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The chemical defoliation of ornamental nursery shrubs *Forsythia* × *intermedia* Zab., *Rosa* cv. Lampion, *Spiraea* × *bumalda* Burv. cv. Froebelii, *Spiraea* × *vanhouttei* Zab.

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Abstract

The defoliants used on shrubs in the nursery were: ethephon, KJ, $Mg(ClO_3)_2 \cdot 6H_2O$, $CuSO_4 \cdot 5H_2O$, $(NH_4)_2SO_4$ in various concentrations separately or as mixtures. Spraying was performed on September 26-28 1972 and 1973. The most effective defoliant for *Rosa* cv. Lampion, *Spiraea* × *bumalda* cv. *Froebelii*, *Spiraea* × *vanhouttei* shrubs was KJ applied at a concentration of 0.2% or used in mixture with ethephon or $(NH_4)_2SO_4$ in lesser concentrations. Effective defoliation of many shrubs including *Forsythia* × *intermedia* was obtained with $Mg(ClO_3)_2$ used at a concentration of 0.24-0.48% or $CuSO_4$ at concentration of 2%. But at the same time these defoliants brought about comparatively the greatest retardation in shrubs development and growth and, in the case of *Forsythia* × *intermedia*, reducted also frost resistance.

INTRODUCTION

Many species of shrubs in moderate climatic conditions lose their leaves very late in autumn. This creates problems for the digging and selling of the plants. Chemical defoliants can be of aid in solving these problems (Macdonald and Kempton 1968; Czarnoleski and Ciesielski 1972; Jones et al. 1974).

The experiments described in this paper were performed to find the best defoliants and to determine the resulting frost resistance and next year growth of certain species of ornamental shrubs in the climatic conditions of central Poland. These experiments were conducted at the same time as those previously published by Marczyński (1977).

MATERIALS AND METHODS

The following plants were used in the experiments: two-year-old forsythia shrubs (*Forsythia* × *intermedia* Zab.); one-year-old rose grafts

(*Rosa* cv. *Lampion*); and two and three-year-old meadowsweet shrubs (*Spiraea* × *bumalda* Burv. cv. Froebelii and *Spiraea* × *vanhouttei* Zab. respectively). These plants were all grown at the ornamental nursery in Umiastów near Warsaw and were ready for sale. The experiments were performed twice. Once with shrubs sprayed September 26-28, 1972 and the second time with shrubs sprayed at the same dates in 1973.

Five defoliants were used in these experiments. They were: ethephon (as Amchem 68 — 250), ammonium sulfate — $(NH_4)_2SO_4$, magnesium chlorate — used as technical preparation including 60% of $Mg(ClO_3)_2 \cdot 6H_2O$ *; copper sulfate — $CuSO_4 \cdot 5H_2O$ **; and potassium iodide — KJ The various concentrations used are shown in Table 1 and 2.

The methods of defoliant application, observation of their influence, and measurement of shrub development and growth were the same as those in the previous experiments with one exception: instead of counting the rose buds in the spring, the number of blossoms in spring and summer was counted.

The frost resistance of the forsythia shoots taken from the field experiments was determined by tests of differences in electrical conductance before and after cooling or freezing. The shoots of the plants sprayed in autumn 1972, were cut on March 15, 1973. Those of the plants sprayed in autumn of 1973 were cut twice — on December 17, 1973, and February 28, 1974. The shoots were cooled at 0°C or frozen at −26°C **. The method of measurement of frost resistance was the same as in the previously described experiment (Marczyński 1977).

The results of these experiments were evaluated statistically using an analysis of variance and Duncan's test for the significance of differences at $P=0.05$.

OBSERVATION AND RESULTS

Defoliation

Forsythia × *intermedia*. Efficient defoliation of shrubs (with more than a 75% leaf drop), was observed in 1973 three weeks after spraying plants with copper sulfate at concentrations of 2% or 3%. Similar results were obtained using a mixture of this preparation with magnesium chlorate or ethephon (Table 1). Magnesium chlorate concentration of 0.3% was nearly as effective as the preparation noted above (73.6% defoliation). In 1973 during the same period efficient defoliation was

* Hereafter chemicals symbols are given only in unhydrated forms.

