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Rooting of *Syringa vulgaris* L. softwood cuttings using auxin, vitamins, phenolic substances, indole, SADH and abscisic acid

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Abstract

The cuttings taken at flowering time or earlier rooted much better than those taken after flowering. The apical cuttings rooted more aboundantly than those taken from medium or basal part of the shoots. Different auxins: NAA, IAA IBA and 2,4-D in optimal concentrations differed very little in their stimulatory effect or rooting. Several substances: indole, tannin, pyrogallol, thiamine, ascorbic acid, pyridoxine, ryboflavine, niacine, retardant SADH, abscisic acid, and boric acid promoted rooting of cuttings when used separately. Their combined effect with auxin was in most cases additive but sometimes synergistic. Three phases of rooting process were discerned.

INTRODUCTION

Auxins are commonly used to promote adventitious root formation in cuttings of *Syringa vulgaris L.* (Thimann and Behenke-Rogers 1950; Turetskaya 1961). Nevertheless cuttings of several lilac cultivars root insufficiently with this treatment. It seemed therefore advisable to investigate several additional factors and substances, besides of auxin treatment, which might improve root production.

MATERIAL AND METHODS

The experiments were carried on in Kórnik Arboretum. The shoots to prepare the cuttings were taken from the middle part of 6-7 year-old tress (3 years after planting). Seven cultivars of lilac were included into the experiment. Except of one experiment presented in table 2 only 1 or 2 cuttings were cut of a shoot, these were "apical" cuttings containing the apex and "medium" ones cut just beneath. The cuttings contained usually one elongated internode. The lower cut was done just below the node.

The auxins were applied always in talc. The fungicides, if used, were mixed with auxin-talc preparates. Vitamins were given in talc or (niacine) in concentrated solutions (quick-dip method), with the time of soaking 5 seconds. Phenolic substances and indole were applied as dilute solutions or as concentrated solutions. Indole and abscisic acid (ABA) were administered with diluted solutions method with 24 hour of soaking. The retardant SADH was given in the form of the preparate Alar-85 with the concentrated solutions method or in talc.

The cuttings were planted in a greenhouse in a layer of perlit 5 cm thick placed on a layer of a mixture of sterilized compost soil and peat (2 : 1). The benches with cuttings were protected with windows against excessive evaportation and shaded when needed. The temperature in the greenhouse was 20-28°. Sprinkling was done by hand. Every 1-2 weeks the leaves of the cuttings were sprayed with Benlate in concentation 0.05%.

The experiment was set up in 3 randomized blocks. Rooting of cuttings was defined as:

1. The number of rooted cuttings per a plot of 8 or 16 cuttings.
2. The average number of roots per cutting.
3. The total length of roots per cutting.

The rooting of cuttings was evaluated twice: 4 and 8 weeks after planting. In this paper only the observations after 8 weeks are given and discussed.

The numbers of rooted cuttings per plot were transformed by using Freeman-Tukey angle transformations and the analysis of variance was made on transformed values. The other values were worked out statistically without transformations, with the method of analysis of variance using Duncan's multiple range test for significance at P = 0.05 only for Table 6 P = 0.01. The criterion of synergism was adopted from G o r t e r (1969).

RESULTS

The date of taking the cuttings from mother plant had marked effect on their capacity to form adventitious roots (Tab. 1). The earlier the cuttings were taken, the larger was the number of rooted cuttings per plot, the larger average number of roots per cutting and longer roots. Naphthaleneacetic acid (NAA) in both concentrations showed marked effect on rooting in this experiment. The interaction "date of taking the cuttings" × "substance used" was significant only for the total length of roots (Fig. 1): the growth substances increased the length of the roots to a larger extent when applied on May 10 or 20 than on later dates;

Table 1

The influence of the date of taking cuttings and of the growth stimulator used on root production in cv. 'Profesor Hoser'

Date of taking cuttings	No. of rooted plants per 16 cuttings	Roots No. per cutting	Total root length per cutting in cm
May 10 (before blooming)	12.8 c	4.1 d	38.3 d
May 20 (beginning of blooming)	10.1 b	3.3 c	26.3 c
May 29 (full blooming)	5.0 a	2.0 b	12.6 b
June 10 (after blooming)	4.2 a	1.5 a	8.1 a
Treatment			
Control	5.2 a	1.7 a	10.7 a
NAA 0.2%	8.9 b	3.2 c	25.2 c
NAA 0.2% + Benomyl * 0.5%	9.1 b	2.5 b	21.7 b
NAA 0.4%	9.0 b	3.6 d	25.4 c

The numbers marked with the same letter do not differ significantly at P = 0.05.
* Active ingredient of Benlate.

