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Uptake and translocation of labelled iodide ion in privet (Ligustrum vulgare L.) as related to its defoliating activity

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Abstract

The $^{131}J^-$ ion applied as KJ solution to lanolin ring on the leaf moved quickly to other parts of the leaf, however, it was transported to the stem and axillary bud in small amount. The $^{131}J^-$ ion from potassium iodide was absorbed very fast by privet (*Ligustrum vulgare* L.). By 45 min after treatment about half of the applied ion was absorbed. This result was also confirmed in field experiments with non labelled KJ with privet and with *Spiraea×bumalda* cv. Froebelii during 2 year experiments. In the conditions of high air humidity (95% r.h.) much more $K^{131}J$ was absorbed than at low air humidity (50% r.h.) at the same temperature (23°). Also at a relatively high temperature (23°) the uptake was more intensive than at a low temperature (4°), at the same air humidity (95% r.h.).

INTRODUCTION

Chemical defoliation will probably soon be a common practice in fruit and ornamental nurseries in countries with long winters. In these countries a danger of early frosts compels the nurseryman to mechanical digging and selling of the plants much before the leaves are naturally shed. Hand defoliation is often applied before digging of plants but it is a very expensive practice and often not feasible, for instance when the plants are thorny or have small leaves on very thin branches.

A number of chemical defoliants and their mixtures have been tested in recent years (Daukaeva 1964; Basak et al. 1973a, b; Larsen 1973). Among them potassium iodide is one of the best, at least for several ornamental plants. (Macdonald and Kempton 1968; Marczyński 1976a, b; Larsen 1973).

The activity of each defoliating compound depends to a large extent

on environmental conditions before, during and after its application (Bukovac 1973; Babiker and Duncan 1975). This is mainly due to the effect of the environment on the uptake of defoliants (Ebetullaev 1968; Hartman et al. 1970; Larsen 1973).

The aim of this investigation was to check the influence of air humidity and temperature on the course of $K^{131}J$ uptake, and also to check the translocation of the absorbed iodide ion within the leaf and from the leaf to the stem. This information seemed necessary for better understanding the mode of action of KJ used as a defoliant.

MATERIAL AND METHODS

1. The time course of $^{131}J^-$ ion uptake by the leaves as dependant on temperature and air humidity. The experiment was performed on one-year-old shrubs of privet (*Ligustrum vulgare* L.) planted into pots 13 cm in diameter.

The experiment was done in the phytotron and the Isotope Laboratory of the Research Institute of Pomology in Skierniewice. Three chambers were used with the following day and night temperatures and air humidity:

1. 23°C and 50% r.h.
2. 23°C and 95% r.h.
3. 4°C and 95% r.h.

The temperature oscillated $\pm 1°$ and r.h. $\pm 5\%$ from the above values. Day length was 12 h, light intensity about 5000 lx.

In each chamber 4 plants were placed 14 days before treatment with defoliants. Each plant was considered as a separate plot.

The plants were treated by dipping whole shoots in a solution containing $^{131}J^-$ ions with an activity of 100 μCi. The surplus solution was removed after treatment by shaking the shoots 4 times with similar strength. From each plant 2 leaves were taken 20-30 s after dipping in the radioactive solution and then other pairs of leaves were removed after 15, 45, 125 and 405 minutes and after 24 and 48 hours.

These leaves were then immediately rinsed 3 times in distilled water and after dissection dried for 20 min in a photographic drier. The measurements of radioactivity of whole leaves were done with a thin window counter AOH-45.

In this experiment we assessed the amount of KJ absorbed during different "times of absorption" i.e. during the times elapsing between treatment with radioactive KJ and rinsing it from the surface of the leaves.

2. The experiment on translocation of $^{131}J^-$ within the plant was done with 2 separate privet shrubs. They were kept in the phytotron chamber "1" at 23° and 50% r.h.

