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Original article

Carry-over effect of gibberellins ($GA_{4/7}$) and ringing on female flowering in Norway spruce (*Picea abies* (L) Karst) seedlings

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Summary – The second year after treatment effect of gibberellins ($GA_{4/7}$) and ringing on increased female flowering was observed in 13-year-old full-sibs of Norway spruce. This carry-over effect was exhibited independently by $GA_{4/7}$ and ringing. $GA_{4/7}$ significantly increased and ringing significantly decreased height growth increment of trees in a year of flower bud initiation. The influence of $GA_{4/7}$ and ringing on flower initiation and height increment is discussed.

***Picea abies* / first flowering / carry-over effect / $GA_{4/7}$ / ringing**

Résumé – Effets différés des gibbérellines 4/7 et de l'annélation sur la floraison femelle de semis d'épicéa commun (*Picea abies* (L) Karst). Deux années après traitement l'effet de gibbérellines 4/7 ($GA_{4/7}$) et de l'annélation d'écorce sur la floraison femelle a été observé sur des descendants plein-frères de familles d'épicéa commun. Cet effet différé se manifeste indépendamment en réponse à $GA_{4/7}$ et à l'annélation. L'année d'initiation florale, $GA_{4/7}$ augmente significativement l'accroissement en hauteur des arbres, tandis que l'annélation le diminue significativement. Les influences respectives de $GA_{4/7}$ et de l'annélation sur l'initiation florale et sur l'accroissement en hauteur sont discutées.

***Picea abies* / première floraison / effet différé / $GA_{4/7}$ / annélation**

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INTRODUCTION

Cone induction in Norway spruce is not easy to attain and most of the positive results in the stimulation of flowering in that species have been obtained using grafted material both in the field and in greenhouses (Luukkanen, 1980; Chalupka, 1985).

Bonnet-Masimbert (1987, 1989) was the first to succeed in the stimulation of flowering in Norway spruce seedlings and cuttings in greenhouse and field conditions. Using gibberellins ($GA_{4/7}$) and girdling he noticed a carry-over effect, observing flowering 2 years after the treatment (Bonnet-Masimbert, 1987). Similar results concerning a carry-over effect were obtained for Japanese and European larch grafts (Heitmüller and Melchior, 1960; Melchior, 1960; Bonnet-Masimbert, 1982), Douglas-fir seedlings (Pharis et al, 1980), Sitka spruce grafts (Philipson, 1985) and Engelmann-white spruce grafts (Ross, 1992).

The aim of the current experiment was to investigate the flowering response of Norway spruce seedlings to $GA_{4/7}$ and ringing applied alone and in combination.

MATERIALS AND METHODS

In the spring of 1991 four full-sib families of Norway spruce (nos. 1958, 1982, 1990, 1991) were selected, each represented by 12 seedlings. The full-sibs resulted from 1980 control crossings done on a first generation seed orchard of Norway spruce in Kórnik, Poland. Seeds were sown in the nursery in spring of 1981, and seedlings were outplanted in spring 1984 with random distribution (single tree plots) within the experimental area. Their average height in 1991 was 282 cm (range 206–400 cm). Seedlings within a family were treated with i) $GA_{4/7}$, ii) ringing, iii) $GA_{4/7}$ + ringing and iv) no treatment (control). There were three seedlings (replicates) per treatment per family. $GA_{4/7}$ was dissolved in ethanol at a 333 mg x mL^{-1} concentration and injected into the trees once on 20 June. The injection was done into a bored hole at the base of the 1989 internode on the stem using a micropipette. The amount of $GA_{4/7}$ solution injected into each seedling was 300 µl, ie, 100 mg of $GA_{4/7}$. Ringing was done on 19 June as semi-circular knife cuts without removing bark, and the distance between the two semi-girdles was about 2 cm.

An analysis of variance (JMP version 3.0.2., SAS Institute, Inc) was used for statistical evaluation of the number of female cones produced in 1993 and annual tree height increment data for 1991 and 1992.

RESULTS

1992 observations

There were no cones in the year 1992 on trees under experiment. This was a year without flowering on any Norway spruce experimental plot located in Kórnik.

1993 flowering response

No flowering was observed on control trees and numerous cones were noted on the treated individuals, where the number of cones per seedling varied from one to 40 (table I). Both $GA_{4/7}$ and ringing significantly enhanced the number of female cones per treated seedling (table IIa and b). Neither differences between families nor any of the interactions between factors were statistically significant.

There were no male strobili on the treated seedlings.

Height increment response

A significant $GA_{4/7}$ x ringing interaction was observed on the 1991 height increment of trees (tables III and IV), and 1 year later (in 1992) $GA_{4/7}$ as well as ringing influenced significantly the height increment of treated trees (table III): the $GA_{4/7}$ treatment increased stem height increment from 39.7

Table I. 1993 flowering: number of female cones per tree.

