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Field experiment on the effect of girdling and gibberellin application on flowering induction of 12 yr old seedlings of Douglas fir and Norway spruce

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Introduction

Climate has a strong influence on flowering of trees and, for field experiments, it is difficult to control environmental conditions. Thus, many experiments on flowering induction in conifers are performed on potted trees, which are at least partly maintained under greenhouse conditions. The benefits of establishing indoor orchards instead of classical soil-based ones have been proposed. However, hundreds of hectares of soil-based seed orchards have been established and must be managed for a more abundant and regular flowering. Also, besides clonal orchards (generally grafted), some seedling seed orchards have been established which, for an equivalent size, are less mature than grafts. This paper deals with preliminary field experiments on Douglas fir *(Pseudotsuga menziesii)* and Norway spruce *(Picea abies)* seedlings.

Materials and Methods

Two experiments using combinations of bark girdling (G) (double semicircular overlapping 5 mm wide girdles) and trunk injections of gibberellins (GA4/7) were tested in 1986 on 12 yr old seedlings, 6–8 m high, raised in the INRA (Orléans) nursery.

Douglas fir

50 seedlings, belonging to 7 open-pollinated families, were divided among 4 treatments applied just before vegetative bud burst: 1) control; 2) girdling; 3) girdling + 50 mg GA4/7 (45% A7) + 5 mg naphthalene acetic acid (NAA); 4) girdling + 100 mg GA4/7 + 10 mg NAA. At treatment time, each tree received soil fertilization with 200 g of $Ca(NO_3)_2$. GA4/7 injections were made in 300 μl of ethanol in the xylem of the 1981 internode. On each tree, 4 branches on both the 1982 and 1984 whorls were selected for shoot measurement and cone counts. Two branches were plastic-bagged (in order to simulate a localized 'greenhouse effect') for 2 wk starting 3 wk after the beginning of the treatment.

Norway spruce

30 seedlings, belonging to 6 open-pollinated families, were divided among 5 treatments. Treatments were applied when about 50% of the lateral shoot elongation was completed and consisted of: 1) girdling; 2) girdling + 2 x 50 mg GA4/7 at a 2 wk interval in the 1983 internode; 3) same as treatment 2 applied in the 1981 internode; 4) girdling + one application of 100 mg GA4/7 in the 1983 internode; 5) same as

treatment 4 applied in the 1981 internode. GA4/7 injections were made in 300 μl of ethanol. On each tree, 4 branches (in the 4 cardinal directions) on both 1983 and 1984 whorls were selected for shoot measurement and cone counts, 2 of them were plastic-bagged for 4 wk, starting at the beginning of treatments.

The length of the terminal and 2 subterminal shoots were measured in the fall on each selected branch and their total number of male and female cones were counted the following spring on the entire branch. Also, the total number of female cones on the entire tree was counted. On each sampling branch, terminal and subterminal shoot elongation and number of male and female cones were subjected to variance analysis (see the text for the analyzed factors) and Duncan's test. The family effects are not presented here.

Results and Discussion

Douglas fir

The main results are given in Table I. Girdling with or without GA4/7 had a strong significant stimulatory effect on both male and female flowering. On the other hand, GA4/7 increased the length of both terminal and subterminal shoots. The higher whorl produced significantly more female cones but, curiously, this was also true for male cones. Bagging the shoot slightly reduced terminal elongation but had no effect on flowering. Finally, all 3 treatments differed significantly from the control for the mean total number of female cones per tree.

Norway spruce

The main results are summarized in Table II. All the trees were girdled, but treatment 1 alone only slightly stimulated flowering compared to GA + girdling treatments. Therefore GA4/7 had a specific and significant effect on both male (only for 1 injection of 100 mg GA4/7) and female flowering (the best results corresponding to 2 injections of 50 mg GA4/7, (treatments 2 and 3). This differential sexual response may be related to differences in the dif-

Table I. Douglas fir: the effect of girdling (G) and of GA4/7 + NAA (GA) on the number of cones per branch and per tree and on shoot elongation.

