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The chemical defoliation of *Ligustrum vulgare* L. and *Spiraea* × *arguta* Zab. shrubs in nursery

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Abstract

To defoliate *Ligustrum vulgare* and *Spiraea* × *arguta* — ethephon, KJ, $Mg(ClO_3)_2 \cdot 6H_2O$, $CuSO_4 \cdot 5H_2O$ and $(NH_4)_2SO_4$ in various concentrations were used alone or in mixtures.

Treating plants with potassium iodide gave the best results. KJ concentrations of 0.05-0,1% and 0.1-0.2% were sufficient to defoliate *Spiraea* and *Ligusturm* respectively. Magnesium chlorate at concentration of 0.24 and 2%$CuSO_4$ were also effective, the latter however, proved slight harmful to the plants.

Spraying with defoliants on Sept. 26 gave better results than treating plants on Sept. 16.

Chemical defoliation decreased negligibly the frost resistance of *Ligusturm vulgare* shrubs.

INTRODUCTION

Under the climatic conditions of Poland leaves of many species of shrubs, *Ligustrum* and *Spiraea* among others, fall down during the second half of November whereas digging and selling time starts on October 10th. Hand stripping of leaves before digging is very expensive and time consuming, therefore it is desired to work out an effective method of chemical shrub defoliation. For many years scientists and growers have searched for universal and efficient defoliants and methods of their application.

Ethylene is a substance most effectivly accelerating senescence and leaf drop (Rakitin 1967; Cunningham and Staby 1975) but being a gas is difficult to use in practice. Experiments with ethephon showed that this preparation could cause defoliation of plants but it is deceptive and can not be recognised as a uniwersal defoliant (Macdonald and Kempton 1968; Larsen 1970b, 1973; Ewan 1970; Jones et al. 1973, 1974).

Many authors find the mixtures of ethephon with other substance more efficient than ethephon alone; the synergism has been often observed (Ewan 1969, 1970; Deen 1970; Kempton 1971; Aitken 1973; Basak et al. 1973a; Larsen 1973; Sterrett et al. 1973, 1974a, b).

Use of simple and cheap inorganic substances whose ions stimulate senescence and leaf drop is the point of continuous interest.

Herrett et al. (1962) noted that iodine ion could induce leaf abscission. They suggested also that potassium iodide could be a good defoliant. This was confirmed in field experiments with deciduous woody plants (Larsen 1966; Macdonald and Kempton 1968; Jonet et al. 1974).

Copper ion in water solution of copper chloride (Ben Yehoshua and Biggs 1970) can accelerate the formation of a separate layer and cause abscission of fruits and leaves on citrus. Copper sulphate is more commonly applied to shrubs than copper chloride (Grosclaude and Detiene 1969; Basak et al. 1973b).

Another chemical tested as a defoliant was ammonium sulphate (Ewan 1969, 1970; Macdonald 1969).

The most popular inorganic defoliant in The Soviet Union is magnesium chlorate (Rakitin and Imamaliev 1959; Ebetullaev 1961, 1967; Polovnikov 1969; Sabinov and Razzakov 1969).

The experiments described in this paper were carried out in order to find the best defoliant and optimal period of its application to *Ligustrum* and *Spiraea* shrubs under the climatic conditions of Poland.

MATERIAL AND METHODS

The experiments were carried out in 1972-1974 in the ornamental nursery in Umiastów near Warsaw. Material consisted of the two years old *Ligustrum vulgare* L. shrubs and three years old *Spiraea* × *arguta* Zab. shrubs ready for sale. Shrubs were sprayed with defoliants in 1972 and 1973 on two dates: September 16 and September 26.

Defoliants for the experiments were chosen on the basis of the results obtained in the earlier work (Marczyński — not published) and included ethephon (as Amchem 68-250), ammonium sulfate — $(NH_4)_2SO_4$, magnesium chlorate — as a technical preparation containing 60% $Mg(ClO_3)_2 \cdot 6H_2O$ *, copper sulfate — $CuSO_4 \cdot 5H_2O$ *, potassium iodide — KJ. Concentrations are present in Table 1 and 2.

The experiment was designated in 4 randomized blocks. Each plot consisted of 15 equally treated shrubs. Defoliants were applied with

* Further on a degree of hydratation of chemicals is omitted.

hand-sprayer of 1 litr capacity with tree Jet 8005 nozzle under the pressure of 2.5 atm, 0.5 l volume of a solution was applied to each plot, Citovett in concentration of 0.025% was used as a wetting agent.

The weather was similar on both dates of treatment, the temperature fluctuate from 6°C to 15°C during the day.

In order to check the influence of hand defoliation on a subsequent shrub growth such a treatment was included in the experiments of 1973. The leaves were hand stripped on October 7, when this work is routinely being performed in the nurseries.

Assessment of defoliation on the base of dry weight of the fallen leaves was made at weekly intervals during 3 weeks following treatment.

Five weeks after spraying three shrubs of each plot were transplanted to a new place and cut. The remaing plants were left uncut in the nursery.

A percentage of bud opening was established in April 1973 and 1974 on the uncut shrubs. The length of one year old cutted plants was measured in October 1973 and 1974.