** The shoots cut on Feb. 28, 1972 were frozen at −22°C instead at −26°C because they were probably less frost-resistant due to the unusually warm temperatures.

Table 1

Per cent of defoliation from four species of ornamental shrubs depending on the defoliant and its concentration

Date of application — Sept. 26-28 1972

Treatment	Concentration *	*Forsythia* x *intermedia* **		*Rosa* cv. Lampion		*Spiraea* x *bumalda* cv. Froebelii		*Spiraea* x *vanhouttei*	
		per cent of leaves fallen after							
		14 days	21 days	14 days	21 days	14 days	21 days	14 days	21 days
Control	H_2O	8.2 a	17.5 a	29.1 a	41.8 a	3.4 a	12.0 a	9.5 a	19.9 a
Ethephon	1000 ppm	16.0 ab	24.5 a	47.4 b	60.8 b	32.8 c	62.1 c	19.9 a	29.1 a
Ethephon	1500 ppm	—	—	42.5 b	52.4 b	—	—	—	—
$Mg(ClO_3)_2$+	(0.4%)								
+ethephon	0.24%+1000 ppm	—	—	67.4 c	79.4 c	—	—	—	—
$Mg(ClO_3)_2$	(0.4%) 0.24%	37.2 c	48.2 b	78.1 d	80.4 c	15.8 b	39.2 b	73.5 c	88.4 bcd
$Mg(ClO_3)_2$	(0.5%) 0.3%	58.9 d	73.6 c	70.1 cd	80.7 c	18.5 b	45.1 b	60.1 b	85.5 bc
$Mg(ClO_3)_2$+	(0.4%)	75.1 ef	88.4 d	—	—	25.2 b	62.0 c	55.5 b	79.2 b
+$CuSO_4$	0.24%+2%								
$CuSO_4$+	2%+1000 ppm	65.5 de	77.6 cd	—	—	55.7 d	88.0 e	82.5 cd	91.6 cd
+ethephon									
$CuSO_4$	2%	77.1 f	84.1 d	80.1 d	85.9 c	56.2 d	84.0 de	75.9 c	88.1 bcd
$CuSO_4$	3%	80.2 f	87.0 d	72.8 cd	86.0 cd	40.7 c	76.9 d	78.5 c	89.9 bcd
KJ+									
+ethephon	0.2%+1000 ppm	28.0 c	44.8 b	95.3 f	100.0 e	89.6 f	98.6 f	80.7 c	86.0 bc
KJ+	(0.4%)								
+$Mg(ClO_3)_2$	0.2%+0.24%	—	—	77.4 cd	86.8 cd	—	—	—	—
KJ+$CuSO_4$	0.2%+2%	—	—	82.3 de	92.7 de	—	—	—	—
KJ	0.2%	25.9 bc	43.9 b	91.0 ef	96.6 e	72.6 e	93.3 f	83.7 cd	90.4 cd
KJ	0.3%	32.9 c	51.1 b	92.4 ef	98.1 e	76.9 e	92.4 ef	95.9 d	97.8 d

* Numbers in brackets ar the concentrations of technical preparation.

** Separate statistical analysis was done for observations at 14 and 31 days after treatment.

Means designated by the same letter do not differ signifcantly at P — 0.05.

ascertained using a concentration of magnesium chlorate 0.24% or 0.48% and copper sulfate concentrations of 2% (Table 2). Potassium iodide applied at concentrations of 0.3% although injuring leaves caused defoliation of less than 53%.

Rosa cv. Lampion. All investigated defoliants caused significant leaf drop as compared with the control shrubs (Table 1, 2). In 1972 the most effective defoliation was shown by potassium iodide in concentration of 0.2% and 0.3% applied separately as well as mixed with ethephon or copper sulphate (92-100% defoliation). The smallest amount of leaves fell (42-47%) from the rose bushes treated with ethephon concentration of 1000 to 1500 ppm (Table 1).

