ACTA AGROBOTANICA
Vol. XXXI (1/2): 181-194, 1978

The effect of controlled temperature and humidity on the effectiveness of chemical defoliation of Ligustrum vulgare L. and Spiraea bumalda Burv. shrubs

S. MARCZYŃSKI * and L. S. JANKIEWICZ **

* Warsaw Agricultural University, Warszawa—Ursynów and
** Research Institute of Vegetable Crops, Skierniewice, Poland

(Received: March 1, 1978)

Abstract

The influence of 3 temperatures: 4°, 13°, and 22°C and of 3 humidities 50% r.h., 77% r.h. and 95% r.h. on the effectiveness of two defolians KJ and $Mg(ClO_3)_2 \cdot 6H_2O$ was investigated in a phytotron. By changing day and night temperature and humidity the weather conditions encountered in nurseries in autumn were simulated. The influence of environment on defoliation depended markedly on the species of plant and on the defoliant. In several cases defoliation started earliest at 13° but over a longer period of time the temperature 4° stimulated markedly leaf shedding.

External factors such as temperature and humidity have a significant influence on the effectiveness of defoliants (Daukaeva and Sergeev 1967; Ebetullaev 1968; Basak et al. 1973 a, b, Larsen 1973).

Several authors are of the opinion that effectiveness of defoliants increases with increasing temperature. This refers especially to ethephon (Amchem rep. 1969; Hartman et al. 1970; Stonov 1973), but was also found with magnesium chlorate (Imamaliev 1960; Ebetullaev 1968; Levin 1969). On the other hand, Niazov (1961) and Basak et al. (1973 a) reported that the effectiveness of magnesium chlorate and potassium iodide depended little on prevailing temperature in particular years. The effect of temperature on the absorption of chemical compounds by leaves is widely discussed in the literature (see Bukovac 1973; Jankiewicz 1979). It is generally accepted that the higher the temperature, the better the absoption.

Defoliants are more effective when the level of soil moisture is high (Imamaliev 1960). A high atmospheric humidity speeds the absorption of chemical substances by leaves (Bukovac 1973; Marczyński and Jankiewicz 1978).

The objective of this experiment was to investigate the influence of temperature and humidity on the effectiveness of potassium iodide and magnesium chlorate which are used as defoliants for several fruit and ornamental trees and shrubs (Macdonald and Kempton 1968; Stonov 1973; Marczyński 1977 a, b; Basak et al. 1973 a; Sergeev and Daukaeva 1967; Larsen 1973).

MATERIAL AND METHODS

The plants were grown in 13 cm diameter pots under 12 hour day the Research Institute of Pomology in Skierniewice (Poland), on one--year-old shrubs of privet (*Ligustrum vulgare* L.) and meadow sweet (*Spiraea bumalda* Burv. cv. Froebelii).

The plants were grown in 13 cm diameter pots under 12 hour day length. The light was provided by 40W fluorescent tubes "Flora" (Zakłady im. Róży Luxemburg, Warszawa) giving predominantly red and blue light. Light intensity at plant level was about 5 lx. Deviations from the fixed temperature and relative humidity were within the range of ±1.5°C and 5% r.h.

The plants were placed into the appropriate phytotron chamber 3 days before treatment with defoliants so that they could partially accomodate to new conditions. The solutions of defoliants were also pla-

Table 1

Treatment in the first experiment, 1973

Treatment [a]	Air temperature of day (in °C)	Air temperature of night (in °C)	Air relative humidity of day and night (in %)	
1*	4	4	77	
2*	13	13	77	
3*	22	22	77	treated
4	22	22	50	with KJ or
5	22	22	95	$Mg(ClO_3)_2$
6	13	4	77	
7	22	4	77	
k — 1*	4	4	77	treated
k — 2*	13	13	77	with H_2O
k — 3*	22	22	77	(control)

[a] All treatments used for *Ligustrum vulgare* shrubs. Those marked with asterix also for *Spiraea*×*bumalda* cv. Froebelii.

ced in the particular chamber some hours before treatment to bring them to the same temperature as air in the chamber.

The plants were treated with a 0.2% solution of potassium iodide KJ or with a 0.3% solution of magnesium chlorate ($Mg(ClO_3)_2 \cdot 6H_2O$). The wetting agent Sandovit, in conc. 0.1%, was added to the solutions in most cases. Control plants were treated with water plus the wetting agent or with water alone. The above-ground parts of the plants were immersed in water (control plants) or in the defoliant solution for 2 seconds. Then they were moderately shaken 4 times to remove excess liquid. After that, the leaves of each plant were counted. The plants were treated with defoliants on September 17th in 1973 and on September 21st in 1974.

