EFFECTS OF CROWN PRUNING AND NITROGEN FERTILIZATION ON FLOWERING OF YOUNG PLANTATION-GROWN JACK PINE TREES IN SOUTHEASTERN MANITOBA

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Introduction

Harvesting of jack pine seed from seed orchards has begun on a small scale in Manitoba. Beginning in the near future, perhaps by about 2005, virtually all jack pine seed required for forest planting in Manitoba will be obtained in seed orchards. Collection cost will be a concern for jack pine, more than for most pine species, because jack pine cones are tightly attached to the stem. Some reduction in cost of harvesting cones from jack pine seed orchard trees might be achieved by pruning the crowns of seed orchard trees. This approach could at least reduce the effort required to reach cones, although it would not reduce the effort required to remove them.

In seed orchards incorporating selected genotypes from advanced breeding generations, there will be genetic advantages to producing seed by controlled pollination. These advantages might include reducing the number of unrelated sublines that need to be carried in the breeding population, and allowing customized matching of genetic material to planting situation. If seed orchard trees can be kept short enough to be pollinated by workers standing on the ground, while still maintaining sufficient flowering activity, controlled pollination for commercial seed production would be more economical (Shelbourne et al. 1986). Pollen for this controlled pollination can be obtained conveniently from unpruned trees.

In a comprehensive review, Ho and Schooley (1995) summarized reproductive responses of conifer seed orchard trees to experimental and operational crown pruning treatments, including seed orchards of trees maintained at a height of up to 2 m for production of control-pollinated seeds. They concluded that appropriate treatments are capable of improving access to cone-bearing branches without necessarily impairing long-term cone production. Changes in pollen quantity and distribution resulting from crown pruning can, however, impair genetic quality of open-pollinated seed orchard seed.

An initial attempt to acquire information for jack pine in Manitoba, on the feasibility of reducing cone collection costs in conventional seed orchards, and of enabling production of control-pollinated seed without climbing, was funded by the Canada-Manitoba Partnership Agreement in Forestry. An experiment was initiated in southeastern Manitoba on flowering response of young jack pine trees to crown pruning treatments. Soil management of jack pine seed orchards may include addition of mineral nutrient supplements, if current and future trials indicate a beneficial effect of supplements. A trial of crown pruning treatments would have little value if conducted under soil nutrient levels that are completely unrepresentative of conditions in actual future seed orchard management regimes. In order to assess the magnitude of interaction between soil fertility and crown pruning on flowering response, contrasting nitrogen levels were applied across all crown pruning treatments.

An experiment was installed in an ordinary commercial plantation, 8-12 years from planting, to avoid risking damage to actual seed orchard trees from application of treatments that might prove harmful. Response will vary among seed orchard genotypes, but there is no reason to expect any systematic response difference between the unselected experimental trees and seed-grown seed orchard trees. Grafted seed orchard trees may respond differently. Information on response of grafted seed orchard trees to pruning treatments found useful for seed-grown trees will ultimately need to be obtained by trials on grafted seed orchard trees.

Complete assessment of the crown pruning and nitrogen level treatments would require data on cost of controlled breeding and cone collection, as well as data on response of flowering

and seed production to these treatments. Furthermore, treatments and data collection would need to be continued for a period of about a decade to ensure reliability of the results. This report provides information only from assessment of flowering response during the first two growing seasons following initial application of treatments. This fragmentary and preliminary information is being reported now because the information obtained appears to be sufficient to justify continuance of the investigation on actual seed orchard trees.

Materials and Methods

Trial location

The trial is located north of Marchand, Manitoba, in section 28, township 6, range 10 EPM, at 49°29' N, 96°18' W, within an extensive plantation. The well drained sandy site was mechanically planted in May 1986 following site preparation with a C&H plow. Survival and growth were very good. Spacing within rows is frequently as close as 1 to 1.5 m, which is closer than desirable. Between-row spacing varies from 2 to 4 m.

Treatments and design

Crown pruning and and nitrogen level treatments are described in Table 1. The crown pruning treatments were intended, respectively, to increase branchiness of the crown through reduced apical dominance (2), to reduce the trees' rate of overall size increase by removing the distal half of the most vigorous shoots (3), and to maintain trees in a dwarfed state for controlled breeding (4). Pruning treatments 2 and 3 were applied with pruning shears near the end of the period of shoot elongation. The dwarfing treatment was applied while shoot elongation was not in progress. The nitrogen supplement treatment was intended to provide a level of available nitrogen judged to be optimal for growth. Phosphorus and potassium were applied so as to provide optimum levels of these elements for all trees in the study.

Two sets of four blocks were delineated, each block containing no fewer than 16 healthy trees. Each block was divided into 2 main plots, which were randomly allocated to the two nitrogen-level treatments. The 8 plot trees in each main plot were randomly allocated to the 4 crown pruning treatments. Application of soil amendments and crown pruning treatments for the first set of blocks occurred at the time these blocks were laid out in June 1992. For the second set of blocks, trees were thinned to a minimum spacing of 4 m before plots were delineated and trees allocated to treatments. The second set was laid out and treatments initiated in June 1993. No treatments were applied after July 1994.