A lanolin ring of 5 mm inner diameter was formed on each of 5 leaves chosen on a plant and immediately after that a 0.022 ml droplet of $K^{131}J$ solution (activity 1.5 μCi) was inserted inside the ring. After an appropriate time 2 of these leaves and the stem region connected with them were sectioned and autoradiographed (Fig. 1B). The spot with the

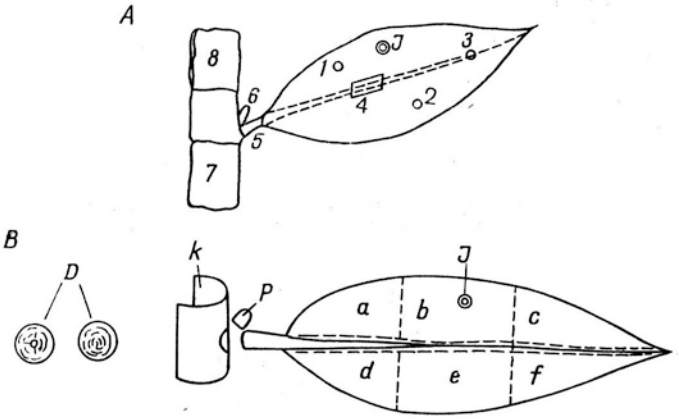


Fig. 1A. The method of taking leaf and stem fragments for drying and determining leaf tissue activity

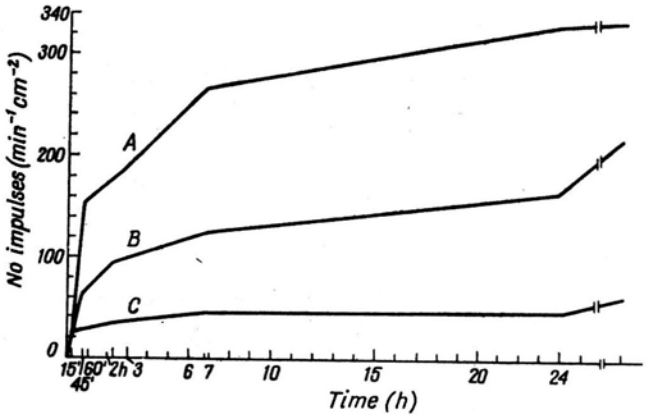
J — the place of $K^{131}J$ application; *1*, *2*, *3* — different fragments of leaf tissue taken for radioactivity determination, *4* — the fragment of the main, nerve, *5* — leaf peduncle, *6* — the bud, *7* and *8* — sections of the bark below and above the leaf

Fig. 1B. The method of dividing the leaf and the stem for autoradiography *K* — bark, *P* — the bud. *D* — cross sections of the wood at the height of leaf peduncle insertion, *J* — the place where $K^{131}J$ was applied, surrounded by a lanolin ring. This spot was rejected before autoradiography. The leaf blade was separated into the main nerve and *6* parts (*a*—*f*) as shown by dashed lines

lanolin ring, where the radioactive compound was applied, was rejected. The remaining 3 leaves and the segments of the stem adjoining to them were cut into parts (Fig. 1A), dried, powdered and tested for radioactivity. This was done 3 hours after treatment, with the leaves of one plant, and 24 hours after treatment, witht the leaves of another plant. The measurements of radioactivity, were done with a thin-window counter AOH-45.

3. To supplement this experiment, the plants of *Ligustrum vulgare* L. and *Spiraea*×*bumalda* Burv. cv. Froebelii were sprayed with non labelled 0,2% KJ and then rinsed carefully after 20-30 seconds or after 1.5, 5, 15, 45, 125 and 405 minutes. The control plants were treated only with

water. Each combination of treatments was done in 4 replications, one plant being a plot. The leaves on the shoots were counted immediately after treatment and then after 3, 6 and 12 days. Before counting, the shoots were always slightly shaken to loosen the leaves which were



18

Fig. 2. $K^{131}J$ uptake by the leaves of *Ligustrum vulgare* L. as dependent on the time of absorption (i.e. the time elapsing between the treatment with $K^{131}J$ solution and rinsing the leaves)

A — 23°,95% r.h., *B* — 4°,95% r.h., *C* — 23°,50% r.h.

slightly attached to the stem. The results were worked out statistically by analysis of variance using Student's "t" test for significance of differences, at $P=0.05$.

RESULTS

The penetration of $^{131}J^-$ ion into privet leaves was closely dependent on air temperature and humidity (Fig. 2). It was found that much of the $^{131}J^-$ was absorbed during the time up to 48 hours by the leaves when the shrubs were kept at 95% r.h., than at 50% r. h. when the temperature was 23°C.