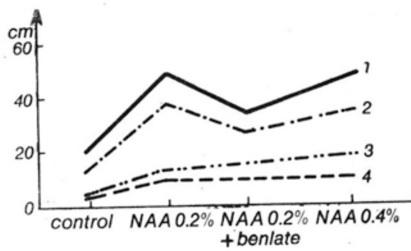

Fig. 1. The interaction "date of taking cuttings" × "substances used" for the total lenght of roots per cutting
1 — May 10, 2 — May 20, 3 — May 29, 4 — June 10

the fungicide Benlate decreased the length of the roots only when used at early dates.

The comparison of rooting ability of cuttings taken from different parts of the shoots (Tab. 2) shows that the "apical" cuttings rooted the best and the basal ones — the worst. There was a significant interaction between the treatment and the type of cuttings concerning the length of the roots: the apical and middle cuttings responded to the auxin treatment much more than basal cuttings. Both fungicides used showed no effect on middle and basal cuttings and slightly deterimental effect on apical cuttings (Fig. 2).

The comparision of the effect of different auxins on adventitious root production showed that 2,4-D in concentrations 0.05% and 0.1% was

Table 2

Comparison of ability to form roots of cuttings taken from different parts of the shoot. Cv. 'Edmond Boissier', cuttings taken on May 23

Type of the cuttings	No. of rooted plants per 8 cuttings	Roots No. per cutting	Total root length per cutting in cm
Apical	6.4 c	6.7 c	49.5 c
Middle	5.3 b	5.4 b	43.1 b
Basal	3.2 a	3.2 a	18.8 a
Treatment (apical, middle, basal taken jointly)			
Control	4.2 a	3.1 a	15.7 a
NAA 0.2%	5.2 b	5.3 b	40.7 bc
NAA 0.2% + Captan 0.3%	5.1 b	5.1 b	39.5 b
NAA 0.2% + Benomyl 0.5%	5.3 b	4.9 b	40.9 c
NAA 0.4%	5.0 b	7.1 c	48.6 d

Details as in Table 1.

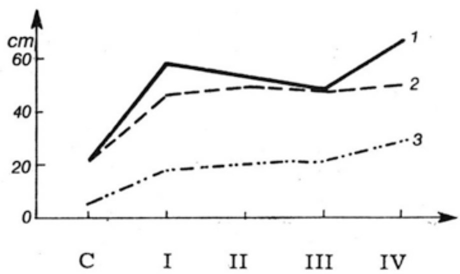

Fig. 2. The interaction "type of cuttings" × "substance used" for the length of roots

1 — apical, 2 — middle, 3 — basal
C — control; I — NAA 0.2%; II — NAA 0.2% + Benlate; III — NAA 0.2% + Captan; IV — NAA 0.4%

one of the best stimulators. All auxins differed, however, very little among themselves in their effect (Tab. 3).

Investigation of the root stimulating effect of indole (Tab. 4) has shown that this compound used separately promoted rooting similarly or even more than auxins. The combined effect of indole and auxin on the average root number per cutting was additive, and on the total length of the roots per cutting was in most cases synergistic. The concentration of indole 50 mg/l seems to be optimal.

The phenolic substances tannin and pyrogallol as well as the retardant SADH and growth inhibitor ABA showed significant promotion of rooting, when applied separetely (Tab. 5). When used jointly with auxin they did not increase the number of rooted cuttings more than auxin

Table 3

The influence of different auxins applied in talc powder on the rooting of cuttings. Cv. 'Maurice de Vilmorine'; cuttings taken on May 24

Treatment	No. of rooted plants per 8 cuttings	Roots No. per cutting	Total root length per cutting in cm
Control	0.0 a	0.0 a	0.0 a
NAA 0.2%	3.3 b	3.1 c	13.2 bcd
NAA 0.4%	4.0 bc	2.8 bc	18.6 d
IBA 0.1%	4.7 bcd	3.1 c	14.8 cd
IBA 0.2%	5.0 cd	2.0 b	8.5 b
IAA 0.1%	3.3 b	1.9 b	11.0 bc
IAA 0.2%	5.0 cd	1.8 b	12.5 bc
2,4-D 0.02%	4.7 bcd	3.2 c	10.6 bc
2,4-D 0.05%	4.3 bcd	3.3 c	12.6 bc
2,4-D 0.1%	5.3 d	3.3 c	15.8 cd
2,4-D 0.4%	3.7 bc	1.8 b	10.3 bc

Details as in Table 1.