Frost resistance was tested in laboratory conditions on *Ligustrum* plants collected from field experiments. Six shoots 30 cm long were cut from each plot, twice from plants sprayed in Autumn 1973. Two shoots of every replication were used as a control and hold at 0°C. The remaing shoots were frozen for 24 h at −26°C. The temperature drop was about 2°C per 6 h. Measurements of the electrical conductivity were taken at the shoot tip, middle and base dircetly before placing the shoots in the freezer and immedieatly after defreezing. The measurements were made with special tanks with electrode needles described by Wilner (1960) coupled with a Hungarian conductometer type OK 102/1.

Assessment of frost resistance was estimated from difference in shoot conductivity before and after cooling or freezing (Wilner 1961; Pukacki 1973).

After the measurements, the shoots were immersed with their lower ends in water and placed in the greenhouse in 20°C. Two weeks later the forced shoots were examined near the top, the middle and toward the base for the symptoms of wood destruction and bark injury eventually caused by the low temperature.

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

Table 1

Per cent of leaves fallen from *Ligustrum vulgare* and *Spiraea* x *arguta* shrubs depending on the defoliant and date of application
Date of treatment: Sept. 16, 1972 — 1st date; Sept. 26, 1972 — 2nd date

Treatment	Concentration *	*Ligustrum vulgare*				*Spiraea* x *arguta*			
		per cent of leaves fallen after:							
		14 days		21 days		14 days		21 days	
		1st date	2nd date	1st date	2nd date	1st date	2nd date	1st date	2nd date
Control	H_2O	8.2 a	32.8 b	31.2 a	47.3 b	7.0 a	16.7 ab	15.1 a	33.9 bc
Ethephon	1000 ppm	49.6 c	43.4 bc	66.4 c	60.3 c	13.9 ab	21.2 b	22.7 ab	47.3 c
$Mg(ClO_3)_2$	(0.4%)								
	0.24%	96.6 fgh	78.0 d	98.8 fgh	85.7 d	82.8 cd	69.3 c	92.9 de	87.4 de
	(0.5%)								
	0.30%	96.4 fgh	87.8 e	97.9 fg	91.9 de	88.8 cd	69.4 c	96.1 ef	88.7 de
$Mg(ClO_3)_2$+	(0.4%)								
+$CuSO_4$	0.24+2%	100.0 i	95.0 ef	100.0 h	98.2 fg	77.9 cd	75.7 cd	91.0 de	86.5 de
$CuSO_4$+	2%+								
Ethephon	+1000 ppm	97.0 fgh	96.0 fg	97.8 fg	98.7 fgh	81.9 cd	81.0 cd	90.8 de	89.3 de
$CuSO_4$	2%	99.7 hi	94.3 ef	99.7 fgh	96.5 ef	80.0 cd	78.4 cd	89.1 de	93.4 de
	3%	99.4 ghi	94.2 ef	99.6 fgh	96.9 ef	77.2 cd	77.3 cd	83.3 d	93.2 de
KJ+ethephon	0.2%+								
KJ	+1000 ppm	100.0 i	97.4 fgh	100.0 h	99.8 gh	98.9 e	100.0 e	100.0 g	100.0 g
	0.2%	100.0 i	94.2 ef	100.0 h	99.3 fgh	100.0 e	99.9 e	100.0 g	99.9 fg
	0.3%	100.0 i	98.0 fghi	100.0 h	100.0 h	100.0 e	99.9 e	100.0 g	99.6 fg

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

Table 2

Per cent of leaves fallen from *Ligustrum vulgare* and *Spiraea* x *arguta* shrubs depending on the defoliant and date of application
Date of treatment: Sept. 16, 1973 — 1st date; Sept. 26, 1973 — 2nd date

Treatment	Concentration	*Ligustrum vulgare*				*Spiraea* x *arguta*			
		per cent of leaves fallen after:							
		14 days *		21 days		14 days		21 days	
		1st date	2nd date	1st date	2nd date	1st date	2nd date	1st date	2nd date
Control	H_2O	1.9 a	3.4 a	5.7 a	13.1 b	0.1 a	11.9 b	1.7 a	24.5 bc
Ethephon	1500 ppm	17.4 b	19.6 b	47.0 cde	49.0 de	9.8 b	26.8 c	16.6 b	39.2 c
$(NH_4)_2SO_4$	10%	46.4 cd	37.4 c	53.0 e	45.0 cde	86.6 de	80.8 d	87.3 de	85.1 d
$Mg(ClO_3)_2$	0.24%	77.3 h	63.3 efg	80.0 hi	81.7 hi	90.2 def	88.6 de	90.4 defg	92.7 defgh
	0.48%	97.3 ij	66.4 fg	97.3 j	77.3 gh	94.8 efg	95.5 efg	95.2 defgh	97.7 ghi
$CuSO_4$	2%	85.2 h	95.1 i	87.1 i	96.6 j	94.7 efg	95.2 efg	95.6 defgh	95.8 efgh
KJ+ $+(NH_4)_2SO_4$	0.05%+5%	36.7 c	56.1 def	46.6 cde	67.7 f	87.7 de	98.7 fg	88.3 def	98.9 hi
KJ+ethephon	0.05%+ +750 ppm	18.3 b	63.0 efg	41.5 cd	79.3 hi	96.3 efg	94.8 efg	96.7 efghi	97.1 efghi
KJ	0.05%	25.1 b	69.0 g	37.8 c	80.3 hi	88.9 de	87.3 de	89.6 defg	93.2 defgh
	0.1%	52.2 de	83.3 h	68.8 fg	94.1 j	95.7 efg	99.5 g	97.1 efghi	100.0 i
	0.2%	79.7 h	99.5 j	86.2 i	100.0 k	99.0 g	99.9 g	99.0 hi	100.0 i

* Spearate statistical analysis was done for observation at 14 days after treatment. Means designated by the same letter do not differ significantly at $P = 0.05$.

