JACK PINE SEEDLING SEED ORCHARD ESTABLISHMENT AND PROJECTED SEED YIELDS

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ABSTRACT.--Jack pine test plantings of open pollinated progenies from proven seed sources can be converted to seedling seed orchards. A combined selection index based on individual as well as family performance can be used to select the best individuals to retain in the orchards. Use of the index will result in retention of more families than under alternate schemes and permit more rigorous selection within families. A broad genetic base is maintained, the dangers of inbreeding are reduced, and the greatest genetic gain is assured. This scheme was applied to a set of data from a 90-seed-source test, a complement of seed sources was selected, and flowering and cone data from these seed sources were used to predict early seed yields in jack pine seedling seed orchards. After initial thinning, 1 hectare of orchard established according to the suggested scheme may yield 266.8 M full seed annually. This is probably a conservative estimate.

When grown under short rotation on good sandy soils, jack pine grows rapidly and produces a greater volume of pulpwood than red pine (Wilde *et al*. 1965). Although small amounts of jack pine are being planted in the Lake States, it is expected to play an increasing role in Lake States planting programs as the demand for paper and paper products increases (King 1973).

Jack pine grown under standard nursery and field conditions produces male and female strobili at 3 to 6 years of age. However, by forcing growth with long photoperiod, fertilization, and wide spacing in the greenhouse and nursery, flowering can be advanced to as early as 17 months after sowing seed (Rudolph 1966, Jeffers and Nienstaedt 1972). Thus, the time between sexual generations in jack pine can be reduced to less than 3 years (Rudolph 1966). With rapid generation turnover, repeated cycles of selection, progeny testing, and breeding can be used to genetically improve jack pine in a short time (King 1973).

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Establishing seedling seed orchards appear to be the best method for mass producing genetically improved jack pine because this species flowers at an early age and presents serious graft incompatibility problems.[2]

Methods for establishing jack pine seedling seed orchards have been suggested by King (1973), Yeatman (1974a) and Klein (1974). This paper includes a brief outline of their schemes. Results obtained from a nursery and field test of jack pine seed sources are used to describe an alternate scheme and to estimate projected early seed yield from the seed orchards.

JACK PINE SEEDLING SEED ORCHARD ESTABLISHMENT

King's Method

King's (1973) scheme begins with selecting--on the basis of seed source tests--the better seed collection areas for the planting region. Between 300 and 400 trees are chosen--no more than 15 individuals per stand--and open-pollinated seed collected and sown in a replicated nursery test. After 2 years' nursery growth, the 200 fastest growing families are selected and used to establish 2 or 3 test plantings on different sites in the planting area. The progeny test plantings are converted to seed orchards when the trees begin to bear regular pollen and cone crops--about 7 to 8 years after field planting. The plantings are measured at this time and thinned by removing all trees from below-average seedlots and some of the poorer trees from above-average seedlots. The plantings are remeasured at age 12 to 14 years and thinned to leave 1 out of every 4 trees of the best 25 seedlots.

Yeatman's Method

Yeatman (1974a) suggests improving the natural populations for seed collection by converting seed production areas into seedling seed orchards. When original stands are cut, replant them with local plus-tree progenies. Yeatman recommends systematically sampling 100 to 200 plus-trees on a unit area basis to avoid selecting close relatives. Selected trees are grafted and included in breeding archives. Open-pollinated progenies are used in first generation orchards followed by controlled-pollinated families (full-sib) from selected parents. Parents are selected for their breeding value determined initially from clonal tests (stem and branch form) and subsequently from progeny tests (survival and growth). Small half-sib family plots are initially established at 1.0 to 1.5 m spacings. A two-stage thinning operation is used: first thinning at 6 to 8 years to about half the original stocking, and second thinning at 11 to 14 years. Ultimately, 30 to 50 percent of the families are selected and family plots are thinned to a single tree per plot.

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[2] Unpublished data on file at the Institute of Forest Genetics, North Central Forest Experiment Station, Rhinelander, Wisconsin.

Klein's Method

Klein (1974) reports a design composed of 20 half-sib families, that have little or no co-ancestry from each of 11 geographic areas. The orchard consists of 24 blocks; each block contains 11 plots (area collections); each plot contains one tree from each of the 20 half-sib families from each area collection. Selection thinnings ultimately reduce the number of trees to one per plot. After thinning, each block contains 11 trees, each from a different area; thus, mating occurs predominantly among sources.

My Method

The scheme I suggest follows King's (1973) closely, deviating only in the selection processes used to rogue the orchards. All families are field tested and selections are based on a combination of seed source, family and individual tree performance. Some outstanding individuals within below average families may be selected but more families are included in the orchards and the dangers of inbreeding are reduced.

