The acropetal effects of indole-3-acetic acid in isolated shoot segments of *Acer pseudoplatanus* L.

I. Growth responses of buds

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Abstract

The subject of this investigation were growth reactions of two opposite lateral buds of *Acer pseudoplatanus* L. stem sections in response to application of indole-3-acetic acid (IAA) and other synthetic growth regulators below the buds. No effect of IAA upon the initiation of bud growth was noted, however, elongation of new shoots was inhibited. This acropetal effect of auxin was enhanced by simultaneous treatment with triiodobenzoic acid (TIBA) or benzyladenine (BA). TIBA alone caused even stronger retardation of shoot growth. Exactly the opposite effect was produced by gibberellic acid (GA_3) applied even 30 cm below the buds. In this case TIBA could reverse the effect of GA_3 treatment. The results concerning acropetal effects of auxin suggest that some type of signalling system functions independently of the direct action of the exogenous IAA.

Key words: bud growth, IAA, acropetal inhibition, correlative growth, *Acer pseudoplatanus* L.

INTRODUCTION

Apical control and correlative growth of various branches in the process of tree formation (Brown et. al. 1967, Champagnat 1978) suggest both basipetal and acropetal regulation of the meristematic activity of shoot apices by endogenous auxin. The present paper reports on the acropetal effects of synthetic IAA on the growth of buds on isolated *Acer pseudoplatanus* L. shoots. In order to identify specific auxin effects, the responses of buds to other growth regulators applied either alone or in combination with IAA were tested simultaneously.

MATERIAL AND METHOD

One-year-old terminal shoots were collected in winter or early spring from well developed side branches of 5-year-old *Acer pseudoplatanus* L. trees grown in forest stands of the Experimental Forest Station in Rogów (Central Poland). Two axillary buds of the same apical node were arbitrarily marked as right and left and the other buds below them were removed. The stem was cut 0.5 cm above and 40 cm below the buds.

Shallow cuts were made and about 6 mm of the outer layers of periderm were removed (to expose the phloem) on two opposite sides of the stem 5, 10, or 30 cm below the buds in three different experimental series. Synthetic growth regulators i.e. indole-3-acetic acid (IAA), benzyladenine (BA), gibberellic acid (GA_3) and triiodobenzoic acid (TIBA) (alone or mixed as shown in the Tables) in a concentration of 0.5% each were applied in the form of a lanolin-water paste (2:1, w/v) to the cuts below the right buds. The cuts below buds designated as "left" were covered with pure lanolin-water paste. Control series included a) treatment with pure lanolin-water paste applied to both (left and right) sides of the shoot, and b) the shoots not wounded on the sides. The lanolin paste on the stem was changed every 5 days and protected with aluminium foil. Growth regulators were applied either on the day the experiment started or on the day when the buds began growing.

The shoots were placed vertically with the basal ends 1 cm deep in distilled water and at room temperature (about 18°C) with natural air humidity and daylight.

The effects of the experimental treatments were characterized daily by determining 1) the number of shoots on which the buds started to grow, and 2) by the time required for bud opening after the beginning of the experiment; the criterion for which was the appearance of internal scales between the external ones. Extension growth of new shoots was measured 20 days after the bud had started to grow.

The first experiment with all series started on January 8, 1986. All series were replicated on February 28, 1986 and some on February 10 and April 2, 1986 and on January 6 of the next year.

The results were subjected to analysis of variance and Student's test $P=0.05$.