Table 4

The influence of indole and auxin on the rooting of cuttings. Indole applied as a dilute solution, auxin used in talc. Cv. 'Me Casimir Perier'; cuttings taken on May 26

Treatment	No. of rooted plants per 16 cuttings	Roots No. per cutting	Total root length per cutting in cm
Control	5.7 a	1.7 a	7.3 a
Indole 10 mg/l	8.6 bc	3.9 d	34.4 c
Indole 50 mg/l	8.7 bc	5.7 f	47.6 d
Indole 100 mg/l	7.7 ab	2.7 b	26.9 b
IAA 0.2%	8.6 bc	3.6 cd	21.9 b
NAA 0.2%	9.7 bcd	3.7 d	25.6 b
IAA 0.2% + Indole 10 mg/l	11.3 d	A* 5.2 e	A 57.2 e
IAA 0.2% + Indole 50 mg/l	9.6 bcd	A 6.2 g	A 62.4 ef
IAA 0.2% + Indole 100 mg/l	10.0 cd	3.2 c	A 33.2 c
NAA 0.2% + Indole 10 mg/l	10.3 cd	S 6.9 h	S 67.4 f

A* — additive effect, S — synergistic effect.
Other details as in Table 1.

alone, but showed additive or even synergistic effect on the total root length and in the case of pyrogallol on the root number per cutting.

The effect of the all vitamins used and of boric acid on root production is presented in Table 6. Each of these substaces applied separately or in combination with auxin showed no effect on the number of

Table 5

The effect of phenolic substances, SADH (Alar), ABA and auxin on the rooting of cuttings. Cv. 'Ludwig Spaeth', cuttings taken on June 8

Treatment	No. of rooted plants per 16 cuttings	Roots No. per cutting	Total root length per cutting in cm
Control	3.3 a	2.2 a	7.1 a
SADH 0.1%	10.0 b	2.7 ab	7.9 a
Tannin 1 mg/l	9.7 b	2.5 a	11.8 abc
Pyrogallol 1 mg/l	9.3 b	2.4 a	9.4 ab
ABA 0.1 mg/l	10.0 b	3.8 c	15.6 bc
ABA 0.5 mg/l	7.0 ab	3.6 bc	15.2 abc
NAA 0.2%	8.0 b	3.6 bc	19.1 c
NAA 0.2% + SADH 0.1%	10.3 b	4.5 cd	A 28.8 d
NAA 0.2% + Tannin 1 mg/l	10.3 b	4.4 cd	A 27.5 d
NAA 0.2% + Pyrog. 1 mg/l	11.0 b	S 5.2 d	S 38.1 e
NAA 0.2% + ABA 0.1 mg/l	12.0 b	4.6 cd	A 27.8 d
NAA 0.2% + ABA 0.5 mg/l	7.3 b	3.8 c	A 28.4 d

A* — additive effect, S — synergistic effect.
Other details as in Table 1.

rooted cuttings per plot. The vitamins increased, however, similarly like the auxin alone the number of roots per cutting and the total length of roots per cutting. Auxin with vitamins or with bonc acid caused marked additive or synergistic increase of the number of roots per cutting and of the total root length per cutting.

The cuttings taken in July produce usually very few adventitious roots. Treatment with auxin alone does improve markedly this result. It seemed therefore important to get information if combinations of an auxin with other root-promoting substances may improve rooting at this season more than auxin alone. The experiment providing such information is presented in Table 7. The auxin was supplied in talc powder and the other substances by the quick dip method which is much more convenient in practice than the dilute solution method. All substances used in this experiment except retardant SADH increased the number of rooted cuttings when used separately and caused marked additive increase of this number when combined with auxin. Especially remarkable was the effect evoked by niacin at a concentration of 2000 mg/l in combination with an auxin. All substances used in this experiment, when combined with an auxin caused an additive or synergistic increase of the number of roots per cutting but only niacin increased additively the root length per cutting.

Table 6

The influence of vitamins, boric acid and auxin on the rooting of cuttings. Cv. 'Mme Felix', cuttings taken on May 27

