Reviews – Katsauksia

Usefulness of hormonal stimulation in the production of genetically improved seeds

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Introduction

Application of growth regulators, primarily gibberellins, has become an efficient method of flowering regulation in many coniferous forest trees. The influence of growth regulators on the generative development of trees can be expressed in various ways. In this paper some results are discussed with respect to various genetic processes in seed orchards.

Stimulation of floral induction

Stimulation of floral induction in many conifers has been obtained after growth regulator application. Increasing the number of strobili is the first important step necessary for a higher production of seeds. However, it is known that strobili abortion is a limiting factor which may strongly diminish the stimulative effect of growth regulator application for different tree species and site conditions. There are some suggestions as how to counteract this negative effect (Krugman 1973, Brown and Sauve 1975, Hare 1981, 1983, Chałupka 1985), but the problem still requires further research.

Shortening of juvenile phase

In the ontogeny of trees, juvenility is defined as the period from fertilization or germination to first flowering (Wareing 1959, Schaffalitzky de Muckadell 1959, Doorenboos 1965, Giertych 1976). The duration of juvenility varies among species from a few to tens of years (Wareing 1959). This creates many barriers in forest tree improvement work.

So far, the application of growth regulators

Table 1. Shortening of juvenile phase in some conifers after treatment with growth regulators.

Species	Juvenile phase		Growth regulator	Reference
	Natural (years)	Shortened to		
Cupressus arizonica	4–5 [1)]	3 months	GA_3	Pharis et al. 1965
Picea abies	20–25 [2)]	12 years	$GA_{4/7}$	Bonnet-Masimbert 1987
Pinus banksiana	3–15 [1)]	17 months	$GA_{4/7}$	Cecich 1981
Pseudotsuga menziesii	10–20 [3)]	6 years	$GA_{4/7}$	Pharis et al. 1980
Sequoia gigantea	20 [1)]	6–12 months	GA_3,$GA_{4/7}$,GA_{13}	Pharis and Morf 1967
Sequoia sempervirens	5–15 [1)]	6–12 months	GA_3,$GA_{4/7}$,GA_{13}	Pharis and Morf 1967
Thuja plicata	15–25 [1)]	4 months	GA_3	Pharis and Morf 1967
Tsuga heterophylla	20–30 [1)]	3 years	$GA_{4/7}$	Pollard and Portlock 1981

1) Seeds of woody plants in the United States, For. Serv., USDA, Agriculture Handbook No. 450, Washington, D.C., 1974.
2) Matthews, J.D. 1955. Production of seeds by forest trees in Britain. For. Comm., Rep. on Forest Res. for the year ending March 1954, London.
3) Puritch, G.S. 1972. Cone production in conifers. A review of the literature and evaluation of research needs. Pacific Forest Res. Centre, Victoria, B.C., Information Rep. BC-X-65.

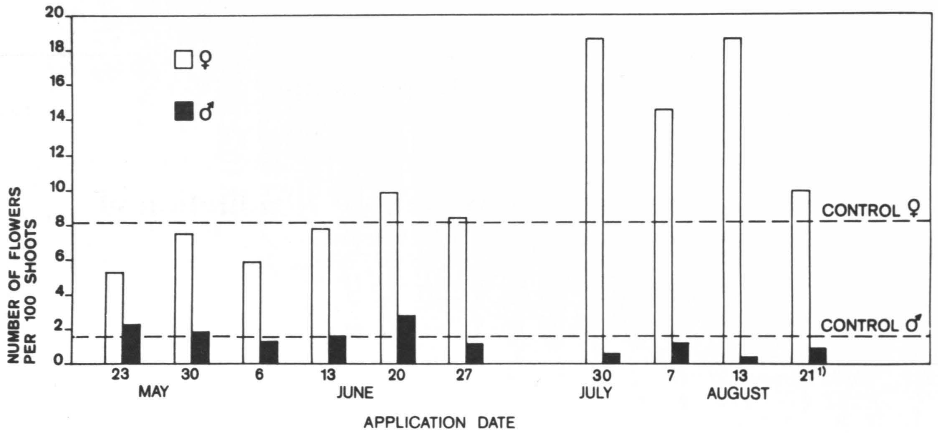

Fig. 1. Flowering intensity of Scots pine grafts in Finland after $GA_{4/7}$ application at different dates (according to Luukkanen 1980).

(mostly gibberellins) combined with other treatments such as photoperiod, temperature and nutrition, has accelerated the initiation of the first strobili only in the case of a few forest tree species (Table 1). The effect of the treatment has been temporary in most cases (Longman 1987).

The shortening of the juvenile phase is necessary to obtain progeny earlier and establish early tests. This is especially important for the forest tree species starting to flower very late. The problem of shortening the juvenile phase still remains unsolved.

Regulation of sex of the strobili initiated

There is little information available on the sex regulation of differentiated strobili (Hashizume 1973, Luukkanen 1980, Chałupka 1984). It has been established that application of gibberellins in the early stage of the vegetative period promotes the initiation of male strobili and in later stages, stimulates female strobili initiation (Figs. 1 and 2).