The uptake of $^{131}J^-$ was much greater at 23°C than at 4°C, when relative humidity was 95%.

Most of the $^{131}J^-$ ion was taken up during the first hours after treatment. During the first 2.5 hours, the leaves took up as much ^{131}J as during the next 45.5 hours (Fig. 2).

Translocation of $^{131}J^-$ from the spot where it was applied to the other parts of the leaf was very active (Table 1). Small amounts of $^{131}J^-$ were also found in the axillary bud and in the bark of the stem. There was always a tendency of translocating more $^{131}J^-$ upward in the bark than downward.

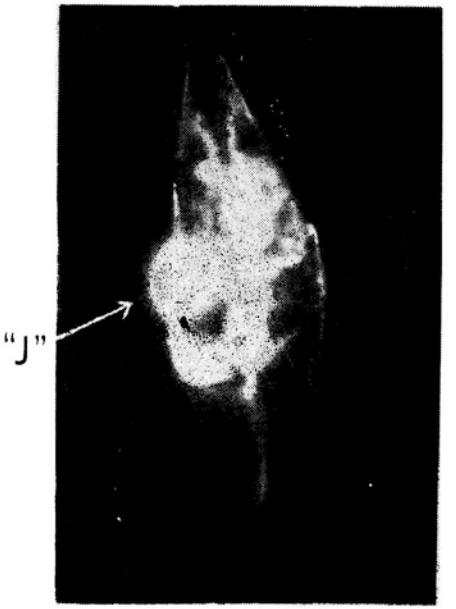


Fig. 3. The autoradiogram of a leaf 24 hours after treating it with the droplet of $K^{131}J$ solution in the place marked "J" (which was rejected before autoradiography). The droplet of labelled KJ was given on the upper side of the leaf. Before autoradiography the leaf was dissected as in Fig. 1B.

Table 1

The radioactivity (in impulses · min^{-1} · 10^{-1} · mg dr. wt.$^{-1}$) of the tissue from different parts of the leaf and shoot of *Ligustrum vulgare* L. after application of $K^{131}J$ as a droplet to only one place on the leaf (see Fig. 1).

Sample No. (see Fig. 1A)	Measurement of radioactivity after: 3 hours, application of the labelled KJ on: the upper side of the leaf	3 hours, the lower side of the leaf	24 hours, the upper side of the leaf	24 hours, the lower side of the leaf
1	335.0	1822.4	265.1	5519.4
2	121.4	326.4	293.6	665.3
3	99.0	252.7	421.7	529.7
4	233.3	1323.9	505.2	1714.6
5	9.6	134.0	66.1	54.7
6	40.6	25.0	31.7	45.8
7	11.6	13.2	16.0	3.3
8	32.0	23.7	24.0	15.1

When $K^{131}J$ was applied on the lower side of the leaf, the amount of $^{131}J^-$ absorbed was much higher (often several times) than when it was given on the upper side.

These results were in concert with those obtained by autoradiography of leaves and stems (Fig. 3).

The results with the non labelled KJ fully confirmed those with radioactive KJ.

When the leaves of privet were rinsed 45 minutes after treatment or later, the majority of the leaves were shed during the next 12 days (66%

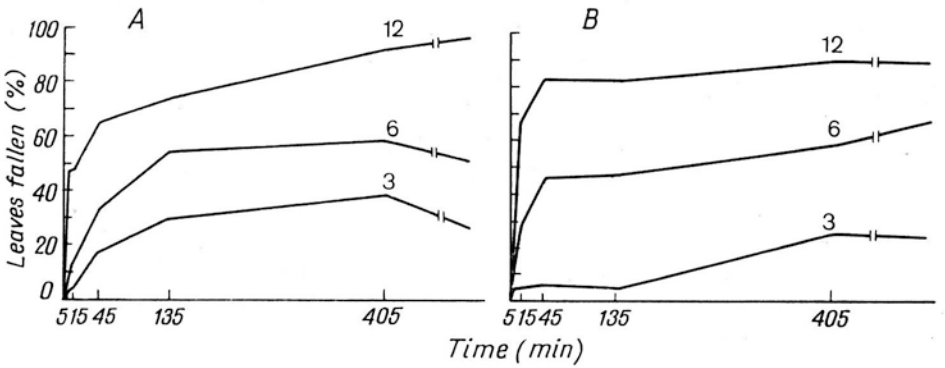


Fig. 4. The influence of the time of non labelled KJ absorption by the leaves on the defoliation of *Ligustrum vulgare* L. shrubs (expressed as % of fallen leaves) A — experiment of the 1st year; B — of the 2nd year. Curves of — 3, 6, 12 — the % of leaves fallen at the 3rd, 6th or 12th day after treatment