The scheme will be applied to a set of data from a 90-seed-source test, a complement of seed sources will be selected, and flowering and cone data from these seed sources used to predict early seed yields in jack pine seedling seed orchards.

THE EXAMPLE SEEDLING SEED ORCHARD

Seed Source and Parent Tree Selection

The 20 most promising seed sources were chosen in our northern Wisconsin planting. of the rangewide seed source study initiated by the Canadian Forestry Service, Petawawa Forest Experiment Station at Chalk River, Ontario, in 1962 (Yeatman 1974b),(Table 1). Total heights of the trees from the 90 seed sources at age 11 was the sole selection criterion. The local source from Nokomis, Wisconsin, (2233) ranked 13 among the 20 selected sources. Trees from the Cloquet, Minnesota, source (2242)--the best of the 20 seed sources--were about 9 percent taller than those from Nokomis, while the poorest trees from the Constance Bay, Ontario, source (2208) were about 4 percent shorter than local trees.

For our purpose, the procedure used rather than the actual seed sources selected is the important point. In a seed source study of 90 to 100 sources 'tested at a single location in the planting area, we should select 10 to 25 of the most promising sources for retesting at additional test locations in the planting region. Inclusion of material from 10 or more sources will help to assure a broad genetic base for advanced generation breeding. And increased adaptive variability may result from crosses between individuals with different adaptive characteristics (Zobel 1971).

Table 1.--Projected seed yield from a young jack pine seedling seed orchard[1]

Source No. IFG	Source No. PFES	State or Province	Local Name	Lat. °N	Long. °W	Female strobili[2] tree	Female strobili[2] ha	Cones[3] ha	Seed[4] ha
2242	3279	MN	Cloquet	46.7	92.6	10.8	1,728	864	21,600
2230	3267	WI	Nekoosa	44.3	89.7	2.8	448	224	5,600
2236	3273	MI	Marl Lake	44.5	84.7	4.7	752	376	9,400
2231	3268	WI	Waupaca	44.3	89.0	8.6	1,376	688	17,200
2241	3278	MN	Brainerd	46.3	94.2	5.1	816	408	10,200
2211	3247	QUE	Harry Lake	46.4	76.2	5.9	944	472	11,800
2238	3275	MI	Gladstone	46.0	86.5	9.7	1,552	776	19,400
2246	3283	MAN	Hadashville	49.5	95.8	7.5	1,200	600	15,000
2209	3244	QUE	Fort Coulonge	45.8	76.7	9.1	1,456	728	18,200
2243	3280	MN	Cass Lake	47.3	94.6	5.8	928	464	11,600
2235	3272	MI	Fife Lake	44.6	85.4	4.9	784	392	9,800
2229	3266	WI	Wisconsin Dells	43.8	89.8	2.0	320	160	4,000
2233[5]	3270	WI	Nokomis	45.6	89.8	8.1	1,296	648	16,200
2210	3246	ONT	Petawawa Plains	45.8	77.4	10.3	1,648	824	20,600
2207	3242	ONT	Douglas	45.5	76.9	8.6	1,376	688	17,200
2232	3269	WI	Mosinee	44.8	89.7	9.0	1,440	720	18,000
2225	3262	ONT	Gowganda Lake	47.6	80.7	4.5	720	360	91,000
2192	3227	QUE	St. Louis de France	46.4	72.6	9.3	1,488	744	18,600
2228	3265	WI	Lone Rock	43.6	90.2	2.8	448	224	5,600
2208	3243	ONT	Constance Bay	45.5	76.1	3.9	624	312	7,800
			Mean or Total			6.7	21,344	10,672	266,800

1 Seed yields per hectare of orchard; 3,200 trees/ha
2 Data from a 5-year nursery test; 160 trees/source
3 50 percent female strobili to mature cones
4 Twenty-five full seed/cone
5 Local source

The example in Table 1 includes only 12 seed sources from the Lake States: more Lake States seed sources would have been desirable. The other eight seed sources are from Manitoba, Ontario, and Quebec. Of these, the Manitoba source probably is very similar to sources in northern Minnesota. Early results in our Wisconsin test suggest that the other seven seed sources are adapted to environmental conditions similar to our test site. The choice of such geographically widely separated seed sources for inclusion in a regional breeding program may be questionable. Advantages of such broad sampling have not been proven biologically and collection from widely separate origins may not be economically feasible. Until more research data is available, one may choose to restrict selection of seed sources to the planting region.

Phenotypic selection of 10 trees in each of the 20 selected stands will provide 200 half-sib families for establishing the progeny test seedling seed orchard. Selected trees should be at least 500 feet apart in a stand to minimize common ancestry. Consequently, it is best to select from relatively "large" stands on good sites, rather than from "small" stands on poor sites. The trees selected should be dominant and with good stem form, a wide branch angle, little evidence of serious second flushing characteristics (Rudolph 1964), and no insect or disease damage. It will not be worthwhile to spend much time and money on the selection of the parent trees using systems such as the "comparison tree method." Simple phenotypic selection of the individual parent trees after a quick survey of the stand is all that is required.

