New Zealand Journal of Forestry Science Vol. 10 No. 2 (1980): 363–6

ARTIFICIAL RIPENING OF GREEN *PINUS RADIATA* CONES DOES NOT REDUCE SEED GERMINATION OR SEEDLING VIGOUR

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Second year cones were picked off 15 **Pinus radiata** D. Don trees in January 1979 (ripe cones) and from the same trees, but from the next year's crop, in July 1979 (green cones). Before seed extraction, the green cones were artificially cured and ripened in paper bags in a warm room (20–24°C) for 10 weeks.

Seed from naturally and artificially ripened cones was sown separately in replicated nursery plots in October 1979. In March 1980 seed germination, measured by the yield of plantable seedlings per 100 (presumed sound) seeds sown, averaged 77% for the naturally ripened cones and 80% for the artificially ripened cones. Seedling height averaged 23 cm in both groups. Artificially ripened cones thus produced apparently normal, fully-mature seed.

Winter harvesting of **P. radiata** green cones, followed by artificial curing, allows mature seed to be extracted in time for normal spring sowing in October, avoiding the usual one year delay in establishing progeny tests from naturally ripened seed.

INTRODUCTION

To avoid a one-year delay in establishing a second-generation progeny test in *Pinus radiata* D. Don, cones resulting from some controlled pollinations were picked in July and artificially ripened in time for seed sowing in October of the same year. In Kaingaroa and Waimihia Forests in the central North Island where the controlled pollinations were made, 2-year-old cones of *P. radiata* are not usually ripe for picking and immediate extraction until November or December.

The only experimental evidence that germination is normal in seed extracted from *P. radiata* cones harvested prematurely and ripened artificially is the study reported from Australia by Fielding (1964). He found that seeds extracted in September from cones picked green or partly green in June, July, and August gave satisfactory germination.

In the present study the seeds from the artificially ripened cones from controlled pollinations were extracted without difficulty and had normal black seed coats. Subsequently a check was made on the germination of the seed and the vigour of resulting seedlings to determine whether artificial ripening could be a source of bias in the progeny test.

Received 7 May 1980; revision 9 June 1980

MATERIALS AND METHODS

The 15 *P. radiata* trees sampled in this study were in Compartment 1350 Kaingaroa Forest (9 trees) 40 km south-east of Rotorua, and in Compartment 767 Waimihia Forest (6 trees) 12 km south-south-east of Taupo. They had been planted in 1969 as part of progeny tests, and in 1975 were selected as second generation plus-trees for breeding. Each tree was used directly as a female parent in a disconnected diallel mating design.

In this study, the 15 mother trees were a random sample of the 96 second generation parents of the "875" series actually selected and used in the diallel crossing programme. Two crosses (i.e., full-sib families) involving each mother tree as a female parent were selected for study to give a set of 15 pairs (with a common mother tree in each pair) for a precise comparison between naturally ripened and artificially ripened seed. The 3–5 cones of one cross (from pollination in 1976) on each mother tree were allowed to ripen naturally on the tree, and were picked in January 1979. The 3–5 cones of the other cross (from pollination in 1977) on each mother tree were picked in July 1979 when they were full size but green.

Cones harvested ripe in January 1979 were opened immediately in a kiln (60°C for 6 h) and the seed was extracted, cleaned to an estimated 95% full seed in a Dakota seed blower, and stored in sealed bags at 3°C. Cones harvested green in July 1979 were stored in large brown paper bags according to the cross. Plenty of air space was left in the bags and the tops were loosely fastened to allow moisture to escape. The bags were kept in an office building at 20–24°C. After 10 weeks in the bags, the cones that had been picked green had turned brown and were considered cured; they were then opened in a kiln, and the seed was extracted and cleaned as for the naturally ripened cones.

After soaking in cold water for 24 h, known numbers of seed (150–200) of each of the 30 seedlots were sown in mid October 1979 at 10 × 10 cm spacing at the Forest Research Institute nursery, Rotorua. Each seedlot was sown in 4 random plots.

In March 1980, for each plot a tally was made of the number of plantable seedlings (i.e., normal healthy seedlings) and the height of plantable seedlings was measured. Analyses of variance were made on the plot means for seed germination percent (i.e., number of seeds sown × 100/number of plantable seedlings) and seedling height.