Factor	*Shoot elongation*		*Flowering*		
			per branch		*per tree*
	terminal	*subterminal*	*male*	*female*	*female*
Treatment					
1 C	16.5^{b}	11.6^{b}	7.2^{b}	0.6^{c}	81^{b}
2 G	16.8^{b}	12.3^{ab}	225.7^{a}	12.4^{b}	266^{a}
3 G + 50 GA	18.9^{a}	12.8^{a}	249.1^{a}	19.2^{a}	367^{a}
4 G + 100 GA	18.4^{a}	12.4^{a}	281.4^{a}	14.9^{b}	279^{a}
Whorl					
1982	14.2^{b}	10.4^{b}	150^{b}	6.5^{b}	
1984	21.1^{a}	14.4^{a}	209^{a}	16.3^{a}	
Bagging					
yes	16.5^{b}	10.4^{a}	215^{a}	11.6^{a}	
no	18.6^{a}	12.6^{a}	169^{a}	11.2^{a}	

For each factor values in the same column followed by the same letter do not significantly differ at 5%.

Table II. Norway spruce: the effect of girdling (G) and of GA4/7 (GA) (H: 1983 internode; L: 1981 internode) on the number of cones per branch and per tree and on shoot elongation.

Factor	*Shoot elongation*		*Flowering*		
			per branch		*per tree*
	terminal	*subterminal*	*male*	*female*	*female*
Treatment					
1 G	20.6[a]	11.2[a]	0.86[b]	0.55[c]	16.5[b]
2 G + 2 x 50 GA H	18.6[b]	11.6[a]	0.15[b]	1.86[b]	33.3[a]
3 G + 2 x 50 GA L	16.2[c]	9.6[b]	0.0[b]	2.75[a]	53.4[a]
4 G + 100 GA H	14.9[c]	9.4[bc]	3.6[a]	1.07[bc]	53.9[a]
5 G + 100 GA L	12.9[d]	8.4[c]	2.8[a]	0.92[bc]	39.9[a]
Whorl					
1983	14.8[b]	9.4[b]	2.8[a]	0.74[b]	
1984	18.8[a]	10.9[a]	0.11[b]	2.12[a]	
Bagging					
yes	15.7[b]	9.9[a]	1.56[a]	1.41[a]	
no	17.7[a]	10.9[a]	1.15[a]	1.64[a]	

For each factor, values in the same column followed by the same letter do not significantly differ at 5%.

ferentiation period between both sexes. Higher branches typically bore more female cones. Differences also existed in the proportion of shoot elongation completed at treatment time (60.3 and 79% for terminal and subterminal shoots of the lower whorl as opposed to 48.6 and 67% for the higher whorl, respectively). Even if female flowering of Norway spruce was generally located at the very top of the tree, these differences in elongation might also be related to a stage of vegetative development in the higher whorls more favorable for flowering induction (Bonnet-Masimbert, 1987).

For the total number of female cones per tree (Table II) there is no significant difference between the 4 GA4/7 treatments. In contrast to the observations on Douglas fir, GA4/7 often reduced the shoot elongation in spruce significantly. Plastic bagging caused a slight but significant reduction in the elongation of the terminal shoot. It had no significant effect on male or female flowering or elongation of subterminal shoots.

Conclusion

It is possible to stimulate the flowering of seedlings of Norway spruce (mainly female) and Douglas fir in the field through a combination of girdling and GA4/7 treatments. GA4/7 is confirmed to be especially necessary for Norway spruce (Bonnet-Masimbert, 1987). Certainly these positive responses were partly due to the fact that 1986 was generally favorable to natural flowering induction. From comparisons between the last 5 yr, we suspect that high sunshine from mid-June to the beginning of July may have a positive effect. Kosinski and Giertych (1982) clearly demonstrated the role of light intensity on flowering of Norway spruce. However, growth response of 1986-girdled Douglas fir in 1987 and 1988 was reduced. Furthermore, bud-burst was delayed for 1–2 wk over the control, indicating a durable physiological stress. So, contrary to the results of Wheeler *et al.,* (1985), girdling can hardly be proposed as a routine treatment in soil-based seed orchards.

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