RESULTS

In successive experiments performed from January to April the buds on shoot segments transferred to room temperature required less time to start growing (from about 22 days in January to about 5 days in April). Both buds initiated growth almost simultaneously in most series, except those in which

Table 1

Length of the new shoots (mm) formed from left (B_L) and right buds (B_R) in control combination and after application of IAA to the cuts on the stem at a distance of 5, 10 or 30 cm below the right buds on the day the experiment started. Means of 8-12 shoot sections. L — pure lanolin paste

Date of shoot cutting and application of growth regulators	Treatments													
			L	L	L	L	L	L	L	IAA	L	IAA	L	IAA
	B_L	B_R	B_L	B_R	B_L	B_R	B_L	B_R	B_L	B_R	B_L	B_R	B_L	B_R
			5 cm		10 cm		30 cm		5 cm		10 cm		30 cm	
Jan. 8, 1986	22.1	26.2	26.1	27.5	26.9	31.9	29.1	30.2	32.5	21.7	27.1	22.6	21.8	23.5
Feb. 10, 1986	—	—	—	—	28.9	29.0	—	—	—	—	34.0	31.9	—	—
Feb. 28, 1986	35.3	31.3	34.5	31.0	40.3	34.7	27.5	30.9	40.0	19.5	36.5	28.0	39.0	31.8
April 2, 1986	35.1	36.8	—	—	30.6	38.2	—	—	29.0	24.3	35.6	23.4	—	—
Jan. 6, 1987	35.0	33.4	22.1	23.2	30.6	31.7	—	—	24.4	17.9	18.1	18.6	—	—
Mean	31.9	31.9	27.6	27.2	31.5	33.1	28.3	30.6	31.5	20.9	30.3	24.9	30.4	27.7
$B_R - B_L$	0.0		-0.4		1.6		2.3		-10.6		-5.4		-2.7	
LSD	—		6.6		4.9		7.3		6.0		5.1		6.6	

IAA+GA₃ and IAA+GA₃+TIBA were applied to the stem cuts. In these series slight acceleration of bud break was observed above the point of application of growth regulators. Acropetal effects of auxin upon initiation of bud growth were not noticeable.

Removal of peridermal tissues on both sides of the shoots did not significantly effect the growth rate of the new shoots formed from either of the two buds above the wounds if no auxin was added to the lanolin paste (Table 1). Application of IAA to the cuts on one side (right) of the shoot inhibited elongation of the new shoot progressively less with the distance between the bud and the point of auxin application below it increasing from 5 to 30 cm (Table 2). The rate of elongation of the other bud (left) was analogous to that of the buds on shoots not treated with auxin. This acropetal growth-retarding effect of auxin from the distance of 10 cm was even increased by simultaneous

Table 2

Length of the new shoots (mm) formed from left (B_L) and right buds (B_R) after application of growth regulators to the cuts on the stem at a distance of 10 or 30 cm below the right bud on the day the experiment started. Means of 9-12 shoot sections. L — pure lanolin paste

Date of shoot cutting and application of growth regulators	Treatments							
	L	IAA TIBA	L	IAA BA	L	IAA TIBA BA	L	TIBA
	B _L	B _R	B _L	B _R	B _L	B _R	B _L	B _R
	10 cm							
Jan. 8, 1986	40.4	11.6	24.4	14.4	31.8	12.1	—	—
Feb. 10, 1986	34.5	19.2	—	—	—	—	—	—
Feb. 28, 1986	28.8	17.8	39.6	25.5	36.3	17.4	—	—
April 2, 1986	28.6	32.3	—	—	—	—	44.0	16.8
Jan. 6, 1987	14.2	9.6	—	—	—	—	28.0	8.8
Mean	29.3	18.1	32.0	20.0	34.1	14.8	36.0	12.8
B _R -B _L	-11.2		-12.0		-19.3		-23.2	
LSD	5.1		7.7		11.4		8.9	
30 cm								
Jan. 8, 1986	15.4	15.5	25.7	27.1	23.2	16.1	—	—
Feb. 28, 1986	27.4	27.3	26.2	21.6	26.8	30.4	—	—
Mean	21.4	21.4	26.0	24.4	25.0	23.3	—	—
B _R -B _L	0.0		-1.6		-1.7		—	
LSD	—		8.5		7.5		—	

application of TIBA, BA, or both together (Table 3). However, treatment with TIBA alone inhibited shoot growth from the bud above the site of application even more than did auxin alone applied at a distance of 5 cm.