The 1973 experiment involved 17 treatments of privet shrubs and 6 treatment of meadow sweet shubs (Table 1). The 1974 experiment in-

Table 2

Treatments in the second experiment. 1974

Treatment [a]	Air temperature of day (in °C)	Air relative humidity of day (in %)	Air temperature of night (in °C)	Air relative humidity of night (in %)
A. Defoliant (KJ or $Mg(ClO_3)_2 \cdot 6H_2O$)+wetting agent				
1*	4	77	4	77
2*	13	77	13	77
3*	22	77	22	77
4*	22	50	22	50
5*	22	95	22	95
6	22	77	4	77
7	22	77	13	77
8	13	77	4	77
9	22	50	4	95
10	22	77	4	95
11	22	95	4	95
B. Defoliant without wetting agent				
B—1	4	77	4	77
B—2	13	77	13	77
B—3	22	77	22	77
B—4	22	50	22	50
B—5	22	95	22	95
C. Control — water				
k—1*	4	77	4	77
k—2*	13	77	13	77
k—3*	22	77	22	77

[a] as in Table 1.

volved 35 treatments of privet shrubs and 8 treatments of meadow sweet shrubs (Table 2). Each treatment in both years was done on 6 plants. One plant was considered as a plot.

The effectiveness of defoliants was evaluated by counting the leaves remaining on the shrubs on the 3rd, 6th, and 12th day after treatment. The shrubs were gently shaken before counting the leaves. The results (per cents of fallen leaves) were evaluated statistically by analysis of variance. The significance of differences between treatments was evaluated with Duncan's test at P=0.05.

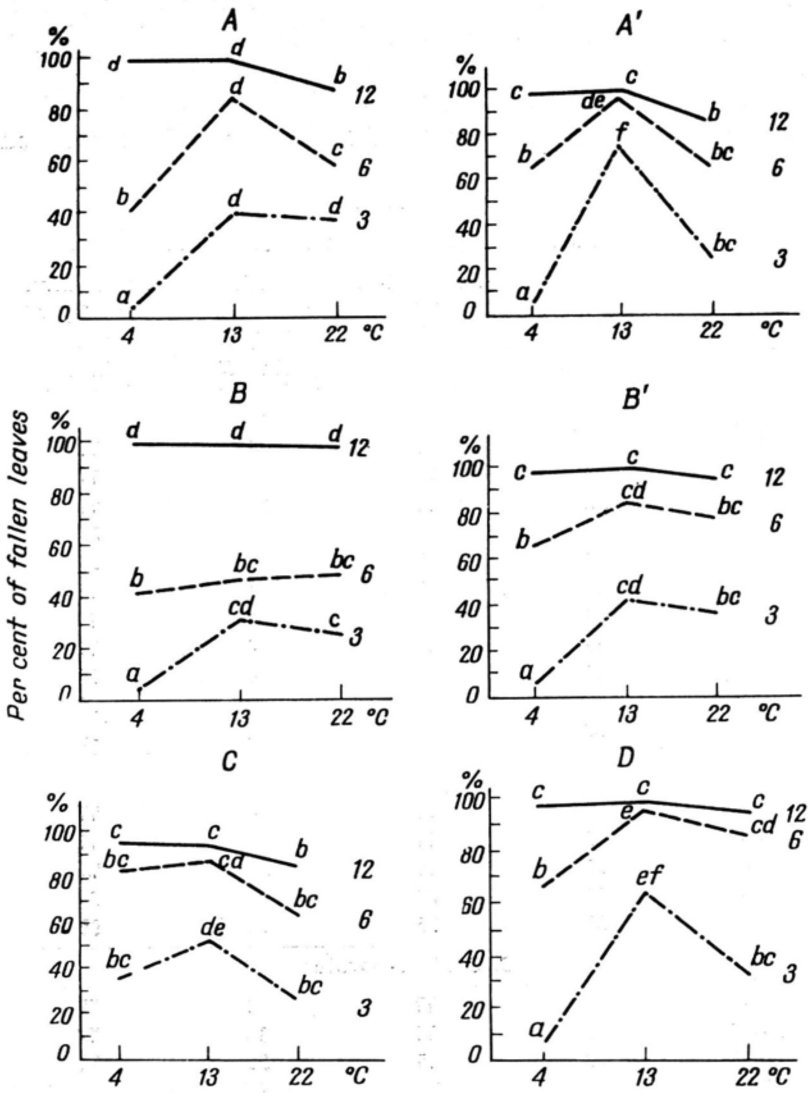

Fig. 1.