Observations

At the time the experiment was laid out at each location, height and diameter (at 0.5 m above ground) were measured and mature cones and current maturing conelets were counted on all plot trees. Each May from initiation to 1995, pollen cone clusters and seed cone flowers were counted or estimated on each tree. Estimation of seed cone flower numbers was based on a count on the terminal portion of the tree and on one-fourth of the radius of the remainder of the crown, multiplied by 4. Number of pollen clusters was estimated from a count on one-fourth of the lower crown only, as pollen cone clusters did not occur on the terminal portion of the crown. Estimation of the number of flowers by this method was done in 1994 and 1995 on unpruned,

Table 1. Crown pruning and nitrogen treatments for jack pine seed orchard crown management study

Factor	Level	Name	Description and dates applied
Crown pruning	1	Control	No pruning
	2	Truncate	Remove single terminal shoot or double terminal shoots; no pruning if 3 or more terminal shoots; at candle stage. Treated June 1992, July 1993 and June 1994
	3	Shear	Pinch off distal half of any shoot 20 cm or longer; at candle stage. Treated June 1992, July 1993 and June 1994
	4	Dwarf	Remove any stem portion more than 1.5 m above ground; September 1992 and April 1994
Nitrogen level	1	Low N	Annual applications of superphosphate, triple superphosphate, and potassium sulfate to bring soil fertility level to 80 lbs./acre (15 Kg/ha) P, 200 lbs./acre (37 Kg/ha) K Applied in second week of July, 1992-1994.
	2	High N	Same as level 1, plus ammonium nitrate to provide available N at 500 lbs./acre (92 Kg/ha)

truncated, or sheared trees, while a complete count was made on dwarfed trees. Height and diameter (at breast height) were measured again in 1995. Height of the highest pollen cone cluster and the lowest seed cone flower were also measured during the 1995 growth period, to determine whether the normal vertical separation of seed and pollen flowers was changed by the pruning treatments.

Statistical analysis

Count data were transformed into common (base 10) logarithms, after addition of 1 to each value. Indicators of departure from normality, and of homogeneity of variability among treatments, were calculated for each response variable, before and after transformation. Based on these criteria, untransformed counts were analyzed for 1995 seed cone flowers at close spacing, while transformed counts were analyzed for other count variables.

Analysis of variance within sets of blocks at the same spacing was performed according to the split-plot design of the experiment, to test the significiance of effects of nitrogen level, crown pruning treatments, and their interaction, on flower production. Tests of significance were at the 95% confidence level. Effects of nitrogen level were tested against the interaction of blocks and nitrogen level, that is, against main plot error. Effects of crown pruning treatment were tested against the interaction of nitrogen level and crown pruning treatment within blocks, that is, against sub-plot error. The denominator for testing the significance of sub-plot error was residual error, estimated from the differences between the trees of each pair given the same crown pruning treatment on the same main plot. For some flower count variables, main plot error or sub-plot error happened to be smaller than residual error. In those cases, residual error was used as the denominator for that F-test. Degrees of freedom for blocks, nitrogen level, main plot error, crown pruning treatment, and sub-plot error were 3, 1, 3, 3, and 21. Degrees of freedom for residual error were 32 for the close-spaced blocks, and 31 for the wide-spaced blocks, in which 1 plot tree died.

To identify which pairs of crown pruning treatments differenced significantly for variables showing a significant F-ratio, the Ryan-Einot-Gabriel-Welsch multiple F test (REGWF) was chosen. This test has the property of reporting at least one significant pair difference for any test having a significant F-ratio, and never reporting a significant pair difference when the F-ratio is not significant (SAS Institute Inc. 1989).

Results

Flowering level and tree size before treatment were similar among tree samples allocated to different treatments. The sum of mature cones, developing conelets, and seed cone flowers in June 1992 ranged from 10 to 17 for the four crown pruning treatments in the close spacing blocks. Height and diameter ranged from 163 cm and 30 mm to 188 cm and 36 mm for the 8 treatment combinations at close spacing at the start of the 1993 growing season.

At the end of the trial, trees in the dwarfing treatment were under 2 m in height, while average heights for control, truncate, and shear trees were above 2.5 m in height. Diameter was relatively unaffected by the dwarfing treatment. Overlap between the highest pollen cone cluster and the lowest seed cone flower was reduced by the dwarfing treatment, but did not differ among the other pruning treatments.

Flower counts were highly variable within treatment combinations for both pollen clusters and seed cone flowers. Most flower count variables had a coefficient of variation higher than 100 before transformation. Variability of counts was usually higher for pollen cone clusters than for seed cone flowers. The transformation to base 10 logarithms reduced the coefficient of variation as well as the departure from normality in most instances.

The most frequent treatment response detected by the experiment was reduced flowering in dwarfed trees (Table 2). Dwarfed trees produced 5 seed cone flowers at both sites in 1994, while seed cone flowers under other treatments averaged 33-41 at close spacing and 42-51 at wide spacing. Seed cone flower counts were also lower for dwarfed trees than for all other crown pruning treatments at wide spacing in 1995. At close spacing in both years, sheared trees had higher pollen cone cluster counts than dwarfed trees, while counts on unpruned trees were significantly higher in comparison to dwarfed trees only in 1995.