RESULTS

There was no significant difference in average seed germination or seedling height between seedlots from cones picked green and artificially ripened, and cones picked ripe (Tables 1 and 2). Differences between the mother trees in seed germination percent were highly significant ($P \leqq 0.01$), with individual mother tree values ranging from 54 to 95% when averaged over both crosses (i.e., natural and artificial ripening). Clearly, mother tree effects, which presumably are partly genetic, had a much greater influence on germination than did the ripening process.

Some appreciable interaction effects between mother tree and ripening process were evident for seed germination but were less so for seedling height. Mother trees 54 and 90 showed apparent adverse effects of artificial ripening on seed germination, and for mother trees 257 and 289, artificial ripening gave better seed germination than natural ripening.

TABLE 1—Analysis of variance of seed germination (%) and seedling height (cm) from naturally and artificially ripened cones picked off 15 **Pinus radiata** trees

Source of variation	df	Mean squares		F-ratios[1]	
		Germination	Height	Germination	Height
Mother tree	14	1054.04	25.33	3.99**	1.57 n.s.
Natural **v.** artificial ripening	1	224.13	0.41	0.85 n.s.	0.03 n.s.
Mother tree × natural **v.** artificial ripening	14	264.04	16.09	2.13*	1.67 n.s.
Plot error	90	123.96	9.63		

[1] ** significant at the 1% level

* significant at the 5% level

n.s. not significant

TABLE 2—Mean seed germination (%) and height of seedlings (cm) from naturally and artificially ripened cones picked off 15 **Pinus radiata** trees

Mother tree number[1]	Seed germination (%)[2]			Seedling height (cm)[3]		
	Natural	Artificial	Mean	Natural	Artificial	Mean
12	76	65	70	22	22	22
48	48	63	56	20	21	21
51	79	85	82	25	22	24
54	83	65	74	25	27	26
66	92	96	94	26	25	25
74	91	99	95	28	24	26
76	69	84	77	19	25	22
88	81	83	82	22	21	22
90	92	76	84	23	19	21
216	88	80	84	23	25	24
229	78	88	83	23	24	23
239	85	84	85	23	23	23
257	72	88	80	22	23	22
276	53	56	54	21	25	23
289	70	86	78	22	18	20
Mean	77	80	79	23	23	23
LSD (0.05) among mother tree means			16			4

[1] Trees numbered 12 to 90 are "875" series second generation plus-trees selected in Kaingaroa Forest; trees numbered 216 to 289 are "875" series second generation plus-trees selected in Waimihia Forest.

[2] Seed germination % $= \dfrac{\text{number of seeds sown} \times 100}{\text{number of plantable seedlings}}$

[3] Mean heights of plantable seedlings assessed in March, 5 months after the seed was sown.

DISCUSSION

Studies of cone development in *P. radiata* in the central North Island (Sweet & Bollmann 1971) highlighted the fact that cones of this species in this region usually reach full size by June, 22 months after pollination. A further 6 months (from June until December) is generally required for the cones to change from green to brown, and for the seed to mature and the seed coats to turn black.

The 10-week curing of the green cones in the present study was obviously effective in maturing the seed and ripening the cones 8–10 weeks earlier than would have occurred with natural ripening on the tree. The curing accelerated cone ripening and seed maturation sufficiently to allow seed to be sown in October, without adverse effects on seed germination or seedling growth.

Interactions between mother tree and ripening process contributed to the general "experimental error" of the study, somewhat weakening the comparison between natural and artificial ripening. However, such interactions are unlikely to occur generally in the species and are probably peculiar to this study because of a general confounding of artificial *versus* natural ripening with possible pollination year effects, and, in individual mother trees, a confounding of artificial *versus* natural ripening with differences in male parents between the two crosses.

As suggested by Fielding (1964), harvesting of green, full-sized cones in winter, followed by artificial curing, has obvious applications in controlled pollination programmes in *P. radiata.* The delay between the completion of pollinations and sowing of seed can be shortened from 38 months to 26 months, assuming that seed is sown in the usual month of October.

In California, a large number of mostly green *P. radiata* cones was collected for provenance trials and gene conservation (Anon. 1978). The green cones were picked in February–March 1978, and stored in a large heated shed until June when the cones were opened in a kiln and the seed was extracted. In this operation, the cones were picked green to avoid losses to squirrels. At Rotorua, the germination of this seed and the appearance and growth of the seedlings was also normal, suggesting no ill effects from the long artificial ripening process.

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