Effect of GA_3 in interaction with IAA was just the opposite (Table 3). Shoot elongation from the bud on the same side as the treatment with phytohormones was greatly increased at the expense of growth of the opposite bud. This effect was equally well manifested, irrespective of the distance of application of growth regulators below the bud (10 or 30 cm). Additional supply of TIBA did not significantly change this stimulatory effect of GA_3 if IAA was present. However, if auxin was excluded, TIBA prevented additional stimulation of shoot elongation by GA above the site of application and the growth rate of the apposite new shoots was stimulated.

When the growth regulators were applied on the day when the buds started to grow no differences between elongation growth of new shoots formed from the left and right buds was noted (Table 4).

Table 3

Length of the new shoots (mm) formed from left (B_L) and right buds (B_R) after application of growth regulators to the cuts on the stem at a distance of 10 or 30 cm below the right bud on the day the experiment started. Means of 8-12 shoot sections. L — pure lanolin paste

Date of shoot cutting and application of growth regulators	Treatments							
	L	IAA GA	L	IAA TIBA GA	L	TIBA GA	L	GA
	B _L	B _R	B _L	B _R	B _L	B _R	B _L	B _R
	10 cm							
Jan. 8, 1986	9.7	37.0	16.8	36.4	—	—	—	—
Feb. 10, 1986	24.0	44.7	13.5	42.9	—	—	19.4	50.9
Feb. 28, 1986	26.0	31.4	23.2	49.0	—	—	—	—
April 2, 1986	—	—	—	—	48.8	27.0	33.2	46.0
Mean	19.9	37.7	17.8	42.8	48.8	27.0	26.3	48.5
B _R -B _L	17.8		25.0		—21.8		22.2	
LSD	5.2		11.5		10.5		9.5	
30 cm								
Jan. 8, 1986	17.2	43.8	9.5	28.1	—	—	—	—
Feb. 28, 1986	18.9	28.1	29.2	33.6	—	—	—	—
Mean	18.1	36.0	19.4	30.9	—	—	—	—
B _R -B _L	17.9		11.5		—		—	
LSD	10.5		7.9		—		—	

Table 4

Length of the new shoots (mm) formed from left (B_L) and right buds (B_R) after application of growth regulators to the cuts on the stem at a distance of 10 or 30 cm below the right bud on the day in which buds started to grow. Means of 9-12 shoot sections. L — pure lanolin paste

Date of shoot cutting	Treatments											
	L	IAA	L	IAA BA	L	IAA GA	L	IAA TIBA	L	IAA TIBA BA	L	IAA TIBA GA
	B _L	B _R	B _L	B _R	B _L	B _R	B _L	B _R	B _L	B _R	B _L	B _R
	10 cm											
Jan. 8, 1986	23.6	17.2	25.1	27.2	27.9	22.8	40.1	26.5	20.1	27.8	22.7	37.5
Feb. 28, 1986	31.5	29.8	26.0	25.8	35.0	34.6	30.4	32.2	39.1	24.2	26.8	33.1
Mean	27.6	23.5	25.6	26.5	31.5	28.7	35.3	29.4	29.6	26.0	24.8	35.3
B _R -B _L	-4.1		0.9		-2.8		-5.9		-3.6		10.5	
LSD	6.7		7.3		7.8		9.2		12.8		12.6	
30 cm												
Jan. 8, 1986	24.0	19.4	27.2	20.7	25.2	30.9	24.5	28.6	21.4	26.3	34.9	24.5
Feb. 28, 1986	35.7	26.6	30.8	39.1	22.8	24.7	32.3	29.3	28.4	26.6	23.3	28.3
Mean	29.9	23.0	29.0	29.9	24.0	27.8	28.4	29.0	24.9	26.5	29.1	26.4
B _R -B _L	-6.9		0.9		3.8		0.6		1.6		-2.7	
LSD	8.2		7.4		6.9		8.5		8.9		7.0	

DISCUSSION

The results of the present investigation confirm the earlier observation of Snow obtained with herbaceous plant shoots (1937, 1940) that auxin applied to stems retards elongation of buds situated above the site of its application. In the case of isolated *Acer* shoots used in this study, auxin applied at the shoot base also inhibited elongation of the new shoots formed from the axial buds, although the date of initiation of shoot growth was not affected. These acropetal effects of auxin retarding shoot elongation in *Acer* are very probably induced during an early phase of bud growth because the inhibition was not effective if application of IAA to the stem had already started.