OBSERVATIONS AND RESULTS

Defoliation

Ligustrum vulgare. The highest degree of defoliation, over 90% after 2 weeks was achieved due to the use of potassium iodide in concentration of 0.1% or higher and 2% and 3% solution of copper sulphate (Tables 1, 2, Fig. 1). There was not significant difference between 2 terms of application in 1972, but in 1973 treatments of Sept. 26th generally resulted in an earlier leaf drop.

Shrubs treated with $Mg(ClO_3)_2$ lost more than 75% of leaves during 3 weeks after spraying. This defoliant was more efficient both in 1972 and 1973 when applied in the first term.

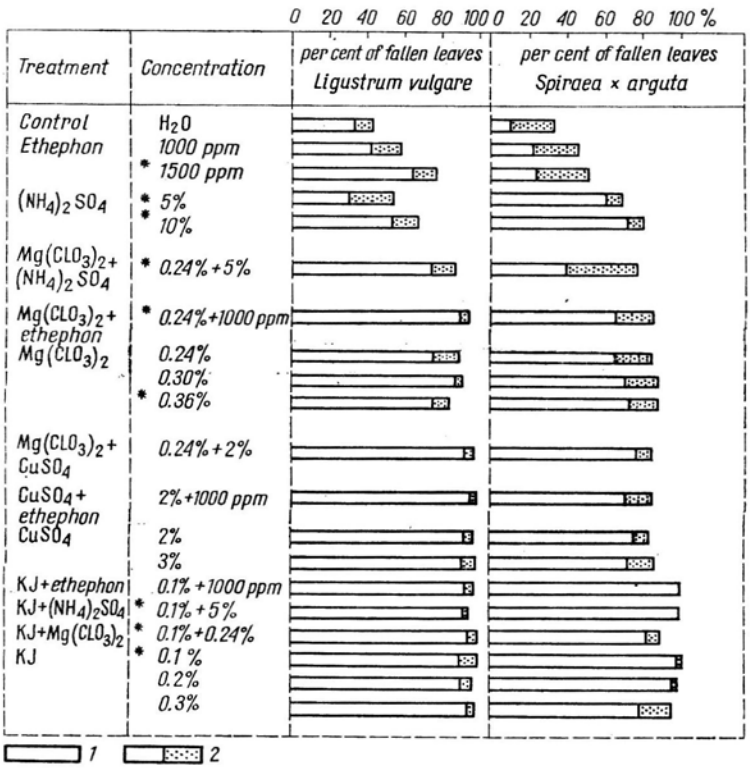

Fig. 1. Per cent defoliation from *Ligustrum vulgare* and *Spiraea* × *arguta shrubs*, depending on the defoliant and its concentration. Date application: Sept. 26, 1972 *
1 — defoliation after 14 days; *2* — defoliation after 21 days

* In this figure several concentrations and chemicals used only at the second date of treatment (asterisk x) are compared with those used at both dates (see Table 1)

Differences significant at P=0.05 in case of *Ligustrum vulgare* — at 14 days after treatment 7.3%, at 21 days after treatment 8.1%; of *Spiraea* × *arguta* — at 14 days after treatment 8.9%, at 21 days after treatment 11,2%

Ammonium sulphate and ethephon were less efficient. A mixture of 0.24% magnesium chlorate and 1000ppm ethephon caused heavier defoliation than both preparations when used alone (Fig. 1), similar synergism was not observed in case of other mixtures.

Spiraea × *arguta*. This species of shrubs were more sensitive to defoliants investigated than *Ligustrum*.

Distinct symptoms of injury and mass leaf drop from shrubs on plots of the majority of treatments appeared already on the fourth and fifth day after application. Ethephon when used alone and ammonium sulphate in lower concentrations proved less effective than in case of *Ligustrum*. The remaining defoliants induced over 85% defoliation 3 weeks after treatment (Tables 1, 2, Fig. 1).

The most effective chemicals were KJ and its mixtures with ethephon and ammonium sulphate. Similary effective was 0.48% magnesium chlorate (Table 1, Fig. 1). With all of these preparations more than 90% leaf drop occured within two weeks and nearly 100% within three weeks after application.

Of the above mentioned preparations only the mixture of 0.05% KJ with 750 ppm ethephon induced quicker defoliation when applied on September 26 in comparison with the treatment perfomed ten days earlier (the experiment of 1973 — Table 2).

Subsequent influence of defoliants on plants

Ligustrum vulgare. No distinct injuries were observed on shrubs in autumn after treatment. Small bark injury appeared only sporadicaly on the top part of shoots on plants treated with copper sulphate.