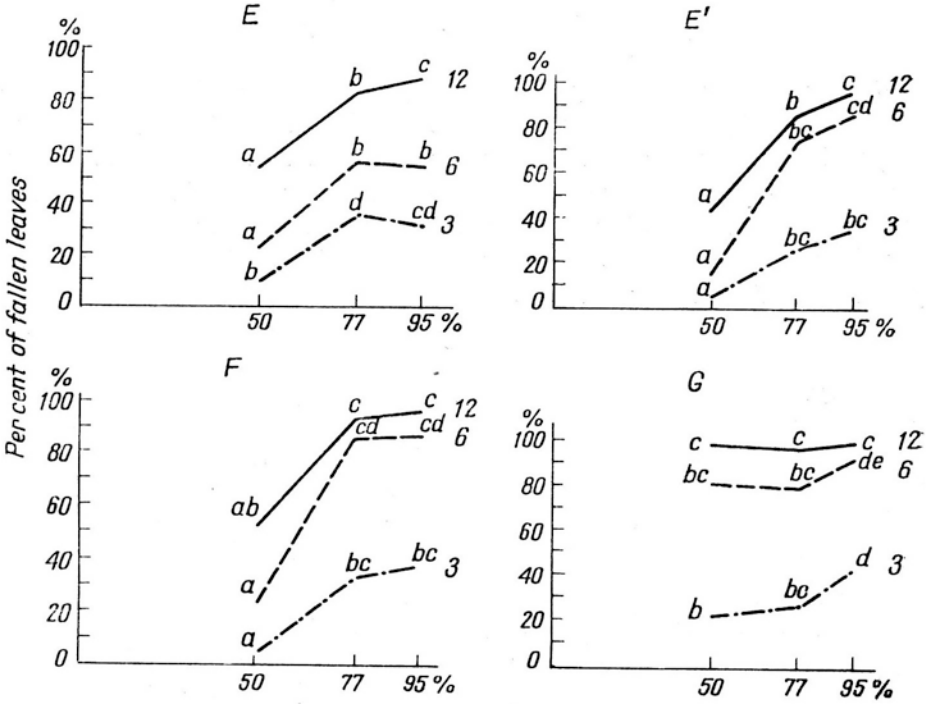

Fig. 1. **Defoliation of *Ligustrum vulgare* L. with potassium iodide as dependent on temperature and air humidity. The curves *3*, *6*, and *12* — leaf fall: 3, 6 and 12 days after treatment. Leaf fall is expressed as per cent from the original number** of leaves present on the shrub at the day of treatment. Wetting agent was added to the treating solution unless marked

A, B, E — results of 1973, A', B', C', D, E', F, G, — results of 1974

A,A' — Effect of constant day and ringht temperatures (abscissa) at 77% relative humidity; B,B' — Effect of different day temperatures (abscissa) and the same (for all treatments) night temperatur 4°C and relative humidity (77%) during day and night; C — Effect of different night temperature (abscissa) and the same (for all treatments) day temperature (22°C) and relative humidity (77%) for day and night; D — as A and A' but without wetting at 22°C (abscissa) with the same (for all treatments) night temperatura 4°C and night (abscissa) at the same (for all traetments) temperature (22°C) for day and night; F — as E but without wetting agent added to the solution; G — Effect of different day humidites at 22°C (abscissa) with the same (for all treatments) night temperatura 4°C and night humidity (95% r.h.)

The points marked with the same letters do not differ significantly at P=0.05

RESULTS

Some leaf fall from privet and meadow sweet shrubs treated with defoliant occurred by the 3rd day after treatment (Figs 1-3). At the 6th and 12th days, defoliation was often considerable but depended markedly on temperature and humidity.

Defoliation of privet shrubs with KJ

When different temperatures were applied day and night at the same relative humidity 77% for all treatments, the defoliation with KJ was initially highest at 13°C in both years (Fig. 1A and 1A′). Later, however, on the 12th day after treatment, the per cent of fallen leaves at 13°C and 4°C became similar. This effect of temperature on the amount of defoliation was not affected consistently by omitting the wetting agent in the dip mixture (Fig. 1D).