In 1973 the fastest leaf drop was from shrubs sprayed with ethephon concentration of 1500 ppm and with KJ at concentration of 0.4%. Within 2 weeks time almost 100% of the leaves were defoliated. Other applied defoliants, except KJ at concentration 0.1% or its mixture with $(NH_4)_2SO_4$, gave a result of 90% leaf drop within three weeks of spraying (Table 2).

Spiraea × *bumalda cv. Froebelii.* In investigations in 1972 the fastest leaf drop resulted from the mixture of 0.2% solution of potassium iodide with ethephon at a concentration of 1000 ppm (after two weeks 89% and after 3 weeks 98% defoliation). Three weeks after spraying an even effect was shown by a solution of KJ concentrate of 0.2% or 0.3% (93% defoliation). Shrubs treated with $CuSO_4$ at the same time lost leaves from 76.9% to 88.0% (Table 1).

In 1973 the best defoliants were a 0.2% solution of potassium iodide as well as a mixture of 0.05% KJ with ethephon concentration of 750 ppm (87% defoliation within 3 weeks). At the same time defoliation of over 70% was obtained with 2% copper sulfate solution, ethephon concentration of 1500 ppm, 0.1% potassium iodide solution, or a mixture of 0.05% KJ with $(NH_4)_2SO_4$ at a concentration of 5% (Table 2).

Spiraea × *vanhouttei.* The majority of defoliants showed a high efficiency, causing 75% leaf drop three weeks after spraying (Table 1, 2). The highest level of defoliation (within 3 weeks from 88% to 98%) was given by KJ concentration of 0.2% or 0.3% as well as $CuSO_4$ or $Mg(ClO_3)_2$ in all investigated concentrations. Relatively good defoliation was also shown by the mixture of 5% $(NH_4)_2SO_4$ and 0.05% KJ. Within two weeks of spraying 75% defoliation was shown (Table 2). This mixture caused larger leaf drop than any of its ingredients used separately in double concentrations.

Table 2

Per cent of defoliation from four species of ornamental shrubs, depending on the defoliant and its concentration
Date of application — Sept. 26-28 1973

Treatment	Concentration *	*Forsythia* x *intermedia* **		*Rosa* cv. Lampion		*Spiraea* x *bumalda* cv. Froebelii		*Spiraea* x *vanhouttei*	
		per cent of leaves fallen after							
		14 days	21 days	14 days	21 days	14 days	21 days	14 days	21 days
Control	H_2O	1.8 a	4.8 a	10.4 a	27.9 a	1.8 a	14.1 a	0.1 a	9.2 a
Ethephon	1500 ppm	8.6 b	15.4 ab	99.0 d	99.3 d	41.3 cd	73.5 de	3.0 b	13.3 a
$(NH_4)_2SO_4$	10%	17.7 c	26.1 abc	77.4 bc	93.7 cd	31.9 c	40.0 b	66.0 ef	76.4 de
$Mg(ClO_3)_2$	(0.4%)								
	0.24%	57.4 f	80.5 de	85.5 c	96.9 d	6.8 ab	17.8 a	59.0 e	86.7 def
$Mg(ClO_3)_2$	(0.8%)								
	0.48%	63.0 f	92.1 e	76.6 bc	94.4 cd	13.7 b	24.6 a	56.4 e	92.8 f
$CuSO_4$+									
+ethephon	1%+750 ppm	44.7 e	58.0 cd	—	—	—	—	—	—
$CuSO_4$	1%	47.1 e	58.4 cd	—	—	—	—	—	—
$CuSO_4$	2%	62.1 f	73.2 cde	78.6 bc	91.8 cd	64.8 ef	78.0 def	76.7 g	90.7 f
KJ+									
+$(NH_4)_2SO_4$	0.05%+5%	15.0 c	22.5 ab	—	—	57.5 ef	70.2 cd	75.5 fg	79.5 de
KJ+									
+$(NH_4)_2SO_4$	0.1%+5%	—	—	62.3 b	81.8 bc	—	—	—	—
KJ+									
+ethephon	0.05%+750 ppm	—	—	—	—	62.6 ef	87.7 f	33.8 d	50.9 c
KJ+									
+ethephon	0.1%+750 ppm	—	—	82.6 c	94.6 cd	—	—	—	—
KJ	0.05%	—	—	—	—	36.6 c	57.3 c	15.2 c	29.1 b
KJ	0.1%	—	—	62.7 b	77.1 b	52.5 de	74.7 de	60.3 e	74.7 d
KJ	0.2%	29.5 d	47.0 bcd	78.9 bc	92.6 cd	68.5 f	86.9 ef	81.1 g	88.1 ef
KJ	0.4%	—	—	95.8 d	98.7 d	—	—	—	—