In spring the tops of the shoots dried up on some shrubs sprayed with the copper sulphate. Occasionaly similar symptoms could be also observed on plants treated with potassium iodide in concentrations of 0.2% or 0.3% (in 1972) and 0.48% magnesium chlorate (in 1973). As a rule heavier injuries manifested on plants sprayed on Sept. 16th than on plants treated ten days earlier.

All the defoliants, except ethephon, applied on September 16th 1972 negatively affected bud opening in Spring 1973 (Table 3). Disturbances in bud opening of shrubs treated on Sept. 26 were less pronounced, however, the plants sprayed on this date with 0.3% KJ or with solutions containing $CuSO_4$ showed significantly lower per cent of opened buds as compared to controls (Table 3, Fig. 2).

Smaller disproportions in spring development related to the date of treatment and chemical used were observed on shrubs sprayed in Autumn 1973. Buds on hand defoliated shrubs showed the poorest development.

Table 3

Influence of defoliants on bud opening and growth of shrubs
Date of application: Sept. 16, 1972 — 1st date; Sept. 26, 1972 — 2nd date

Treatment	Concentration	*Ligustrum vulgare*				*Spiraea* x *arguta*		
		bud opening in % Apr. 1973		total length of one--year-old shoots in cm, Oct. 1973		bud opening in % Apr. 1973	total length of one-year-old shoots in cm, Oct. 1973	
		1st date	2nd date	1st date	2nd date	1st date and 2nd date [a]	1st date	2nd date
Control	H_2O	99.7 i	96.8 hi	753 bcde	1307 f	94.8 c	1112 g	1044 fg
Ethephon	1000 ppm	97.1 hi	98.2 hi	744 bcde	1262 f	91.9 c	752 ab	970 cdefg
$Mg(ClO_3)_2$	0.24%	84.5 efg	93.4 gh	745 bcde	1156 ef	82.2 b	1013 efg	969 cdefg
	0.30%	92.8 efg	91.3 fgh	539 abcd	972 def	77.9 b	826 abcde	1074 g
$Mg(ClO_3)_2$+ +$CuSO_4$	0.24%+2%	38.9 a	86.7 fg	208 a	799 cde	81.1 b	1070 g	1006 efg
$CuSO_4$+ethephon	2%+1000 ppm	31.4 a	78.8 def	321 ab	993 ef	78.0 b	778 abc	1017 efg
$CuSO_4$	2%	48.4 ab	82.6 efg	394 abc	806 cde	82.8 b	687 a	992 defg
	3%	60.1 bc	70.9 cde	224 a	705 bcde	77.4 b	891 bcdef	963 cdefg
KJ+ethephon	2%+1000 ppm	47.2 ab	91.5 fgh	408 abc	1006 ef	47.4 a	905 bcdefg	1043 fg
	3%	40.0 a	85.6 efg	189 a	1072 ef	46.3 a	789 abcd	955 bcdefg

a) Means for two dates application are given because the interaction between treatments and dates is insignificant.
Separate statistical analysis was done for each feature investigated. Means designated by the same letter do not differ significantly at $P = 0.05$.

Slightly better but still worse than on the control plants bud opening was observed on shrubs treated with 2% $CuSO_4$ and 0.48% $Mg(ClO_3)_2$ (Table 4).

The enlargement of lenticels on shoots treated with ethephon was noticed.

Analyse of the defoliant effect on the new growth showed that copper sulphate significantly decreased the length of shoots on shrubs treated in 1972.

In 1973, no differences between chemicals were observed as far as their influence on the new growth was concerned, however, the effect of the date of application proved significant. The new growth of plants sprayed on the earlier date was averagely 172 cm shorter than on later defoliated plants (Table 4).

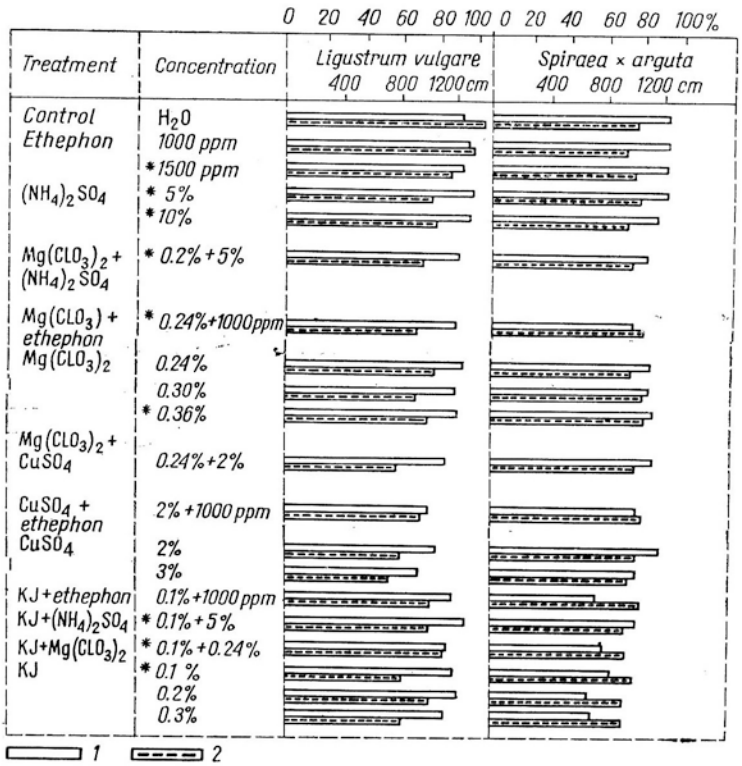

Fig. 2. Influence of defoliants on bud opening and growth of shrubs. Date of application: Sept. 26, 1972 *

1 — bud opening in % (Agr. 1973); *2* — total lenght of one-year-old shoots in cm (Oct. 1973). Other explanations in Fig. 1 (see Table 2).