Table 2. Response of young jack pine trees to crown pruning treatments at low and high nitrogen levels. Means for the same response variable, for different levels of the same treatment factor, followed by different letters, were significantly different at the 95% confidence level according to the REGWF test. Flower count means other than for 1995 seed cone flowers at close spacing, were back-transformed from means of common logarithms, used for flower count analysis to reduce departure from normality.

Spacing	Treatment factor	Level	Spring ht, cm 1993	Spring ht, cm 1995	Seed cone flowers 1994	Seed cone flowers 1995	Pollen clusters 1994	Pollen clusters 1995
Close	Crown pruning	1	183	283	33 a	57	15 ab	55 a
		2	169	267	34 a	67	5 ab	15 ab
		3	174	251	41 a	51	27 a	62 a
		4	171	182	5 b	47	2 b	8 b
Close	Nitrogen	1	173	259	14 b	39 b	9	59
		2	175	233	34 a	72 a	8	13
Wide	Crown pruning	1	233	310	51 A	121 A	10	51
		2	230	277	42 A	120 A	12	42
		3	241	281	46 A	94 A	18	33
		4	238	194	5 B	31 B	6	10
Wide	Nitrogen	1	228	262	30	85	15	66
		2	243	271	25	77	8	13

Response to nitrogen level was significant only for seed cone flowers at close spacing. Number of seed cone flowers was approximately doubled by the high N treatment in both years. The two spacings seem to differ in flower production under low N, while being similar in flower production under high N in both years. Point estimates of pollen cone cluster number suggest a severe suppression by high N at both spacings in 1995, which failed to reach statistical significance. Because the error term for testing the significance of nitrogen level is main plot error, with only 3 degrees of freedom, a larger F-ratio is required to reject the null hypothesis, in comparison with tests of significance for response to crown pruning treatments.

The interaction of nitrogen level with crown pruning treatment was not significant for any response variable.

Discussion and Conclusions

Results of this experiment indicate that a reduction in the number of seed cone flowers

and pollen clusters is likely to occur following crown pruning similar to the dwarfing treatment used here. This result was expected, and is not of practical importance, because the dwarfing treatment is not intended for use in seed orchards managed for production of open-pollinated seed. The purpose of including the treatment in this experiment was to learn whether production of seed cone flowers on the trees treated in this way would be sufficient to allow commercial seed production by controlled pollination. Although pollen cone clusters were also counted on the dwarfed trees, there would be no reason to use dwarfed trees to produce pollen for controlled pollination. Mean counts of 5 seed cone flowers on dwarfed trees in 1994, were low enough to discourage commercial seed production by controlled pollination. Counts in 1995, a year after the last treatment, improved to 31 and 47 flowers at wide and close spacings. These values should provide sufficient productivity for commercial production of control-pollinated seed, if the average yield of seed from each pollinated flower is reasonable high. It may be necessary to allow intervals of 3 years between successive applications of the dwarfing treatment, to allow induced buds to produce ripe cones.

No differences were found in any flower count variable among unpruned, truncate, and shear treatments. Introduction of truncate or shear treatments into the management regime of a jack pine seed orchard appears unlikely to impair flowering. In any event, the risk of harm seems low enough to permit introduction of these treatments into management of an open-pollinated jack pine seed orchard on a trial basis. Flowering behaviour, seed production, and cost of seed harvest could then be monitored within the context of routine seed orchard management so as to gain reliable information on the usefulness of these crown pruning treatments. Acquisition of equivalent data from an experimental site producting seed of no special value would probably be uneconomical.

The contrast between the apparent responses of seed cone flowers and pollen cone clusters to nitrogen level, presents some difficulty in designing an ideal seed orchard soil management regime. High nitrogen may improve seed flower production while reducing pollen production, although the evidence for both responses was equivocal in this experiment. If further investigation is desired on flowering and seed production responses to varying nitrogen level, it would be best done by continuing observation on trees designated for this purpose in a jack pine seed orchard. In light of the absence of seed flower response to nitrogen level in the blocks at wide spacing, it may be most prudent to withhold nitrogen supplements in routine seed orchard management for the immediate future.

Suppression of pollen production by high nitrogen could be useful for management of dwarfed trees in a control-pollinated seed orchard, where pollen was produced in a separate area on unpruned trees. Pollen cones on the dwarfed seed trees might be removed before they ripen, to reduce or eliminate the need for isolation of seed cone flowers (Ho and Schooley 1995). Any reduction in the number of pollen cones on the dwarfed trees achieved by high nitrogen or another effective treatment would reduce the cost of removing pollen cones.

The zone of overlap between pollen and seed cone portions of the crown was not affected by the truncation and shearing treatments. Application of these pruning treatments would therefore not appear to increase the risk of self-pollination in an open-pollinated seed orchard.

The lack of significant interaction between nitrogen level and crown pruning treatments indicates that it will not be necessary to re-assess response to crown pruning treatments if further experience indicates a different optimum level for soil nitrogen level in jack pine seed orchards.

Literature Cited

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