* Numbers in brackets ar the concentrations of technical preparation.
** Separate statistical analysis was done for observations at 14 and 21 days after treatment.
Means designated by the same letter do not differ significantly at P = 0.05.

The subsequent influence of defoliants on plants

Forsythia × *intermedia*. The first small necrotic spots were observed on young shoots two weeks after spraying forsythia with copper sulfate. As the concentration of $CuSO_4$ increased, so did the number of injuries. The most damaged were the top parts, where the shoots were only partly lignified. Magnesium chlorate caused similar injury of the shoots, especially at a concentration of 0.48%.

In spring of 1973 it was proved that in comparison with control plants, the bud opening was worse on shrubs to which $CuSO_4$ was applied at a concentration of 3%. This was also true for a mixture of $CuSO_4$ and $Mg(ClO_3)_2$ or ethephon (Table 3).

During the next year's experiment it was proved that nearly all defoliants cause buds to be poorly opened. Less buds opened on shrubs treated with $CuSO_4$ or $Mg(ClO_3)_2$ especially when these were used in the highest concentrations. There was also a marked weakness of bud opening in hand — defoliated shrubs (Table 4).

While measuring shoots in autumn 1973 it was observed that control shoots had longer year-growth than those sprayed with $Mg(ClO_3)_2$ at a concentration of 0.24%, or 0.3% KJ solution, or with a mixture of $CuSO_4$ and ethephon (Table 3).

The measurements in autumn 1974 showed that there was a tendency toward decreased growth of shrubs treated with solutions of $CuSO_4$ or $Mg(ClO_3)_2$ although the differences were insignificant (Table 4)

Rosa cv. Lampion. Rose bushes treated with defoliants evidently were not different from control plants. However, precise measurements taken in 1973 showed some differences. Magnesium chlorate caused a reduced number of flowers formed on the shrubs and impaired vegetative growth (Table 3). The number of flowers was reduced by copper sulfate as well, but when it was used in concentration no higher than 2%, no negative influence of this preparation on growth of roses was found. The most effective defoliant — potassium iodide applied at a concentration of 0.2% or 0.3% — slightly reduced intensity of flowering but did not show a negative influence on shrub growth (Table 3).

In 1974 it was found that only $CuSO_4$ and $Mg(ClO_3)_2$ produced a reduction of flowering but no defoliant significantly diminished shrub growth (Table 4).

Spiraea × *bumalda cv. Froebelii*. Minor bark injury was observed on the shrubs three weeks after spraying with $CuSO_4$ in a concentration of 3%.

In spring of 1973 and 1974 on the shrubs treated with all concentra-

Table 3

Influence of defoliants on bud opening and growth of shrubs
Date of application — Sept. 26-28 1972