* Differences significant at P=0.05 in case of *Ligustrum vulgare* — for bud opening 17.4%, for total length of one-year old shoots 410 cm; of *Spiraea* × *arguta* — for bud opening 7.6%, for total length of one-year-old shoots do not differ significantly

Table 4

Influence of defoliants bud opening and growth of shrubs
Date application: Sept. 16, 1973 — 1st date; Sept. 26, 1973 — 2nd date

Treatment	Concentration	*Ligustrum vulgare*			*Spiraea x arguta*		
		bud opening in % Apr. 1974		total length of one-year-old shoots in cm. Oct. 1974	bud opening in % Apr. 1974		total length of one-year-old shoots in cm, Oct. 1974
		1st date	2nd date	1st and 2nd date [a, b]	1st date	2nd date	1st and 2nd date [a]
Control	H_2O	97.9 gh	98.4 h	904	92.8 cde	95.5 e	5648
Hand defoliated	—	—	68.7 a	907	—	87.5 bc	4578
Ethephon	1500 ppm	94.7 efg	97.3 gh	760	93.8 de	94.9 de	4607
$(NH_4)_2SO_4$	10%	93.8 ef	97.3 fgh	767	90.6 cd	93.9 de	4897
$Mg(ClO_3)_2$	0.24%	88.2 d	96.1 fgh	812	91.8 cde	94.1 de	4740
	0.48%	79.9 b	90.3 de	811	90.9 cde	92.5 cde	4893
$CuSO_4$	2%	80.5 bc	79.4 b	780	81.6 a	92.6 cde	4311
KJ+$(NH_4)_2SO_4$	0.05%+5%	95.3 fgh	95.4 fgh	829	94.3 de	93.4 cde	5215
KJ+ethephon	0.05%+750 ppm	95.1 fg	97.0 fgh	780	83.7 ab	93.3 cde	5110
KJ	0.05%	96.5 fgh	96.2 fgh	849	94.0 de	94.0 de	5203
	0.1%	95.1 fg	93.3 e	820	85.5 ab	90.9 cde	4423
	0.2%	87.3 d	86.2 cd	742	81.8 a	83.6 ab	4484

do not differ significantly

a) Explanation in Table 3.

b) Differences between dates of application are significant. Shrubs treated with defoliants in 2nd date had one—year—old shoots longer averagely 172 cm than shrubs treated in 1st date.

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

Spiraea × *arguta*. In Autumn 1972, a month after spraying, browning of buds on the top parts of shoots appeared on shrubs treated with 0.3% potassium iodide. The apical part of the thinnest shoots dried up next spring.

All the defoliants investigated with the exception of ethephon and ammonium sulphate lowered the number of the open buds. The strongest retardations in spring development of buds was observed on shrubs treated with KJ in concentration of 0.2% and 0.3% (Table 3, Fig. 2).

Defoliants used in 1973 showed weaker phytotoxicity than during experiments in 1972. Differences in the number of open buds on defoliated and control plants did not exceed 14% (Table 4).

KJ and $CuSO_4$ caused the most severe bud injuries, especialy when used in the first term.

Length measurements of one year growth did not show any differences in growth of shrubs sprayed in the second term in 1972 (Fig. 2). However, considerable differences occurred between shrubs sprayed with defoliants in the first term (Sept. 16).

Growth of shrubs treated with 2% and 3% copper sulphate and with its mixture with ethephon was significantly decreased. Plants sprayed with 0.2% and 0.3% KJ, 1000 ppm ethephon and 0.3% $Mg(ClO_3)_2$ responded in a similar way (Table 3).

No significant differences between chemicals and dates of treatment were observed in case of shrubs defoliated in 1973 (Table 4).

Frost Resistance

Influence of chemical defoliants on frost resistance was investigated with laboratory methods on *Ligustrum vulgare*. *Ligustrum* is known of its considerable frost resistance, which was however, reduced by chemical defoliation what is evident from the increase in the electric conductivity in shoots frozen in —26°C (Table 5, 6).

The decrease in the frost resistance was caused by the higher concentrations of $CuSO_4$, KJ and $Mg(ClO_3)_2$. Generally, earlier defoliant application made the plants more sensitive to frost. This is in agreement with Dennis and Howell (1974) results with defoliation of cherry trees. No such correlation was observed in case of shoots cut for measurements on Feb. 28 1974 (Table 6).

In the course of the subsequent observation only slight bark and wood injuries were noted two weeks after freezing and buds opened normally. No frost injuries were observed in spring on *Ligustrum* and *Spiraea* grown outdoor (minimum winter temperature —18°).