The most spectacular effects on elongation growth of the bud directly above the point of application were caused by triiodobenzoic acid, a known synthetic regulator retarding polar transport of auxin (Niedergang-Kamien and Skoog 1956, Niedergang-Kamien and Leopold 1957). This substance not only increased the inhibition of bud elongation due to basal

treatment of the shoot with IAA, but was even more inhibitory when applied alone. It also prevented stimulation by gibberellic acid which occurs when this phytohormone is applied without TIBA. Benzyladenine did not reduce growth retardation by TIBA in interaction with IAA, while the effects of this interaction were excluded when GA_3 was applied simultaneously. This well documented interference of TIBA in the system imposing acropetal inhibition of bud elongation suggests involvement of shoot polarity in respect to auxin transport which, however, can be also modulated by other phytohormones.

Acropetal translocation of the regulating signal suggests that the mechanism involved in bud growth control is different from the direct effects caused by synthetic IAA molecules applied to the shoot, because effective acropetal transport of this phytohormone is not known (Leopold 1961, Thimann 1972, Goldsmith 1977). Maybe the regulation system associated with the change of configuration of the vectorial field formed by the translocation of auxin waves is involved, as described hypothetically by Zajaczkowski and Wodzicki (1978).

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Akropetalne efekty kwasu indolilo-3-octowego w wyizolowanych odcinkach pędów Acer pseudoplatanus L.

I. Reakcje wzrostowe pąków

Streszczenie

Badano w kulturze wodnej reakcję wzrostową dwóch naprzeciwnych pąków pachwinowych strefy podwierzchołkowej wyizolowanych i zdekapitowanych 40-cm. odcinków rocznych pędów na syntetyczny kwas indolilo-3-octowy (IAA) dostarczony do łodygi, poniżej jednego z pąków.

W celu wykazania specyficzności działania IAA zastosowano również inne syntetyczne regulatory wzrostu, t.j. kwas trójiodobenzoowy (TIBA), benzyloadeninę (BA) i kwas giberelinowy (GA_3). Nie stwierdzono wpływu IAA na inicjację wzrostu pąków, natomiast zaobserwowano zmniejszenie przyrostu długości nowych pędów utworzonych z pąków leżących powyżej miejsca dostarczenia tej substancji. Wyniki wykazały również, że IAA, podobnie jak inne syntetyczne regulatory wzrostu dostarczone do łodygi po inicjacji wzrostu pąków, nie miał wpływu na dalszy ich wzrost, co sugeruje indukcyjny charakter regulacji akropetalnej. BA i TIBA dostarczone do łodygi wraz z IAA wzmagają akropetalne hamowanie, natomiast GA_3 stymuluje wzrost nadległego pąka. Również sam TIBA działa hamująco na wzrost pąka, jednak efekt ten nie może być odwrócony przez jednoczesne dostarczenie GA_3 , jak w przypadku IAA. Wyniki wskazują na specyficzność działania IAA w akropetalnej regulacji aktywności wzrostowej merystemów wierzchołkowych pędu.

Z uwagi na polarny, bazypetalny transport auksyny w tkankach roślinnych, wyniki obecnych doświadczeń nasuwają przypuszczenie, że zaobserwowane akropetalne efekty syntetycznego IAA są przejawem funkcjonowania mechanizmu regulacyjnego, w którym główną rolę odgrywają zjawiska sygnałowe, nie wymagające przemieszczania się molekuł substancji czynnej.