Treatment	Concentration	*Forsythia* x *intermedia*		*Rosa* cv. Lampion		*Spiraea* x *bumalda* cv. Froebelii		*Spiraea* x *vanhouttei*	
		B	L	F	L	B	L	B	L
Control	H_2O	82.5 c	1150 c	105 fg	320 ab	65.2 cd	704 bc	80.2 c	906 ab
Ethephon	1000 ppm	81.1 c	890 abc	108 g	311 ab	67.0 d	639 abc	81.9 c	908 ab
Ethephon	1500 ppm	—	—	97 de	320 ab	—	—	—	—
$Mg(ClO_3)_2$+ +ethephon	0.24%+1000 ppm	—	—	101 ef	317 ab	—	—	—	—
$Mg(ClO_3)_2$	0.24%	77.9 bc	803 a	88 abc	283 a	58.8 abcd	740 c	77.1 c	928 ab
$Mg(ClO_3)_2$	0.3%	80.8 c	916 abc	85 a	284 a	63.0 bcd	710 c	73.5 bc	985 ab
$Mg(ClO_3)_2$+ +$CuSO_4$	0.24%+2%	60.8 a	1115 bc	—	—	43.5 a	630 abc	54.5 ab	894 ab
$CuSO_4$+ +ethephon	2%+1000 ppm	61.9 a	786 a	—	—	47.4 ab	444 a	64.2 abc	856 a
$CuSO_4$	2%	73.9 abc	1116 bc	86 a	346 b	48.8 ab	438 a	72.0 bc	988 ab
$CuSO_4$	3%	65.7 ab	807 a	87 ab	308 ab	46.3 a	654 abc	49.6 a	1024 ab
KJ+ +ethephon	0.2%+1000 ppm	80.6 c	977 abc	94 cd	320 ab	46.9 ab	560 abc	75.8 c	1003 ab
KJ+ +$Mg(ClO_3)_2$	0.2%+0.24%	—	—	93 bcd	280 a	—	—	—	—
KJ+$CuSO_4$	0.2%+2%	—	—	93 bcd	341 b	—	—	—	—
KJ	0.2%	70.0 bc	958 abc	98 de	304 ab	50.6 abc	705 bc	76.3 c	1074 b
KJ	0.3%	81.3 c	852 ab	94 cd	314 ab	44.7 a	483 ab	63.3 abc	829 a

L — total length of one-year-old shoots in cm.
B — bud opening in %.
F — number of flowers during summer (for roses only).
Separate statistical analysis was done for each column.
Means designated by the same letter do not differ significantly at P = 0.05.

Table 4

Influence of defoliants on bud opening and growth of shrubs

Date of application — Sept. 26-28, 1973

Treatment	Concentration	*Forsythia* x *intermedia*		*Rosa* cv. Lampion		*Spiraea* x *bumalda* cv. Froebelii		*Spiraea* x *vanhouttei*	
		B	L	F	L	B	L	B	L
Control	H_2O	71.4 d	716 ab	68.8 d	347	60.2 c	1365 cd	95.8 e	2008
Hand defoliated	—	35.2 b	591 a	61.9 bcd	350	46.9 b	1299 bcd	75.5 ab	1897
Ethephon	1500 ppm	72.1 d	735 ab	53.3 abcd	310	58.8 c	1167 abcd	95.7 e	1685
$(NH_4)_2SO_4$	10%	60.4 cd	791 b	54.2 abcd	323	58.3 c	1360 cd	89.2 c	1984
$Mg(ClO_3)_2$	0.24%	37.8 b	680 ab	46.3 ab	294	54.5 c	1462 d	89.9 cd	2031
$Mg(ClO_3)_2$	0.48%	7.7 a	548 a	41.9 a	296	54.6 c	1362 cd	69.5 a	1891
$CuSO_4$+ +ethephon	1%+750 ppm	44.7 bc	627 ab	—	—	—	—	—	—
$CuSO_4$	1%	56.6 c	660 ab	—	—	—	—	—	—
$CuSO_4$	2%	7.0 a	523 a	51.0 abc	246	48.9 b	1444 d	81.3 b	1773
KJ+ +$(NH_4)_2SO_4$	0.05%+5%	56.2 c	746 ab	—	—	55.4 c	1191 abcd	91.4 cde	1943
KJ+ +$(NH_4)_2SO_4$	0.1%+5%	—	—	54.8 abcd	334	—	—	—	—
KJ+ +ethephon	0.05%+750 ppm	—	—	—	—	56.0 c	1311 bcd	94.6 de	2031
KJ+ +ethephon	0.1%+750 ppm	—	—	64.4 cd	350	—	—	—	—
KJ	0.05%	—	—	—	—	55.7 c	1046 abc	94.5 de	1989
KJ	0.1%	—	—	58.6 abcd	325	57.1 c	1014 ab	93.5 cde	1883
KJ	0.2%	52.9 c	724 ab	53.4 abcd	322	31.4 a	973 a	83.2 b	2057
KJ	0.4%	—	—	57.2 abcd	319	—	—	—	—

do not differ significantly

L — total length of one-year-old shoots in cm.