Table 5

Degree of frost resistance of *Ligustrum vulgare* shoots determined by the method of electrical conductance test. The higher difference in electrical conductance, the lower frost resistance
Shoots were cut for measurement March 15, 1973. Date of treatment with defoliants Sept. 26.1972 *

Treatment	Concentration	Difference in electrical conductance before and after cooling or freezing of shoots (in μs)	
		0°C	−26°C
Control	H_2O	−0.04	5.87 abc
Ethephon	1000 ppm	−0.02	6.06 abcd
	1500 ppm	0.22	5.08 ab
$(NH_4)_2SO_4$	5%	0.14	4.64 a
	10%	−0.28	6.39 abcd
$Mg(ClO_3)_2$	0.24%	−0.37	7.75 bcd
	0.30%	0.26	7.46 abcd
	0.36%	−0.29	6.02 abcd
$CuSO_4$+ethephon	2%+1000 ppm	−0.10	8.22 cd
$CuSO_4$	2%	−0.22	8.92 d
	3%	0.07	6.34 abcd
KJ+ethephon	0.1%+1000 ppm	−0.17	6.14 abcd
KJ+$(NH_4)_2SO_4$	0.1%+5%	0.50	6.36 abcd
KJ+$Mg(ClO_3)_2$	0.1%+0.24%	0.07	8.38 cd
KJ	0.1%	−0.18	7.11 abcd
	0.2%	0.08	8.70 cd
	0.3%	−0.37	7.95 bcd

* Only the results for second date are given. Interaction between treatments and dates is insignificant.
Separate statistical analysis was done for each column. Means designated by the same letter do not differ significantly at P = 0.05.

DISCUSSION

Finding defoliants of a broad spectrum of action and giving no harmful effects on the plant growth and development is very important for horticultural production. The results presented in this paper indicate that KJ proved the most efficient defoliant. Potassium iodide in concentrations of 0.05% induced over 90% leaf drop in 3 weeks on *Spiraea* × *arguta*. *Ligustrum* was less sensitive to KJ and higher dosages were needed to cause its defoliation, that is 0.1% and 0.2%, such concentrations did not affect plant growth and development nor caused

Table 6

Degree of frost resistance of *Ligustrum vulgare* shoots determined by the diference in electrical conductance before and after cooling or freezing of shoots (in μs). The higher difference in electrical conductance, the lower frost resistance
Date of treatment with defokants: Sept. 16, 1973 — 1st date; Sept. 26, 1973 — 2nd date

Treatment	Concentration	Shoots were cut for measurements:					
		Dec. 17, 1973		Febr. 28, 1974			
		1st and 2nd date *		1st date		2nd date	
		0°C	−26°C	0°C	−26°C	0°C	−26°C
Control	H_2O	1.02	2.97 a	−1.70	1.12 abc	−2.14	1.11 abc
Hand defoliated	—	0.97	3.62 a	—	—	−1.71	1.03 ab
Ethephon	1500 ppm	0.98	3.33 a	−1.87	1.13 abc	−1.71	0.89 ab
$(NH_4)_2SO_4$	10%	1.29	5.15 bc	−2.20	2.96 d	−1.90	2.62 cd
$Mg(ClO_3)_2$	0.24%	1.16	5.06 bc	−1.72	2.39 abcd	−1.41	3.40 d
	0.48%	0.94	5.07 bc	−1.58	2.55 bcd	−1.77	2.16 abcd
$CuSO_4$	0.2%	0.97	6.27 c	−1.36	3.63 d	−1.88	2.54 bcd
KJ+ $+(NH_4)_2SO_4$	0.05%+5%	1.12	5.20 bc	−1.85	1.97 abcd	−1.68	2.78 cd
KJ+ethephon	0.05%+ 750 ppm	1.15	4.41 ab	−2.16	1.64 abc	−1.43	2.45 bcd
KJ	0.05%	1.08	4.38 ab	−1.63	0.75 a	−1.73	2.73 cd
	0.1%	1.02	5.12 bc	−1.91	1.11 abc	−2.19	3.19 d
	0.2%	1.06	6.51 c	−2.11	2.17 abcd	−1.40	3.00 d

* Explanation in Table 3.
Seperate statistical analysis was done for each column investigated. Means designated by the same letter do not differ significantly at P = 0.05.

any grave injuries. Larsen (1966), Macdonald and Kempton (1968), when testing usefulness of KJ as a defoliant on other species and applying its higher concentrations sometimes observed the negative influence of this preparation on the subsequent plant growth.

Copper sulfate in the concentration of 2% proved also an efficient defoliant giving about 90% defoliation within 3 weeks, however it retarded plant growth and development and caused necrotic spots on *Ligustrum* shoots. Similar injuries were observed by Grosclaude and Detiene (1969) who used 0.5% $CuSO_4$ solution to defoliate peach trees.

Basak (1974) stated low phytotoxicity of 1.5% and 2% $CuSO_4$ to apple trees. To defoliate the shrubs *Ligustrum vulgare* and *Spiraea* × *arguta* $CuSO_4$ might be used only in case if no better chemical could be available.

Magnesium chlorate used in concentration of 0.25—0.6% for defoliation of fruit trees and shrubs (Niazov 1961; Kuznietsov and

Ebetullaev 1967) proved to be an effective chemical, which gave no harmful effects. This compound when used by the author in the concentrations ranging from 0.24% to 0.48% caused the leaf drop of the tested shrubs but down the spring bud opening of both species and decreased *Ligustrum* growth, especially when used in the higher concentration. It seems, however that $Mg(ClO_3)_2$ in concentration of 0.25-0.3% may be safely enough used in practice.