Treatment	*Replication*	*Family no*				*Mean values*
		1958	*1982*	*1990*	*1991*	
Control	I	0	0	0	0	
	II	0	0	0	0	
	III	0	0	0	0	0.00
$GA_{4/7}$	I	1	40	13	2	
	II	0	25	0	0	
	III	0	0	3	5	7.42
Ringing	I	0	0	0	0	
	II	0	5	0	0	
	III	13	0	0	8	2.17
$GA_{4/7}$ + ringing	I	25	10	15	25	
	II	6	15	35	2	
	III	22	2	13	25	16.25

to 49.7 cm, while ringing reduced it from 50.8 to 38.2 cm. Significant differences were also observed between families (tables III and V).

Table II. Influence of $GA_{4/7}$ and ringing on the number of female cones per tree in 1993.

a. Results of variance analysis

Source of variation	*df*	F	P
Total	47		
$GA_{4/7}$ (GA)	1	20.7743	0.0001
Ringing (R)	1	5.6997	0.0230
Families (F)	3	0.2630	0.8515
GA x R	1	2.0936	0.1576
GA x F	3	0.6329	0.5992
R x F	3	2.6065	0.0687
GA x R x F	3	2.3326	0.0927
Error	32		

b. Significant main effect means

	Treated with	*Untreated*
$GA_{4/7}$	11.8	1.1
Ringing	9.2	3.7

DISCUSSION

The year 1993 was characterized by very abundant female flowering of Norway spruce not only in our experimental plots but also throughout Poland. This flowering probably resulted from the very sunny June of 1992 when average daily sunshine was 10.5 h. According to Chalupka (1975) a minimum 9 h daily sunshine in June is needed for a good Norway spruce cone crop the next year.

The 1993 flowering was the first observed on the experimental seedlings and all flowers were initiated above the place of the $GA_{4/7}$ injection and/or ringing.

Results obtained clearly revealed a carry-over effect of both $GA_{4/7}$ and ringing in the stimulation of female flowering in Norway spruce seedlings in the second year after treatment, even though the ringing alone effect was rather small (table I). This could be explained by the method of ringing trees with very slight knife cuts without bark removing. These results confirmed those obtained by Bonnet-Masimbert (1987).

Table III. Height growth response in Norway spruce seedlings treated in 1991 with $GA_{4/7}$ and ringing. Results of variance analysis.

Source of variation	*1991 increment*			*1992 increment*		
	df	F	P	*df*	F	P
Total	47			44		
$GA_{4/7}$ (GA)	1	1.1036	0.3013	1	4.7561	0.0375
Ringing (R)	1	1.0567	0.3117	1	6.1240	0.0194
Families (F)	3	0.2097	0.8889	3	3.2526	0.0359
GA x R	1	4.8520	0.0349	1	0.6021	0.4441
GA x F	3	0.5762	0.6349	3	0.3100	0.8179
R x F	3	0.7239	0.5452	3	0.8173	0.4948
GA x R x F	3	0.6980	0.5602	3	0.0922	0.9637
Error	32			29		

Table IV. Interaction between $GA_{4/7}$ and ringing on the 1991 tree height increment.

	Height increment (cm)	
	$GA_{4/7}$	*No* $GA_{4/7}$
Ringing	84.9	72.9
No ringing	73.0	77.2

Table V. Mean 1992 tree height increment for families.

	Family no			
	1958	*1982*	*1990*	*1991*
Height increment	38.7	44.6	37.8	56.3
(cm)	(4.2)	(4.7)	(4.3)	(5.5)

Standard error in parentheses.

The effect in the second year after treatment has usually been attributed to girdling and/or strangulation alone (Heitmüller and Melchior, 1960; Melchior, 1960; Ross, 1992), or to the interaction of $GA_{4/7}$ and girdling (Pharis et al, 1980; Bonnet-Masimbert, 1982, 1987; Philipson, 1985). This is the first time when the carry-over effect appeared also as a result of $GA_{4/7}$ alone.

Bonnet-Masimbert (1987) explained the carry-over effect as an indirect effect of treatment on shoot vigor or bud size that could affect cone initiation in the following year. In his experiment girdling alone or with $GA_{4/7}$ increased the terminal shoot elongation the next year, which was the cone initiation year.