B — bud opening in %.

F — number of flowers during summer (for roses only).

Separate statistical analysis was done for each column.

Means designated by the same letter do not differ significantly at P = 0.05.

tion of 0.2% or higher, buds opened significantly less than on the control shrubs (Table 3, 4).

In autumn of 1973, plants sprayed with $CuSO_4$ at a concentration of 2% or with a mixture of $CuSO_4$ with ethephon showed shorter one-year-old shoots than control plants. At the same time, shrubs treated with 0.3% KJ solution also showed shorter shoots than the control plants, although slightly longer than those treated with $CuSO_4$ (Table 3).

The next year's experiment showed significantly decreased growth only on shrubs treated with 0.1% or 0.2% KJ solution (Table 4).

Spiraea × *vanhouttei.* No distinct shoot injury was observed in the autumn after spraying shrubs with defoliants. But in the spring the tops of the thinnest shoots were dried up on shrubs sprayed with the highest concentrations of KJ or $CuSO_4$.

In spring of 1973 bud opening was significantly delayed by 3% $CuSO_4$ solution or its mixture with $Mg(ClO_3)_2$ (Table 3). In Spring of 1974 this delay was the greatest on plants treated with 0.48% $Mg(ClO_3)_2$ solution and on hand defoliated plants (Table 4).

There was no significant difference in the length of one-year-old shoots between defoliated shrubs and control plants. This was true both in 1973 and 1974 (Table 3 and 4).

Frost resistance

The frost resistance of chemically defoliated shrubs was determined by laboratory methods (Table 5) and from field observation (Table 6). Only *Forsythia* × *intermedia* shrubs were investigated in this part of the experiments.

After the shoots were frozen no significant differences were ascertained in the increase of electrical conductance among the various treatments in the cases of shoots cut on March 15, 1973 (Table 5) and December 17, 1973 (Table 6). The tendency to increased shoot conductance was observed on shrubs treated with $CuSO_4$, $Mg(ClO_3)_2$ or (in the case of shoots cut on March 15, 1973) KJ. On the next case (shoots cut on February 28, 1974) it was ascertained that magnesium chlorate distinctly decreased the frost resistance of defoliated shrubs (Table 6).

Later observation of frozen shoots showed a tendency to more bark and wood injury of shoots treated with magnesium chlorate and copper sulfate. Similar results were obtained during field obserwation in spring of 1974 (a minimal winter temperature was —17°C) where the above ground part of some shrubs died. The most marked frost injury was noticed on plants defoliated with $CuSO_4$ or $Mg(ClO_3)_2$. In most cases

Table 5

Degree of frost resistance of *Forsythia* x *intermedia* shoots determined by the method of electrical conductance test. The higher difference in electrical conductance, the lower frost resistance
Date of treatment — Sept. 26, 1972. Shoots were cut for measurements — March, 15, 1973

Treatment	Concentration	Difference in electrical conductance before and after cooling or freezing of shoots (in μs)		
		0°C	−26°C	
Control	H_2O	−0.91	19.86	do not differ significantly
Ethephon	1000 ppm	−0.73	22.03	
$Mg(ClO_3)_2$	0.24%	−0.90	18.92	
$Mg(ClO_3)_2$	0.3%	−1.06	22.33	
$CuSO_4$+ +ethephon	2%+1000 ppm	−0.92	22.10	
$CuSO_4$	2%	−1.08	24.95	
$CuSO_4$	3%	−1.36	17.85	
KJ+ethephon	0.2%+1000 ppm	−0.72	19.73	
KJ	0.2%	−1.07	23.56	
KJ	0.3%	−0.92	26.19	

their higher concentrations were more dangerous than the lower ones. Hand defoliation of shrubs also caused a distinct tendency toward decreasing frost resistance. All the frozen shrubs sprouted new shoots at the bud bases.