Treatment		No. of rooted plants per 16 cuttings		Roots No. per cutting		Total root length per cutting in cm	
		without auxin	with auxin	without auxin	with auxin	without auxin	with auxin
Control		8.0 a		1.2 a		6.1 a	
NAA 0.2%			12.0 abc		2.3 bc		15.6 bc
Thiamine	0.02	13.6 abc	12.6 abc	2.4 bcd	3.8 efg A	17.7 bcdef	25.2 efghij A
—	0.1	13.6 abc	13.6 abc	2.5 bcd	4.2 efgh A	17.2 bcde	27.4 hijk A
—	0.5	12.0 abc	12.6 abc	2.1 b	3.6 efg A	15.8 bc	21.3 bcdefgh A
Ascorb. acid	0.02	12.0 abc	14.6 bc	2.1 b	3.5 efg A	18.1 bcdefg	31.6 ijkl A
—	0.1	10.6 abc	15.0 c	2.3 bc	4.2 efgh A	18.4 bcdefg	31.6 ijkl A
—	0.5	10.6 abc	13.6 abc	2.1 b	3.3 def A	14.9 bc	27.8 hijk A
Pyridoxine	0.02	11.3 abc	10.0 abc	1.6 ab	4.5 ghij S	14.6 bc	29.4 hijk A
—	0.1	10.3 abc	11.6 abc	2.3 bc	4.3 fghi A	14.3 bc	26.8 ghijk A
—	0.5	10.0 abc	11.6 abc	2.5 bcd	5.3 ij S	16.1 bcd	34.8 kl A
Ryboflavine	0.02	11.0 abc	11.3 abc	2.0 b	3.2 cde A	16.4 bcd	24.6 defghij A
—	0.1	11.0 abc	12.3 abc	2.3 bc	3.9 efgh A	14.8 bc	24.6 defghij A
—	0.5	12.0 abc	11.6 abc	2.4 bcd	4.0 efgh A	18.2 bcdefg	33.2 jkl A
Nicotinic acid	0.02	11.0 abc	10.6 abc	2.2 b	3.8 efg A	13.4 b	26.3 fghijk A
—	0.1	12.0 abc	12.0 abc	2.4 bcd	4.9 hij S	16.6 bcde	39.3 l S
—	0.5	9.6 ab	11.3 abc	2.2 b	3.3 def A	15.2 bc	22.9 cdefghi A
Boric acid	0.2	12.6 abc	12.6 abc	2.1 b	3.7 efg A	14.5 bc	29.3 hijk A
—	0.5	11.3 abc	12.6 abc	2.4 bcd	5.4 j S	16.8 bcde	38.4 l S
—	1.0	9.6 ab	11.3 abc	2.1 b	3.7 efg A	16.2 bcd	24.6 defghij A

P=0.01.
Other details as in Tables 1 and 4.

Table 7

Root promoting effect of pyrogallol, niacin and SADH applied by the method of concentrated solutions and of auxin applied in talc. Cv. 'Primrose' cuttings taken on July 3

Treatment	No. of rooted plants per 8 cuttings	Root No. per cutting	Total root length per cutting in cm
Control	0.7 a	0.6 a	1.6 a
SADH 2125 mg/l	1.7 ab	1.6 b	13.2 b
Pyrogallol 1000 mg/l	2.3 b	2.4 c	18.8 c
Niacin 1000 mg/l	2.7 c	2.0 bc	23.8 d
Niacin 2000 mg/l	3.0 bc	2.3 c	30.1 e
NAA 0.2%	4.3 cd	3.6 d	31.7 ef
NAA 0.2% + SADH 2125 mg/l	5.3 de	A 5.2 ef	33.8 ef
NAA 0.2% + pyrogallol 1000 mg/l	A* 6.3 ef	A 4.8 e	35.0 f
NAA 0.2% + niacin 1000 mg/l	A 6.7 ef	S 5.9 f	A 56.0 g
NAA 0.2% + niacin 2000 mg/l	A 7.3 f	A 5.1 e	A 61.8 h

A* — additive effect, S — synergistic effect.
Other details as in Table 1.

DISCUSSION

Rooting ability of lilac cuttings depended markedly on the date when they were prepared. The best results being obtained with cuttings made at flowering time or earlier. Also Sonnenfeld (1961) has found the best rooting response in lilac cuttings made at flowering time. Preparing cuttings in May or June was also advised by Coggeshall (1962) and Turetskaya (1953). It has to be stressed, however, that making the cuttings before flowering is not economic. The shoots are very small at that time and not many cuttings can be collected from one bush. Therefore the treatments presented in Table 7 which caused a rooting of over 90% of cuttings in July seem to be of importance for practice.

The youngest parts of a shoot containing the apex and with the wood not yet fully lignified showed the best rooting response. Also Coggeshall (1962) advised to take terminal cuttings.

The fact that different auxins showed similar root promoting properties whith lilac cuttings was not surprising since several earlier papers reported such result (Białobok and Jankiewicz 1953; Thimann and Behnke-Rogers 1950). Promising results received with

2,4 D are of value because this compound is very cheap and common on the market of many countries. It has to be born in mind, however, that this compound shows antagonism with several substances with which other auxins stimulate synergisticly the rooting of cuttings (Basu 1969).