Establishment of Progeny Test-Seedling Seed Orchard

For the greatest return from a jack pine breeding program, genetically improved stock should be planted on the best jack pine sites. Therefore, the test plantings should be established on better sandy loam soils with a climate similar to the planting region (Wilde et al. 1965).

A randomized, complete block design with two to four tree family plots is recommended. Rows should be spaced wide enough (2.5 m) to permit use of equipment in the planting for the first few years after establishment. Trees within rows should be planted at close spacings (0.5 m) to permit early culling of the poorest trees. Thus, at an initial spacing of 0.5 by 2.5 m, 1 hectare of planting will contain 8,000 trees (20 sources, 10 families per source, and 40 seedlings per family).

Six to 8 years after establishment the trees in the progeny test should be evaluated for height and diameter growth, form, and pest incidence. A combined selection index based upon individual as well as family performance is then used to select the best individuals (Falconer 1960).

Thinning schemes similar to those recommended by King (1973), Yeatman (1974a), and Klein (1974) that result in elimination of a large proportion of families based on average family performance ignore differences in variation patterns among individuals within the families. Combined selection assures the greatest genetic gain and because a large number of families are retained after roguing, a broader genetic base will be maintained in first generation orchards. This may result in greater potential genetic gain in advanced generation orchards (Canavera 1975).

A second generation of orchards can then be established using controlled pollinated full-sib families produced from the best individuals from the first generation orchard. Selected parents from two or more orchards in the planting area should be included in the crossing scheme and new selections should be added to the program periodically to keep the genetic base as broad as possible.

PROJECTED SEED YIELD

The number of female strobili per tree (table 1) at the beginning of the fifth growing season in a nursery test was used to estimate annual seed production from a young jack pine seedling seed orchard established according to the scheme recommended in this paper.

If an average of 160 individuals from each of the 20 seed sources are retained in the seed orchard after the initial thinning, then 1 hectare of orchard may produce 266.8 M full seed annually, an equivalent of 213.4 M plantable seedlings. The basic assumptions used in this example are: (1) the trees in the orchard will produce the same number of females as in the nursery test, (2) 50 percent of the female strobili will mature into cones, (3) there will be 25 full seed per cone, and (4) 80 percent of the full seed will yield plantable seedlings.

The 50 percent female abortion rate is based on actual observation over a number of years. Twenty-five full seed per cone is an average based on a preliminary study of the seed yield from individual cones (Jeffers 1972). Newer studies now in progress suggest that 25 seeds per cone may be a conservative estimate. We set the percent plantable seedlings at 80 percent of full seed because the USDA Forest Service (1974) reports germination capacities from 69 to 87 percent and because seed from seed orchards should be of high quality in a physiological sense as a result of insect control and optimum growing conditions. However, the goal should be germination capacities exceeding 90 percent because plant production should be under optimum conditions in the nursery or greenhouse and culling should not exceed 10 percent.

Thinning is likely to remove some of the provenances and perhaps some families within the remaining provenances from the production seed orchard. Depending on the provenance and family variation in strobili production, this could affect the potential for seed yield after roguing.

The seed sources are arranged in order of decreasing heights in table 1 (352 cm to 310 cm); it is clear that the correlation between heights and seed potential is not significant (r = 0.170). Therefore, the effect of roguing on the basis of heights would be random in terms of seed yield. Family variation within provenances in potential seed production is significant (Jeffers and Nienstaedt 1972), but there is nothing that would suggest that the roguing would reduce the seed production potential.

The projected seed yields are probably conservative. Because seed for the rangewide seed source test was sown directly in the nursery and the trees were grown at a 1 by 1 foot spacing, the number of females produced per tree probably is less than the number produced by orchard trees grown at wider spacings. By sowing progeny test seeds in the greenhouse and raising the seedlings under intensive greenhouse, nursery, and field techniques, earlier and heavier flowering will occur (Rudolph 1966), and thinning of seed orchards will promote crown development resulting in additional increased flower production among remaining trees.

The projected seed yield data indicate that a five-fold difference in seed yields may exist among trees from different seed sources. And variation in number of females per tree among trees within sources in our nursery test were even greater. This great variation in seed yield among different genotypes will continue to exist throughout the life of a seed orchard, but we have no assurance that the early good seed producers will continue to be the best. And we don't know if the best seed producers will have continued fast vegetative growth. Studies on other species suggest that this will not be the case. This lack of information necessitates continued research on flowering and potential seed yield. In addition, much valuable information may be obtained if seed orchard managers in the future will keep accurate records of growth, flowering, and seed production throughout the life of the orchards.

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