The field observation in spring of 1973 (a minimal winter temperature was —13°C) did not show any frost injury of defoliated shrubs.

DISCUSSION

The results presented indicate, that all chemicals investigated could work as defoliants for ornamental shrubs. The efficiency of the defoliants depended on the concentration applied and on the species. The most universal defoliant was potassium iodide, although this preparation poorly defoliated *Forsythia* × *intermedia* shrubs even after using a 0.3% solution which decreased subsequent frost resistance and growth of shrubs. The same preparation used at a concentration of 0.2% caused, within three weeks the falling of about 90% of the leaves from shrubs of *Spiraea* × *bumalda*, *Spiraea* × *vanhouttei* and *Rosa* cv. Lampion. These results were in agreement with the earlier reports (Larsen 1966; Macdonald and Kempton 1968). From among shrubs defoliated with KJ at a concentration of 0.2%, only *Spiraea* × *bumalda*

Table 6

Degree of frost resistance of *Forsythia* x *intermedia* shoots determined by the method of electrical conductance test and field observation

The higher difference in electrical conductance, the lower frost resistance. Date treatment — Sept. 26, 1973

Treatment	Concentration	Shoots were cut for measurements				% of killed shoots after overwintering in field conditions
		Dec. 17, 1973		Feb. 28, 1974		
		Difference in electrical conductance before and after cooling or freezing of shoots (in µs)				
		0°C	−26°C	0°C	−22°C	
Control	H_2O	−2.51	14.19	−1.25	12.47 ab	3.8 ab
Hand defoliated	—	0.46	18.47	−1.72	21.05 abc	42,3 cde
Ethephon	1500 ppm	−0.50	14.43	−1.13	11.83 a	0.0 a
$(NH_4)_2SO_4$	10%	−2.49	17.98	−1.53	13.60 ab	5.8 ab
$Mg(ClO_3)_2$	0.24%	−1.38	22.64	−1.05	25.16 c	30.1 bcd
$Mg(ClO_3)_2$	0.48%	×*	×	×	×	59,6 de
$CuSO_4$+ethephon	1%+750 ppm	0.37	19.73	−1.67	16.20 abc	15.4 abc
$CuSO_4$	1%	−0.84	15.28	−2.17	15.02 ab	15.4 abc
$CuSO_4$	2%	−0.22	17.32	−1.33	20.56 abc	73.2 e
KJ+$(NH_4)_2SO_4$	0.05%+5%	−1.89	22.22	−1.44	21.77 bc	7.7 ab
KJ	0.2%	−1.25	16.61	−0.68	18.08 abc	9.6 ab

do not differ significantly

* Shoots lethally frozen in field and no plant material for measuring.

Separate statistical analysis was done for each column. Means designated by the same letter do not differ significantly at P = 0.05.

shrubs had weaker growth in the next year. But when a mixture of KJ at a concentration of 0.05% with ethephon at a concentration of 750 ppm was used, good defoliation was also obtained and there was no observation of negative influence of the defoliants on the growth of shrubs. Similar interaction of these preparations was observed on *Rosa* cv. Lampion, as with other plant species and warieties noted already: Deen (1971), Evan (1971) and Aitken (1973). It is indeed interesting that interaction and successful results have been obtained with the use of 0.05% solution of KJ with a 5% solution of $(NH_4)_2SO_4$ as used for defoliation of *Spiraea* × *vanhouttei*, because ammonium sulfate is easy to purchase and inexpensive.

Copper sulfate appears to be almost as effective defoliant of *Rosa* cv. Lampion and *Spiraea* × *vanhouttei* shrubs as potassium iodide. This preparation, alongside magnesium chlorate, proved to be the most effective defoliant for forsythia shrubs. Copper sulfate caused more injury and stronger retardation of development and growth than other defoliants. This is not in agreement with Basak et al. 1973a, b) results with defoliation of apple trees.