The lack of effect or even detrimental effect of fungicides used as an admixture to the talc-auxin preparate in this experiment was not expected since earlier papers of several authors reported higher per cent of rooted cuttings with fungicide added to the auxin preparations (van Elk 1969; Piątkowski *et al.* 1973). Probably spraying the leaves with Benlate performed regularly in this experiment protected sufficiently also the parts of the cuttings which were dipped in the medium.

A synergistic effect between the auxin and indole was reported by Gorter (1969) and Basu (1969). Our results show that there was a synergistic effect of NAA with indole but only an additive one of IAA with indole on the number of roots per cutting and on the total root length per cutting. Auxin with indole did not cause, however, any significant increase of the number of rooted cuttings per plot over that caused by auxin alone. Since indole alone shows marked root-promoting activity it seems that both substances: auxin and indole are acting on two rather different systems involved in adventitious root production.

The retardant SADH, phenolic substances: tannin and pyrogallol, and the growth inhibitor abscisic acid, all stimulated the production of roots in cv. Ludwig Spaeth cuttings. All these substances are known from earlier papers to promote rooting of cutings of several other species (Read and Hoysler 1969; Basu *et al.* 1969, 1970, Roy *et al.* 1972a, b; Jankiewicz *et al.* 1973; Bojarczuk and Jankiewicz 1975). However, there were also data indicating an antagonistic effect of pyrogallol with an auxin in *Phaseolus* cuttings (Basu 1969). Meskhi and Dzhokhadze (1973) gives pyrogallol as an exemple of a substance inhibiting growth of the root system of *Phaseolus* and *Zea* and growth of tissue culture of carrot. SADH did not promote rooting of magnolia cuttings (Jankiewicz *et al.* 1973).

Root promoting properties of several vitamins were often reported in literature (Thimann and Behnke-Rogers 1950; Turetskaya 1961). Rarely, however, the whole collection of them was investigated in one experiment and very rarely their effect as well on the number of rooted cuttings as on the number of roots per cutting and their total length was taken into account. The activity of vitamins in this experiment was characterized by a complete lack of influence on the number of rooted cuttings regardless whether they were used separately or when with an auxin (with exception of niacine, Table 7). Boric acid did not differ from them in this respect. Their effect on the number of roots per cutting and on the total root length was beneficial, especially when they were used in combination with the auxin. Another problem encountered in this vitamin experiment, which is worthwhile to be considered is — why they all affect the rooting so uniformly. We have expected much more diversity among them.

Considering the effects of different root promoting substances used in this experiment the authors came to the conclusion that several links (phases) may be discerned in the process of adventitious root formation:

1. The formation of root primodia on a cutting or stimulation of the development of preexisting root primordia. Some aspects of this process were discussed in the papers of Haissig (1972) and Syrovatko (1972). The number of rooted cuttings depends, probably, mainly on this link.

2. Interaction and competition among developing root primordia. The number of roots per cutting depends, obviously, largely on this process. Abundant supply of nutrients, microelements and substances used to synthesize enzymes, like for instance vitamins lower the competition among primordia and may increase the number of roots per cutting.

3. The growth of already formed roots. This proces may be supported by the same substances as the second one but may also depend on some others, more specific.

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Zakorzenianie się sadzonek zielnych *Syringa vulgaris* L. pod wpływem auksyn, związków fenolowych, indolu, SADH, i kwasu abscysynowego

Streszczenie

Sadzonki pobierane w czasie kwitnienia lub wcześniej zakorzeniały się znacznie lepiej niż pobierane później, ale niektóre sposoby traktowania zwiększały zakorzenianie sadzonek pobranych w lipcu do 90%. Sadzonki wierzchołkowe zakorzeniały się obficiej niż sadzonki brane z środkowej lub podstawowej części pędu. Różne auksyny zastosowane w optymalnych stężeniach stymulowały w podobny sposób zakorzenianie się. Szereg substancji: indol, tanina, pirogallol, tiamina, kwas askorbinowy, pirydoksyna, ryboflawina, niacyna, retardant SADH, kwas abscysynowy i kwas borowy stymulowały zakorzenianie się sadzonek, gdy były zastosowane pojedynczo. Ich współdziałanie z auksynami miało charakter addytywny lub synergistyczny. Zastosowano metodę roztworów stężonych dla pirogallolu, niacyny i SADH oraz metodę proszkową dla witamin. W procesie zakorzeniania sadzonek i wyróżniono 3 fazy.