Ammonium sulphate proved to be less efficient than the above mentioned preparations, especially in case of *Ligustrum* shrubs, causing however no injuries or slow down of growth. This preparation was used with success by Ewans (1969, 1970) for defoliation of roses. Macdonald (1969) found that $(NH_4)_2SO_4$ was less effective during cold and wet weather but this was not confirmed in the author's experiments with *Spiraea* in Autumn 1972. It seems that due to an easy accessibility of this preparation and its low phytotoxicity it may periodically be used for defoliation of certain ornamental shrubs.

Ethephon in the concentrations tested showed small activity due probably to low temperature at the time of application.

The choice of an optimal date for the defoliation of woody plants in the nurseries depends on the climatic zone. In temperate zone of the northern hemisphere it falls between early September and mid October (Imamaliev 1960; Molchanova 1965; La'rsen 1970a). Results obtained by the author in the ornamental shrub nursery in central Poland indicate that the second date of spraying (Sept. 26) was more suitable for chemical defoliation than the earlier treatment (Sept. 16). Applying the chemicals on Sept. 16 usually resulted in more pronounced bark injury as well as retarded growth and development and reduced frost resistance. It showed particulary clear in case of *Ligustrum* shrubs treated in Autumn 1972. Similar results were obtained by Basak (1974) for apple trees. Quicker leaf drop from plants treated with defoliants (KJ, $CuSO_4$) in the second date can be explained by the more advanced state of plant dormancy, when the leaves are ready to fall, what makes them more receptive to chemicals. Higher efficiency of $Mg(ClO_3)_2$ applied earlier is difficult to explain, the more so that between both dates of treatment no distinct differences in air temperature occurred. Less harmful effects on plants defoliated later can be undoubtedly related to stronger woodiness and more advanced dormancy (Lloyd and Convillon 1974).

No frost injuries were found in field on defoliated plants, however, laboratory tests showed a negligible decrease in frost resistance of *Ligustrum* shrubs treated with chemicals after their shoots had been frozen at —26°C. Temperatures lower than that seldom occur in Poland, therefore this small reduction of frost resistance may not be taken

into consideration. Imamaliev (1960) and Niazov (1961) stated, that $Mg(ClO_3)_2$ used to defoliate fruit trees in the nursery increased their frost resistance. Kuznietsov (1961) and Basak at al. (1973b) came to an opposite conclusion and their results seem more reliable.

The results presented here indicate the need to continue this kind of experiments with other species of ornamental shrubs in order to find efficient and safe defoliants to be widely used in nursery practice.

REFERENCES

Aitken J.B., 1973. Chemical defoliation of young, budder pekan trees. Hort Science 8 (1): 50-51.

Basak A., Jankiewicz L.S., Czynczyk A., 1973a. The use of CEPA, SADH and mineral salts to defoliate apple trees in nurseries. Acta Hort. 34: 135-138.

Basak A., Czynczyk A., Jankiewicz L.S., 1973b. The influence of KJ, $CuSO_4$ and $Mg(ClO_3)_2$ on defoliation and subsequent frost resistance and growth of apple trees in nursuries. Acta agrobot. 26: 167-189.

Basak A., 1974. Chemiczna defoliacja jabłoni w szkółce. Doct. dissert. Warsaw Agricultural University.

Ben Yohoshua S., Bigss R.H., 1970. Effects of iron and copper ions in promotion of selective abscission and ethylene production by citrus fruits and the inactivation of indoloacetic acid. Plant Physiol. 45: 604-607.

Cunningham J.L., Staby G.J., 1975. Ethylene and defoliation of ornamental lime plants in transit. Hort Science 10 (2): 174-175.

Deen J.L., 1970. Chemical defoliation. Ann. Rep. Glas. Crops Res. Inst. 171.

Dennis F.G., Howell G.S., 1974. Cold hardiness of tart cherry bark and flower buds. Research Rep. Mich. St. Univ. Agri. Exp. Station No. 220.

Ebetullaev A.A., 1971. Defoliatsiya seyantsev yabloni v pitomnikie. Dokł. TSKhA 72: 193-199.

Ebetullaev A.A., 1967. Effektivnost' defoliantov v plodvoykh pitomnikah. Khimiya Selsk.-Khoz. 7: 542-544.

Ewan J.W., 1969. Roses-chemical defoliation. Results of Hort. Exp. ADAS Shardlow Hall: 52-57.

Ewan J.W., 1970. Defoliation of deciduous nurserystock. Paper read N.F.N. British Growers Look Ahead Conference 1970.

Grosclaude Ch., Detienne G., 1969. Intérêt et possibilités d'une défeuillaison artificielle des arbres fruitiers. Pépiniériste Horticulturs, Maraichers 89: 5112-5116.

Harrett R.A., Hatfield H.H., Crosby D.G., Vlitos A.J., 1962. Leaf abscission induced by the iodide ion. Plant Physiol. 37: 358-363.

Imamaliev A., 1960. Udalenie listév u plodovykh sazhenstev. Sadovodstvo 9: 23-24.