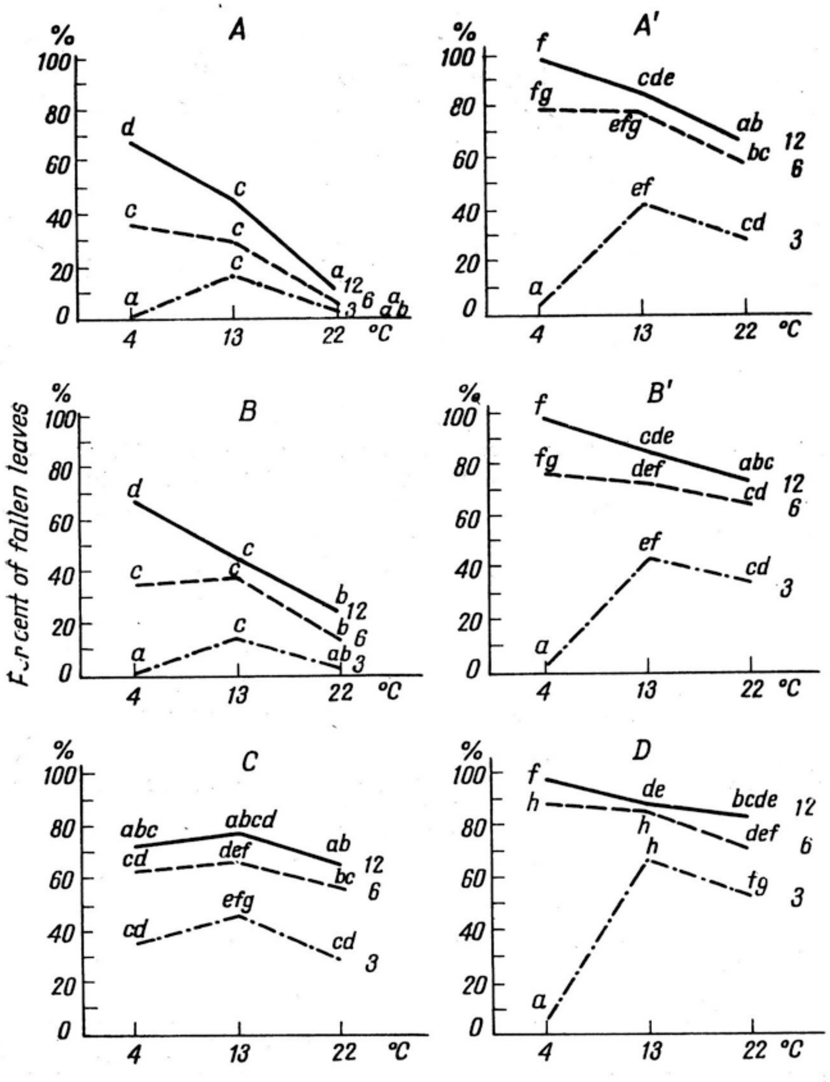

Fig. 2.