In my experiment only the $GA_{4/7}$ increased tree height increment, while ringing reduced it in the year of cone initiation. Such contrasting results indicate that the mode of action of gibberellins or ringing is not explainable by growth per se. It might involve other aspects of growth processes during the year preceding the year of flower initiation, eg, mitotic activity and subsequent changes in the shoot apex structure. This suggestion is supported by the results of Hejnowicz and Obarska (unpublished), who showed an increase of mitotic activity in the apical meristems and cataphyll primordia in Norway spruce after $GA_{4/7}$ spraying; this resulted 1 year later in an increase of bud length on sprayed shoots. Similar results

were obtained for Scots pine (Hejnowicz, 1987).

It was revealed earlier that an abundant cone crop in Norway spruce was significantly correlated with specific weather patterns for 2 years before flowering (eg, June temperature and July sunshine 1 year before flower initiation, and June sunshine and temperature 1 year before flowering) (Chalupka, 1975). This could support a carry-over effect in flower stimulation in Norway spruce.

Recently, Hejnowicz and Obarska (1995) described in Norway spruce an autumn initiation of first bud scale primordia for the bud formed the next growing season. Thus it is possible that in a year preceding flower induction $GA_{4/7}$ and/or other treatments (also climatic factors) function as triggering agents inducing initial changes in the apical meristems which lead to reproductive as opposed to vegetative development (Chałupka, 1980).

Different factors or treatments applied 1 year before flower induction could make the tree apical meristems more susceptible to the influence of some direct floral induction stimulus. In the 1991 experiment a proper amount of solar energy expressed by very high daily sunshine in June 1992, ie, during the time of generative structure differentiation, could be such a stimulus.

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REFERENCES

Bonnet-Masimbert M (1982) Effect of growth regulators, girdling, and mulching on flowering of young European and Japanese larches under field conditions. *Can J For Res* 12, 270-279

Bonnet-Masimbert M (1987) Preliminary results on gibberellin induction of flowering of seedlings and cuttings of Norway spruce indicate some carry-over effects. *For Ecol Manage* 19, 163-171

Bonnet-Masimbert M (1989) Field experiment on the effect of girdling and gibberellin application on flowering induction of 12-yr-old seedlings of Douglas fir and Norway spruce. *Ann Sci For* 46 (suppl), 47s-50s

Chalupka W (1975) Wpływ czynników klimatycznych na urodzaj szyszek u świerka pospolitego (*Picea abies* (L) Karst) w Polsce [Relation between cone crops of *Picea abies* ((L) Karst) in Poland and the climatic factors]. *Arbor Kórnickie* XX, 213-225

Chalupka W (1980) Regulation of flowering in Scots pine (*Pinus sylvestris* L) grafts by gibberellins. *Silvae Genet* 29, 118-121

Chalupka W (1985) *Regulacja kwitnienia na plantacjach nasiennych sosny zwyczajnej* (Pinus sylvestris *L) i świerka pospolitego* (Picea abies *(L) Karst)* [*Regulation of Flowering in Seed Orchards of Scots Pine* (Pinus sylvestris *L) and Norway Spruce* (Picea abies *(L) Karst)*]. Instytut Dendrologii PAN, Kórnik, Poland, 146 p

Heitmüller HH, Melchior GH (1960) Über die Blühfördernde Wirkung des Wurzelschnitts, des Zweigkrümmens und der Strangulation an japanischer Lärche (*Larix leptolepis* (Sieb & Zucc) Gord). *Silvae Genet* 9, 65-72

Hejnowicz A (1987) Changes in the development of apical meristem of *Pinus sylvestris* in response to gibberellin application. *For Ecol Manage* 19, 99-106

Hejnowicz A, Obarska E (1995) Structure and development of vegetative buds, from the lower crown of *Picea abies*. *Ann Sci For* 52, 433-447

Luukkanen O (1980) Hormonal treatment increases flowering of Norway spruce grafts grown in a plastic greenhouse. *Finn Found For Tree Breed Ann Rep* 1979, 21-26

Melchior GH (1960) Ringelungsversuche zur Steigerung der Blühwilligkeit an japanischer Lärche (*Larix leptolepis* (Sieb & Zucc) Gord) und an europäischer Lärche (*Larix decidua* Mill). *Silvae Genet* 9, 105-111

Pharis RP, Ross SD, McMullan E (1980) Promotion of flowering in the *Pinaceae* by gibberellins. III. Seedlings of Douglas fir. *Physiol Plant* 50, 119-126

Philipson JJ (1985) The promotion of flowering in large field-grown Sitka spruce by girdling and stem injection of gibberellin $A_{4/7}$. *Can J For Res* 15, 166-170

Ross SD (1992) Promotion of flowering in Engelmann-white spruce seed orchards by $GA_{4/7}$ stem injection: effects of site, clonal fecundity, girdling and NAA, and treatment carry-over effects. *For Ecol Manage* 50, 43-55