Jones D.L., Nichols D.G., Thompson W.K., Jager L.A., 1973. Chemical defoliation of deciduous nursery plant. Australian Jour. Exper. Agric. Anim. Husb. 13: 460-464.

Jones D.L., Nichols D.G., Thompson W.K. 1974. Further studies on chemical defoliation of deciduous nursery plants. Australian Jour. Exper. Agric. Anim. Husb. 14: 412-417.

Kempton R.J., 1971. Chemical defoliation of roses and deciduous shrubs. Ann. Rep. Glass. Crops Res. Inst. 77.

Kuznietsov M.D., 1961. Defoliatsiya v pitomnikie. Sadovodstvo 9: 30-32.

Kuznietsov M.D., Ebetullaev A.A., 1963. Khimicheskaya defoliatsiya sieyanstsev yabloni v pitomnikie. Izv. Timir. Selsk.-Khoz. Akad. 5: 86-99.

Larsen F.E., 1966. Potasium ioide induced leaf abscission of deciduous woody plants. Proc. Amer. Soc. Hort. Sci. 88: 690-697.

Larsen F.E., 1970a. Pre-storage promotion of leaf abscission of deciduous nursery stock with Bromodine. J. Amer. Soc. Hort. Sci. 95: 231-233.

Larsen F.E., 1970b. Promotion of leaf abscission of deciduous nursery stock with 2-chloroethylphosphonic acid. J. Amer. Soc. Hort. Sci. 95: 662-663.

Larsen F.E., 1973. Stimulation of leaf abscission of tree fruit nursery stock with Ethephon-surfactant mixtures. J. Amer. Soc. Hort. Sci. 98: 34-36.

Lloyd D.A., Convillon G.A., 1974. Effects of date of defoliation of flower and leaf bud development in the Peach (*Prunus persica* L.). J. Amer. Soc. Hort. Sci. 99: 514-518.

Macdonald A.B., Kempton R.J., 1968. Chemical defoliation of deciduous nursery stock Ann. Rep. Glass. Crops Res. Inst. 133-141.

Macdonald A.B., 1969. Chemical defoliation. Gard. Chron. 166: 22-24.

Molchanova Z.J., 1965. Vliyanie khimicheskoi defoliatsii na perezimovku vinogradnoi lozy. Fiziol. Rast. 12: 683-687.

Niazov A., 1961. Defoliatsiya v pitomnikie. Sadovodstwo 9: 31-32.

Polovnikov J., 1969. Primieniaem khlorat magniya. Sadovodstwo 9: 23.

Pukacki P., 1973. Laboratoryjne metody oceny odporności roślin drzewiastych na niskie temperatury. Arboretum Kórnickie 18: 187-198.

Rakitin J., Imamaliev A., 1959. Khimicheskaya defoliatsiya plodovykh diereviev. Fizjol. Rastenii 6: 61-66.

Rakitin J., 1967. Etilen kak vysokoeffektivnyi defoliant. Fizjol. Rastenii 14: 936-991.

Sabinov M.K., Razzakov M.D., 1969. Defoliatsiya listiev yabloni i vinograda v plodovykh pitomnikakh Uzbekistana. Khimiya Selsk.-Khoz. 7: 218-220.

Sterrett J.P., Leather G.R., Tozer W.E., 1973. Defoliation response of woody seedings to Endothall/Ethephon. Hort. Science 8: 387-388.

Sterrett J.P., Leather G.R., Tozer W.E., 1974a. An explantation for the synergistic interaction of Endothall Ethephon on foliar abscission. J. Amer. Soc. Hort. Sci. 99: 395-397.

Sterrett J.P., Leather G.R., Tozer W.E., Foster W.D., Webb D.T., 1974b. Foliar abscission woody plants with combinations of Endothall and Ethephon. Weed. Sci. 22: 608-615.

Wilner J.W., 1960. Note of two electrolytic methods for determining frost hardiness of fruit trees. Can. J. Plant. Sci. 40: 563-565.

Wilner J.W., 1961. Relationship between certain methods and procedures of testing for winter injury of outdoor exposed shoots and roots of apple trees Can. J. Plant. Sci. 41: 309-315.

Chemiczna defoliacja krzewów *Ligustrum vulgare* L. i *Spiraea* × *arguta* Zab. w szkółkach

Streszczenie

Stosowano: ethephon, KJ, $(NH_4)_2SO_4$, $Mg(ClO_3)_2 \cdot 6H_2O$, $CuSO_4 \cdot 5H_2O$ w różnych stężeniach, osobno i jako mieszaniny.

Najskuteczniejszym preparatem był jodek potasu. Do defoliacji krzewów *Spiraea* × *arguta* wystarcza zastosowanie 0,05 lub 0,1% KJ, do defoliacji *Ligusturm vulgare* — 0,1 lub 0,2%. Skuteczną defoliację powodował 0.24% roztwór chloranu magnezu i 2% roztwór siarczanu miedzi. Siarczan miedzi powodował stosunkowo najwięcej uszkodzeń i zahamowań w rozwoju i wzroście krzewów.

Opryskiwanie 26 września dało lepsze rezultaty niż opryskiwanie 16 września.

Defolianty chemiczne obniżyły lekko mrozoodporność krzewów *Ligustrum vulgare*, co nie powinno mieć w praktyce zasadniczego znaczenia.