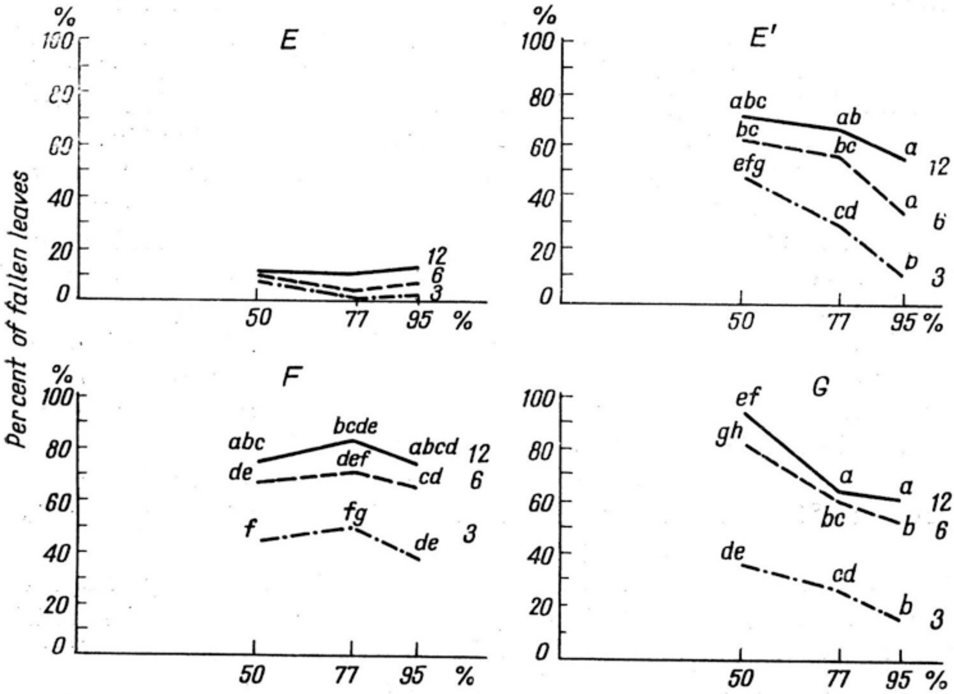

Fig. 2. Defoliation of *Ligustrum vulgare* L. with magnesium chlorate as dependent on temperature and air humidity. The curves: *3*, *6* and *12* — leaf fall (in percentage): 3, 6 and 12 days after treatment; wetting agent added to the treating solution unless marked

A, B, E -- results of 1973, A', B', C, D, E', F, G — results of 1974

A,A′ — Effect of constant day and night temperatures (abscyssa) at 77% relative humidity; B,B′ — Effect of different day temperatures (abscyssa) and the same (for all treatments) night temperature (4°C) and relative humidity (77%) during day and night; C — Effect of different night temperature (abscyssa) and the same (for all treatments) day temperature 22°C and relative humidity (77%) for day and night; D — as A and A′ but without wetting agent added to the solution; E,E′ — Effect of different humidities during day and night (abscyssa) at the same (for all treatments) temperature 22°C for day and night; F — as E but without wetting agent added to the solution; G — Effect of different day humidites at 22°C (abscyssa) with the same (for all treatments) night temperature (4°C) and night humidity (95% r.h.)

When only the day temperature was varied and the night temperature was the same in all treatments of a given series (Fig. 1B and 1B′), the tendency for initial heaviest leaf fall at 13°C was less accentuated and the differences in the leaf fall at 13°C and 22°C were not consistent.

When only the night temperature was varied among treatments and the day temperature was the same (22°C), (Fig. 1C) the heaviest defoliation occurred initially at 13°C but the differences among the treatments were smaller than in the case of constant day and night temperatures.

The level of relitive humidity in conditions of constant day and night temperature (22°C) markedly affected defoliation. The leaf fall was smallest at 50% r.h. and very pronounced — at 95% r.h. (Fig. 1E and 1E′). Omitting the wetting agent in the dip mixture did not significantly influence this result (Fig. F). When only the day humidity was varied among treatments and the night temperature (4°C) and humidity (95% r.h.) was the same (Fig. 1G), the low day humidity (50% r.h.) showed much less adverse influence on the effectiveness of the treatment.

The effectiveness of magnesium chlorate — another defoliant applied on privet shrubs, was dependent in a different way on temperature and humidity. Although with constant day and night temperatures the defoliation in both years was initially the heaviest at 13°C (see leaf fall after 3 days — Fig. 2A and 2A′), later on, however, at the 6th and 12th days after treatment, the defoliation was, in both years, heaviest at 4°C, and smallest at 22°C.

When only the day temperature was varied and the night temperature was 4°C for all treatments (Fig. 2B and 2B′), the inhibition by the temperature 22°C was slightly alleviated.

When only the night temperature was varied and the day temperature was the same (22°C) for all given treatments (Fig. 2C) the initial heavier defoliation was found at 13°C, but on the 12th day no differences were visible among shrubs kept in various temperatures.

Omitting the wetting agent in the dip mixture did not change markedly the effects of temperature on defoliation but the defoliation was earlier (Fig. 2D).

Humidity influenced the effectiveness of magnesium chlorate in a different way from that of KJ (Fig. 2E′). Unexpectedly, the defoliation