These results could be used for selective stimulation of flowering in individual grafts. This kind of manipulation of the flowering process should be studied in more detailed experiments.

Changes in the distribution of strobili in the crown

In an experiment with *Picea glauca* an interesting and hopeful effect was observed by Marquard

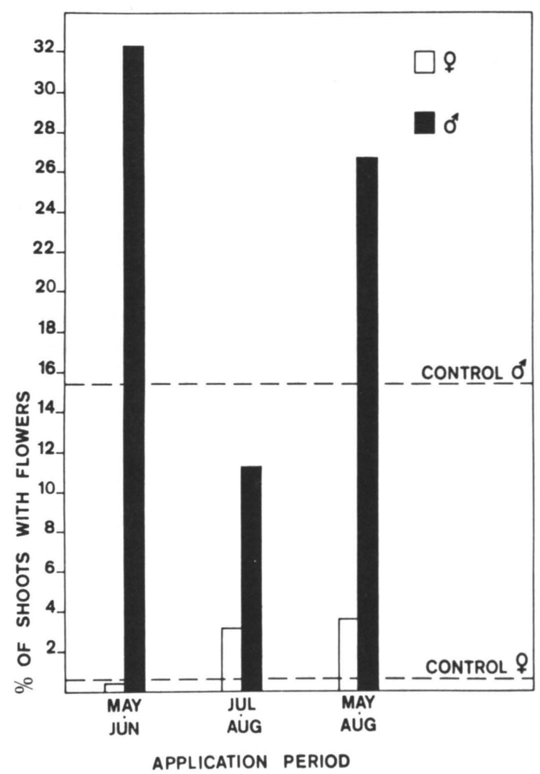

Fig. 2. Flowering intensity of Scots pine grafts in Poland after $GA_{4/7}$ application at different times during the growing season (according to Chałupka 1984).

and Hanover (1984b). Gibberellin treatment changed the natural female strobili distribution, shifting it to a more distal shoot position. This creates better chances for out-crossing and for higher production of filled and genetically more differentiated seeds.

It has also been established that gibberellins are effective in promoting female flowering in the lower part of graft crowns of in *Larix* sp. (Bonnet-Masimbert 1982), *Picea glauca* (Marquard and Hanover 1984a), and *Pinus sylvestris* (Chałupka 1980, Kurm 1987). These results are useful from the practical point of view because the lower a cone is located in the crown, the easier it is to collect it. However, on the other hand, we know that the percentage of empty seeds is nearly twice as high in the lower part of the crowns of Scots pine grafts than in the upper part; this is mainly a consequence of self-fertilization (Hadders 1971, Shen et al. 1981). Calculated self-fertilization estimates for *Larix decidua* grafts were even higher (Burczyk et al. 1991). Similar tendencies were also observed in Douglas-fir seed orchards (see e.g. Shaw and Allard 1982, El-Kassaby et al. 1986, Omi and Adams 1986). From these results, the following questions arise: (1) is the hormonal stimulation of flowering over the whole crown beneficial?, and (2) is this stimulating effort really effective in inducing female strobili initiation in the lower part of the crown?

Results from genetic studies strongly point to the need to collect Scots pine cones from the top of grafts (Shen et al. 1981). Spraying or injecting gibberellins only in the upper part of crowns effectively stimulated flowering on individual branches of Scots pine grafts (Chałupka 1980, 1987, 1991), increasing genetic efficiency.

The effect of gibberellin application on the stimulation of female flowering in the lower part of crowns can be used more efficiently however. Planting grafts at wider spacings would induce a greater flow of air among the trees and increase the mixing and transport of pollen. Self-fertilization in the lower crown parts would therefore be diminished.

Equal clonal participation in the production of seeds

One of the main principles of seed orchards technology is the maximal promotion of genetic diversity of the progeny. It means that all clones constituting the seed orchard ought to partici-

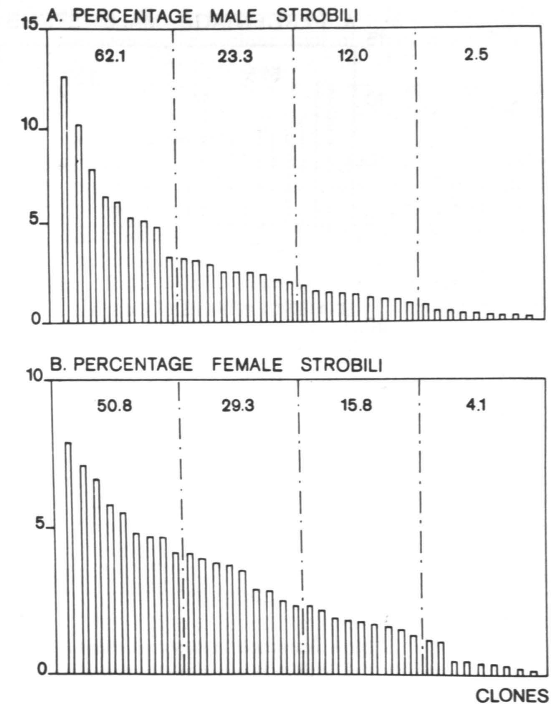

Fig. 3. Mean percentage of male and female strobili produced by 36 clones in a Swedish Scots pine seed orchard (after Jonsson et al. 1976).

pate equally in the production of seeds.

