are principal and associate plant geneticist, respectively, U.S. Dep. Agr., Forest Service, North Central Forest Exp. Sta., Inst. of Forest Genetics, Rhinelander, Wis.

2 Unpublished data on file at North Central Forest Experiment Station, Rhinelander, Wis.

control-pollinated with a pollen mixture. All seeds were extracted from the resulting cones and from open-pollinated cones collected from the same clones. After removal of small seeds, which were empty, samples of the large seed were X-rayed to determine the percent of filled seed.

## Results and Discussion

*Clonal Characteristics:*-Significant differences in cone production were present among clones (0.005 level) and replications (0.05 level) in 1964 (6 years after grafting), and among clones (0.05 level) but not among replications in 1967 (9 years after grafting). In 1964 the cone production among clones varied from an average of 1 to 45 cones per ramet, with the best ramet producing 126 cones. In 1967 the cone production among clones varied from an average of 44 to 183 cones per ramet, with the best ramet producing 473 cones. The correlation between average cone production in 1964 and 1967 was high (r = 0.733, 0.01 level) ; in other words, clones that produced well in 1964 also did so in 1967.

The data suggest that the slower growing parents were the most prolific cone producers. The average number of cones per ramet by clonal class was as follows

| Clonal class: | *1964* | *1967* |
|---|---|---|
| Fastest growing parents | 11 | 87 |
| Dominant parents | 15 | 76 |
| Fastest growing + dominant parents | 13 | 82 |
| Intermediate parents | 35 | 132 |

pollinated clones are compared (table 2).

Two important facts are clear: (1) The seed yield per cone is a highly variable clonal characteristic, and (2) the yield of filled seed per cone can be increased as much as 100 percent through the use of controlled pollination. Both are important in seed orchard management.

TABLE 2.—*Yield of filled seed*[1] *in 1967*

| Class | Clone number | Open-pollinated | | Control-pollinated | |
|---|---|---|---|---|---|
| | | Seeds per cone | Filled seeds per cone | Seeds per cone | Filled seeds per cone |
| F | 1885 | 69 | 20 | 43 | 28 |
| F | 1887 | 46 | 12 | 55 | 22 |
| F | 1889 | 64 | 23 | 77 | 46 |
| F | 1890 | 94 | 41 | 100 | 80 |
| D | 1886 | 88 | 32 | 83 | 51 |
| D | 1888 | 70 | 40 | 72 | 70 |
| D | 2517 | 87 | 23 | 65 | 20 |
| D | 2518 | 81 | 18 | 79 | 45 |
| Average | | 75 | 26 | 72 | 45 |

[1] All seed less than 1 mm. in diameter were excluded.

A seed orchard established for mass production of superior seed rather than for research purposes would, of course, have included only the dominant and fastest growing parent selections. Nevertheless, the data suggest that clones that have slow vegetative growth are heavy cone producers. This relationship would be an important consideration in white spruce selection and seed orchard management. Cone production and vegetative growth on grafts should be routinely studied in established clonal seed orchards.

Potential seed production in a seed orchard is a function of the yield of cones per ramet and the yield of filled seed per cone. The yield of filled seed per cone varies depending on the genetic and physiological conditions of the female parent or ramet, the amount of available pollen and the weather during pollination, and the amount of subsequent insect damage. The seed yields per cone of the eight control

The differences among clones are undoubtedly related to their genetic makeup and to the micro-environments of the individual ramets. The variation emphasizes the importance of keeping careful records of the seed yield of individual clones when they first start to produce seed. Clones, such as No. 1887, which produced few cones with many empty seed, may be culled from the orchard. (Some vigorous, high-quality clones might be retained if they are good pollen producers, even if they are poor seed producers.)

The increased yield of filled seed per cone as a result of controlled pollination suggests that in the first seed years, when the pollen supply is low, artificial pollen release may be needed to increase the yield of filled seed.

*Potential Seed Yield.*-We computed potential seed yields for several seed orchard spacings (table 3). These were based on the open-pollinated and controlpollinated yields of filled seed per cone (table 2) and on an average number of cones per ramet of 82.

Relatively small seed orchards of white spruce can produce large numbers of seeds and seedlings at an early age. Assuming that 80 percent of the filled seed will produce plantable seedlings, 7 acres of seed orchard planted at a spacing of 30 by 30 feet will

produce 1 million seedlings provided adequate pollen is available. Initial spacing in white spruce orchards may be 15 by 15 feet with subsequent thinning to 30 by 30 feet. At the closer spacing, a 7-acre orchard in a good seed year could, on the basis of our results, yield enough seed for 4 million seedlings less than 10 years after grafting.

In evaluating production potential, the periodic nature of seed crops and climatic conditions should be considered. Both 1964 and 1967 were good seed years, while 1965 and 1966 were relatively poor. Good white spruce seed crops can be expected every 2 to 6 years (USDA Forest Service 1948). In managed orchards, good crops every second or third year might be a good estimate. While we believe the estimates (table 2) to be conservative, it should be kept in mind that this study was limited to 12 clones and a single planting. Better estimates of potential production from white spruce seed orchards must await data from a large number of clones established in a range of environments.

TABLE 3.—*Expected yield of cones and filled seed per acre of orchard during a good flowering year, for fast-growing and dominant selections*

| Spacing (feet) | Cones per acre | Filled seed per acre | |
|---|---|---|---|
| | | Open-pollinated | Control-pollinated |
| | *Number* | *Number* | *Number* |
| 15 by 15 | 15,672 | 410,606 | 711,509 |
| 20 by 20 | 8,489 | 222,412 | 385,401 |
| 25 by 25 | 5,224 | 136,869 | 237,170 |
| 30 by 30 | 3,918 | 102,652 | 177,877 |

## Literature Cited


Hadders, G., and Ahgren, A.
1958. Kott-och froproduktion samt frokvalitet hos 12'eriga ymptrad av tall. (Cone and seed production and seed quality of 12-year-old grafted Scots pine). Svenska Skogsv: Foren. Tidskr. 56(4): 455-468.

Johnsson, H.
1961. Kottskord och frotbyte fran froplantager av tall. (Cone and seed yields from pine seed orchards.) Svenska Skogsv: Foren. Tidskr. 59(l): 1-21.

Ruden, T.
1961. Er det ngdvendig 'a pdskynde arbeidet med skog-froplantasjene? (Is it necessary to speed up work on seed orchards?) Norsk Skogind. 15(12): 570-575.

USDA Forest Service.
1948. Woody plant seed manual. US Dep. Agr. Misc. Publ. 654, 416 p.

Van Buijtenen, J. P.
1966. The effect of spacing, fertilization, and cultivation on flowering and seed production in loblolly pine. Eighth Southern Conf. on Forest Tree Improv., Savannah, Ga., June 16-17, 1965. P. 141-146.

Wright, J. W.
1964. Flowering age of clonal and seedling trees as a factor in choice of breeding system. Silvae Genet. 13 (/Y): 21-27.