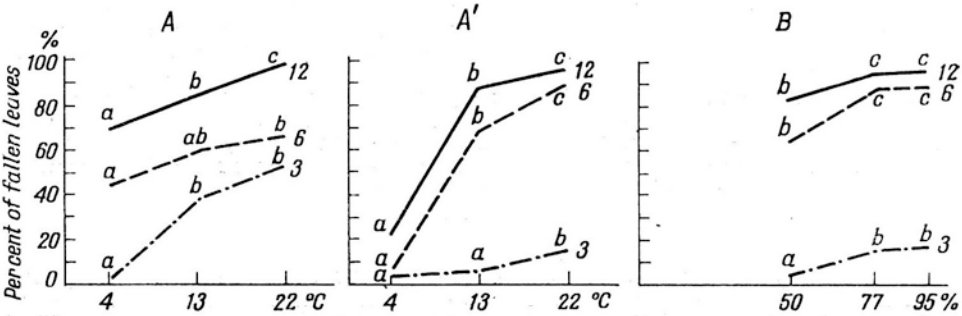

Fig. 3. Defoliation of *Spiraea* × *bumalda* cv. Froebelii with potassium iodide as dependent on temperature and humidity. The curves: *3*, *6* and *12* as in Fig. 1. Wetting agent was added to the solution

A — resuts of 1973, A', B — results of 1974

A,A′ — Effect of constant day and night temperatures (abscyssa) at 77% relative humidity; B — Effect of different humidities during day and night (abscyssa) at the same for all treatments temperature (22°C) for day and night was slowest and smallest with the highest relative humidity (95% r.h.). A similar result but more pronounced was obtained when only the day humidities were varied and the night humidity was kept at the same level in all treatments (95%), (Fig. 2G). When the wetting agent was not added to the dip mixture, the shrubs kept in different humidities lost their leaves to a similar degree (Fig. 2F — see differences after 6 and 12 days).

The shrubs of meadow sweet were treated only with KJ. The effect of temperature (constant day and night) on the degree of defoliation was different in this species from that in privet. In both years the defoliation of meadow sweet shrubs was earlier and heavier the higher the temperature (Fig. 3A and 2A′).

The effect of humidity on meadow sweet shrubs defoliation was similar to that which was observed in the case of privet shrubs treated with KJ: defoliation was heavier in higher humidities.

Control plants in these experiments did not lose leaves to a considerable extent.

DISCUSSION

As already mentioned, there are several data in the literature showing that the results of chemical defoliation depend on temperature and air humidity. These data are drawn, however, from field experiments and, therefore, are not very helpful for precise description of this dependence. Undoubtedly temperature and humidity influence the affectiveness of chemical defoliation in a complex way. On one hand, they affect the absorption of defoliants and on the other, the mechanism of leaf shedding and the physiological mechanism of defoliant action.

The effect of constant day and night temperature on the meadow sweet shrubs seems to be rather simple to interpret. These shrubs lost their leaves earlier the higher the temperature. In this case higher temperature probably stimulated absorption of KJ as well as the mechanism of leaf shedding.

In the case of privet shrubs defoliated with KJ or $Mg(ClO_3)_2 \cdot 6H_2O$, the earliest defoliation at 13°C, and the rather heavy leaf fall which occurred later on plants kept at 4°C may be interpreted as an interaction of 2 factors: the slowing down of the absoption of the defoliant with the lowering of temperatures, and the progressive inhibition of the abscission zone formation with increasing temperature. Due to this, the earliest defoliation may occurr at a moderate temperature in which the absorption is not very slow and the inhibition of the abscission zone formation is not very strong. After 6 or 12 days, the stimulation of abscission zone formation in low temperature, which is probably a gradual and slow process, is more and more visible especially in plants treated with magnesium chlorate. The full interpretation of these phenomena without additional experiments is, of course, not possible.

The plants which were kept at a particular temperature for only one half of the 24 h period exhibited the effect of this temperature less, and their behaviour was also influenced by conditions encountered during the second half of the 24 h period.

Our experiments dealing with the effects of temperature on defoliation show, the following:

1. Temperature affects defoliation of different species differently (compare privet shrubs and meadow sweet shrubs treated with KJ).

2. The interaction of particular defoliants with temperature shows differences.

3. Low positive temperature (4°C and 13°C), stimulates in privet shrubs, leaf fall caused by magnesium chlorate and to a smaller extent by potassium iodide.

At relative humidity 77%, the air water pressure deficit differs for particular temperatures. It is 1.4 mm Hg for 4°C, 2.6 mm Hg for 13°C and 4.6 mm Hg for 22°C. Defoliation depends on humidity and water pressure deficit as is shown in Fig. 1E-2E′. If one wants to correct the results presented in Fig. 1A-3A from this point of view, the values from Fig. 1E-2E′ and 3C may be used for interpolation. Thus, the values in Fig. 1A, 2A and 3A rather do not need to be changed, whereas the values for 22°C in Fig. 1A′ should be raised by 6-7 per cent units. In Fig. 2A′ this change for 22°C would be about 7-13 per cent units lower and for 13°C probably one half of that. This does not change consistently the description of the dependence of defoliation on temperature which we have presented.