Substantial differences exist between clones in this respect and only 50 % of them produce nearly the total amount of male and/or female strobili (Figs. 3 and 4). Eriksson et al. (1973) calculated that 25 % of *Picea abies* clones contributed about 65 % of genes to the progeny. Thus an important problem arises for seed orchard managers as how to include poor flowering clones into the parental pool.

Let's consider Scots pine seed orchards as a model for solving this problem. It is known that gibberellins applied at the proper time can stimulate male or female flowering in Scots pine grafts (Luukkanen 1980, Chałupka 1984). It has also been established that gibberellins stimulated flowering more effectively in poorly flowering clones (Luukkanen and Johansson 1980, Chałupka 1985) (Figs. 5 and 6). These two effects together allow us to influence flowering by applying gibberellins to selected clones at the proper time. It would thus be possible to modify and equalize clone participation in strobili and seed production.

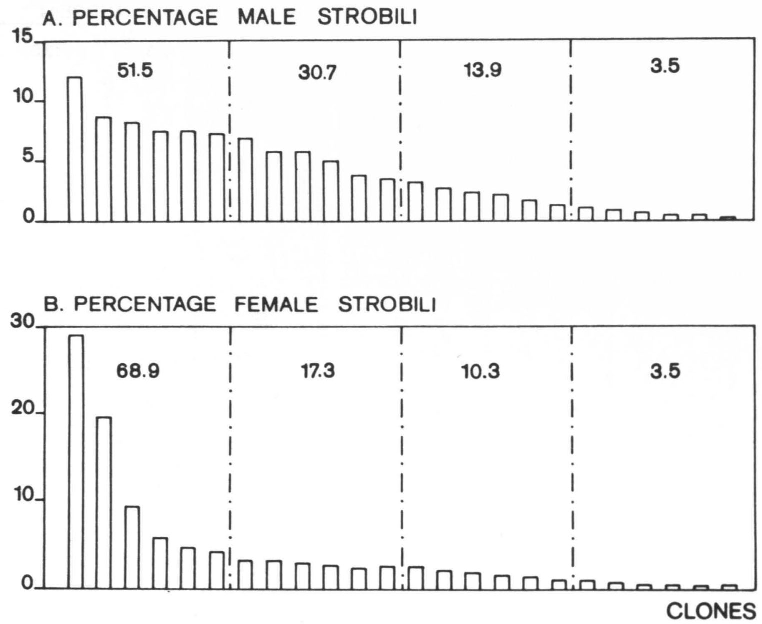

Fig. 4. Mean percentage of male and female strobili produced by 24 clones in a Polish Scots pine seed orchard (after Wesoły 1984).

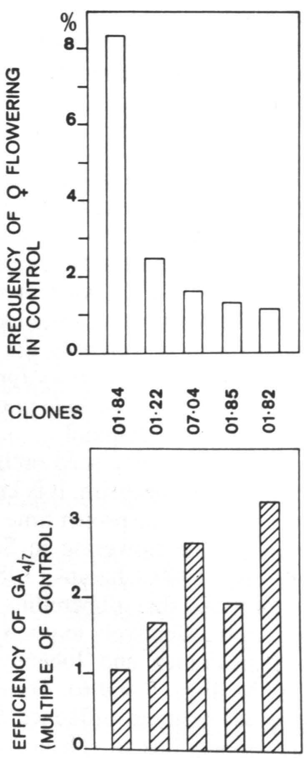

Fig. 5. Efficiency of $GA_{4/7}$ in Scots pine clones of different female flowering ability (after Chałupka 1985).

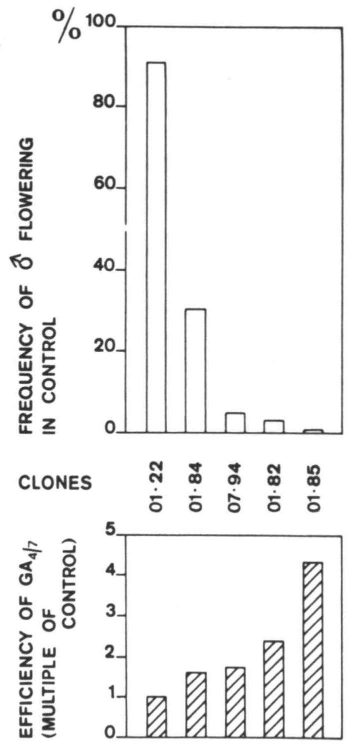

Fig. 6. Efficiency of $GA_{4/7}$ in Scots pine clones of different male flowering ability (after Chałupka 1985).

Conclusion

There are still several unsolved problems in the regulation of flowering in forest seed orchards. These problems are related to different genetic processes occurring in the seed orchards and they should be taken into account in endeavouring to produce genetically improved seeds.

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