Magnesium chlorate used at concentrations from 0.24 to 0.48% gave strong defoliation of the investigated plants, but in some cases also retarded spring bud opening and growth of shrubs. This was evidenced most strongly with the defoliation of *Forsythia* × *intermedia* shrubs. This preparation is known in the Soviet Union as one of the most effective and the least injurious defoliants for cotton plants, as well as fruit trees and shrubs (Kuznietsov and Ebetullaev 1963; Stonov 1973).

Ammonium sulfate was shown to be a less effective defoliant, but when used in a concentration of 10% it resulted in about 75-95% defoliation with *Rosa* cv. Lampion and *Spiraea* × *vanhouttei* and did not bring any injury or marked weakening of shrub growth. Likewise Evan (1971) and Roberts (1972) used ammonium sulfate at a concentration of 15-20% for the defoliation of roses. They showed that bushes, according to their variety, dropped from 80% to 95% of their leaves and after wintering were no more seriously injured than control plants.

The least effective defoliant at the concentrations used appeared to be ethephon. Indeed ethephon at a concentration of 1500 ppm, used in autumn 1973, caused almost complete defoliation within two weeks of *Rosa* cv. Lampion. However, a year earlier at the same concentration and during the same time, it caused a 50% leaf drop from bushes of the same variety. This difference can be explained by the influence of higher temperatures in autumn 1973 in comparison with 1972. The firm Amchem (1969) as well as Hartman et al. (1970) found

that a rise in temperature resulted in marked increase of ethephon activity.

With the demonstrated results it can be shown that defoliants have an influence on the decreasing of frost resistance on *Forsythia* × *intermedia*. The largest susceptibility to low temperatures was shown in the case of forsythia shrubs treated with a solution of $CuSO_4$ or $Mg(ClO_3)_2$. However, shrubs defoliated by hand or with KJ showed a slight tendency toward the decreasing of frost resistance. Defoliation of *Forsythia* in Polish climatic conditions is a high risk, because in the case of a strong frost, plants can be partly or fully destroyed. During the defoliation of fruit trees similiar results were obtained by Kuznietsov (1961) and Basak et al. (1973b) in contrast to data of Immaliev (1960) and Niazov (1961).

The lowering of frost resistance of defoliated plants, for example *Prunus cerasus*, has been explained by Howell and Stochouse (1973). They showed that earlier, than in nature, leaf abscission influences the lowering accumulation of carbohydrates. This touches off the latering process of natural frost resistance in autumn, the weakening of frost resistance in winter, and its earlier loss in spring. Similiarly Tumanov et al. (1972a, b), in experiments with birch, black currants and pines, proved that artificial shortening of the vegetative period decreases frost resistance of woody plants.

The present date suggests that in further investigations on defoliation, careful attention must be given to the level at which the given treatment influences the natural frost resistance of plants, especially when it is not too high.

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Chemiczna defoliacja w szkółce krzewów *Forsythia* × *intermedia* Zab., *Rosa* cv. Lampion, *Spiraea* × *bumalda* Burv. cv. Froebelii, *Spiraea* × *vanhouttei* Zab.

Streszczenie

Do defoliacji krzewów w szkółce zastosowano: ethephon, KJ, $Mg(ClO_3)_2 \cdot 6H_2O$, $CuSO_4 \cdot 5H_2O$, $(NH_4)_2SO_4$ w różnych stężeniach, osobno oraz w postaci mieszanin. Opryskiwanie wykonano 26-28 IX 1972 i 1973 r. Najskuteczniejszym defoliantem krzewów *Rosa* cv. Lampion, *Spiraea* × *bumalda* cv. Froebelii, *Spiraea* × *vanhouttei* był KJ w stężeniu 0,2% lub mieszaniny niższych stężeń tego preparatu z ethephonem lub z $(NH_4)_2SO_4$. Skuteczną defoliację wielu krzewów, w tym *Forsythia* × *intermedia*, powodowały 0,24-0,48% roztwory chloranu magnezu oraz 2% roztwór siarczanu miedzi. Wywołały one jednak równocześnie stosunkowo największe zahamowanie rozwoju i wzrostu krzewów, a w przypadku *Forsythia* × *intermedia* także poważne ograniczenie mrozoodporności roślin.