There are several data in the literature concerning the effects of humidity on the absorption of chemical compounds (see Bukovac 1973). However, only fragmentary data were collected on the effect of humidity on chemical defoliation (see Larsen 1973). Our results showed an unexpected fact that humidity can influence, in a quite different way, the defoliating activity of the two compounds used.

The influence of humidity on defoliation with KJ was such as could be expected from its effect on absorption of chemicals by leaves: the higher the humidity, the better, the defoliation (probably due to better absorption of KJ). Better absorption of KJ marked with ^{131}J by privet leaves in higher humidity was shown by Marczyński and Jankiewicz (1978).

A much lower adverse effects of low humidity treatment when it was given only during the day (Fig. 1G) is understandable since considerable absorption could occur during the night, when the humidity was 95%. This is of importance since cool, humid nights are a normal occurrence in the autumn when defoliation is practiced. It is difficult to explain why the omittion of the wetting agent in the dipping mixture improved defoliation. Possibly this was connected with the method of treating the plants: the layer of liquid on the leaf surface could be thinner after dipping, when a wetting agent was added to the mixture. Therefore, the deposit of defoliant on the leaf could be smaller.

The effect of humidity on the effectiveness of defoliation with $Mg(ClO_3)_2 \cdot 6H_2O$ was the opposite of that observed with KJ: the higher the humidity, the slower and smaller the defoliation. This result was also obvious when different humidites were given to plants only during the day, and high humidity (95% r.h.), and low temperature (4°C) were maintained during the night. Low night temperatures stimulated leaf fall so the defoliation was, in this case, greater (compare Figs E′ and 2G). It is not easy to explain why higher humidity reduces the defoliation caused by magnesium chlorate. Markedly lower retention of the solution on leaves kept at a high humidity after dipping seems unlikely. There are two other possibilities: 1. High humidity diminishes the absorpition of magnesium chlorate (which is itself a highly hygroscopic substance). We have no idea however, by which mechanism this could be achieved. 2. High humidity inhibits the formation of the absciccion zone. This mechanism is also rather unknown.

One can suppose that magnesium chlorate injures the superficial cells of the leaf causing the production of ethylene which is an important factor in the formation of the abscission layer. Better defoliation at a high humidity without a surfactant added to the dipping mixture suggests that a surface phanomena may be involved as a causal factor in the described response of privet to magnesium chloride at high humidity. Further experiments are being conducted to elucidate fully the observed phenomena.

The anthors are greatly indebted to Doc. dr. K. Szczepański and dr. S. Reyman for their help in statistical analysis.

This paper was partly supported by the US. Department of Agriculture, Agricultural Research Service Grant No. FG — Po, 265.

SUMMARY

The influence of temperature and humidity on the effectiveness of two defoliants, potassium iodide KJ and magnesium chlorate $Mg(ClO_3)_2 \cdot 6H_2O$, was investigated in the phytotron. Separate groups of plants were kept in chambers with different conditions, 3 days before and 12 days after the treatment. They

were treated by dipping the aerial part of a plant in a solution of defoliant Some plants were kept at the same temperature and humidity day and night whereas others had different day and night conditions. The effect of different temperatures was investigated at a constant relative humidity 77% and the effect of different humidities at a constant temperature 22°C. Privet (*Ligustrum*) shrubs treated with KJ showed fastest defoliation at 13°C, however, after 12 days, the shrubs kept in both 4°C and 13°C lost a similar per cent of leaves. Meadow sweet shrubs (*Spiraea*), defoliated with KJ, lost more leaves the higher the temperature. Privet shrubs treated with magnesium chlorate showed the reverse dependance on temperatures with a lower per cent of fallen leaves at higher temperatures. Different temperature treatments only during half of a 24 h period diminished the differences among treatments. The effectiveness of KJ was higher, the higher the relative humidity of the air. However, effectiveness of $Mg(ClO_3)_2 \cdot 6H_2O$ showed reverse dependance on humidity. Omitting the wetting agent in the dip mixture of magnesium chlorate diminished differences among plants kept in different humidities.

REFERENCES

Amchem Products. Inc., 1969: Technical service data sheet.

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

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

Bukovac M. J., 1973. Foliar penetration of plant growth substances with special reference to tree fruits. Acta Hort. 34: 69-78.

Daukaeva R. S., Sergeev L. I., 1967. Khimicheskaya defoliatsya plodovykh rastenii v pitomnikakh i nasazhdeniyakh Bashkirii i Urala. Ministerstvo Selskogo Khoziaistva BASSR. Ufa.

Ebetullaev A. A., 1968. Vliyanie niekotorych faktorov na effektivnost' khimicheskoi defoliatsii seyantsev jabloni Khimiya Selsk. Khoz., 6, 55-57.

Hartman H. T., Tombesi A., Whisler J., 1970. Promotion of ethylene evolution and fruit abscission in the olive by 2-chloroethanophosphonic acid and cycloheximide. J. Amer. Soc. Hort. Sci. 95: 635-640.

Imamaliev A., 1960. Udalenie listev u plodovykh sazhentsev. Sadovodstvo. 9: 23-24.

Jankiewicz L. S., (red.) 1979. Fizjologia roślin sadowniczych. PWN, Warszawa.

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

Marczyński S., 1977a. The chemical defoliation of *Ligustrum vulgare* L. and *Spiraea* × *arguta* Zab. shrubs in nursery. Acta agrobot. 30: 103-120.

Marczyński S., 1977b. The chemical defoliation of ornamental nursery shrubs *Forsythia* × *intermedia* Zab., *Rosa* cv. Lampion, *Spiraea* × *bumalda* Burv. cv. Froebelii, *Spiraea* × *vanhouttei* Zab., Acta agrobot. 30: 121-134.

Marczyński S., Jankiewicz L. S., 1978. Uptake and translocation of labelled iodide ion in the privet (*Ligustrum vulgare* L.) as related to its defoliating activity. Acta agrobot. 31: 61-70.

Larsen F. E., 1973. Promotion of laef abscission in fruit nursery stock. Acta Hort. 34: 129-133.
Levin A. M., 1969. Defoliatsiya i sort. Sadovodstvo 9: 22-23.
Niazov A., 1961. Defoliatsiya v pitomnike. Sadovodstvo 9: 31-32.
Stonov I. D., 1973. Defolianty i desykanty. Izd. Khimia. Moskva.

Wpływ kontrolowanej temperatury i wilgotności na skuteczność chemicznej defoliacji krzewów *Ligustrum vulgare* L. i *Spiraea bumalda* Burv.

Streszczenie

Badano w fitotronie wpływ temperatury i wilgotności na działanie dwu defoliantów: jodku potasu KJ i chloranu magnezu $Mg(ClO_3)_2 \cdot H_2O$. Poszczególne grupy roślin przebywały w komorach fitotronowych o różnych temperaturach i wilgotności, począwszy od trzeciego dnia przed traktowaniem do 12 dnia po potraktowaniu defoliantem. Rośliny traktowano przez zanurzenie części nadziemnej w roztworze defolianta. Niektóre rośliny przebywały w jednakowej temperaturze w ciągu dnia i nocy, podczas gdy inne miały inną temperaturę otoczenia we dnie, a inną w nocy.

Wpływ różnych temperatur był badany przy takiej samej wilgotności względnej powietrza wynoszącej 77%, a wpływ różnych wilgotności — przy stałej temperaturze 22°C. Krzewy ligustru traktowane KJ wykazywały początkowo silniejszą defoliację w 13°C, jednak po 12 dniach procent utraconych liści w 4°C i w 13°C był podobny. Krzewy tawuły defoliowane jodkiem potasu traciły tym więcej liści, im wyższa była temperatura otoczenia. Krzewy ligustru traktowane chloranem magnezu wykazywały odmienną zależność: im niższa była temperatura, tym większy procent opadłych liści. Rośliny przebywające w różnych temperaturach tylko przez połowę doby, podczas gdy przez drugą połowę miały warunki takie same, mniej różniły się stopniem defoliacji niż rośliny trzymane w poszczególnych temperaturach przez całą dobę. Skuteczność KJ była tym większa, im wyższa wilgotność powietrza, natomiast skuteczność chloranu magnezu — tym mniejsza. Niedodanie zwilżacza do roztworu chloranu magnezu, w którym zanurzono rośliny, zmniejszało różnice między roślinami przebywającymi w atmosferze o różnej wilgotności. Rośliny kontrolne, opryskane tylko wodą lub wodą ze zwilżaczem, prawie nie traciły liści w czasie trwania doświadczenia.