in the 1st year and 85% in the second). It was also found that it was sufficient to rinse the leaves after 6 h 45 minutes in one year of experimentation or after 45 minutes in the other year to get the same degree of defoliation as in non-rinsed plants. Such a large difference between the results of the 2 consecutive years indicates a great influence of external conditions on the rate of KJ absorption.

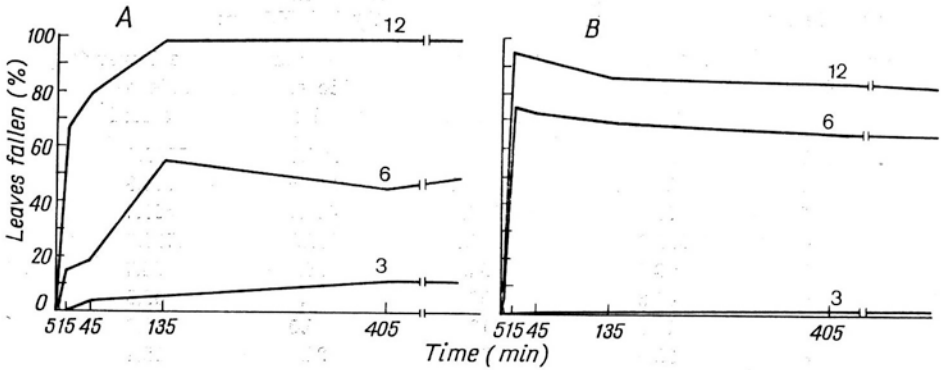


Fig. 5. Defoliation of *Spiraea bumalda* Burv. cv. Froebelii. For other details see Fig. 4.

The shrubs of *Spiraea bumalda* cv. Froebelii responded more to KJ treatment than privet plants. Twelve days after treatment *Spiraea* shrubs lost already 69% of their leaves in the experiment of the first year and 95% in that of the second year — when the leaves were allowed to absorb KJ only for 15 minutes. The time of absorption sufficient for causing 95% defoliation was 135 minutes in the first year and only 15 minutes in the second. The difference between the results obtained in these two years was almost the same as for *Ligustrum* i.e. 9 fold.

When the leaves of *Spiraea* were not rinsed or rinsed only after a longer period, part of the leaves were desiccated and were not shed, this sometimes happens when high concentrations of defoliants are used.

DISCUSSION

The most important finding in this experiment is that $^{131}J^{-}$ moves rather freely within the leaf, but is weakly transported to the bark of the subtending shoot and to the bud situated in the axil of the leaf. Fast movement of the iodide ion inside the leaf explains why it is not necessary to cover the whole leaf surface with KJ to cause shedding (Marczyński and Jankiewicz 1978).

From the point of view of residues it seems important that the iodide ion was found to not move in large amounts into the buds and the stem.

The translocation of KJ within the leaf and outside it was probably not investigated earlier. Herrett et al. (1962) suggested, however, that the iodide ion does not move from one bean leaf to the others. The other defoliants behave variously: ethephon does not move within the bean plant (Sterrett et al. 1974). The defoliant BEXT marked with S^{35} was not translocated in cotton (Kraft and Bokariev 1967) but in bean plants small amounts of it were translocated to the youngest leaves. The systemic properties of the preparate Butifos are not yet certain (Barietas and Otemisov 1973, Turkova and Zubkova 1970).

The other data presented in this paper, concerning the rate of KJ absorption as well as the influence of humidity and temperature on the uptake of this compound do not solve any general problem, since these aspects of the uptake of substances have already been investigated by several authors. Obtaining such data, however, seemed important from the point of view of getting a quantitative picture of the uptake of a particular substance used more and more commonly in practice.

The experiments with $^{131}J^-$ showed that its uptake by the leaf is very fast. About half of the applied amount was taken up during the first 45 minutes after treatment. This result was confirmed by a two-year field experiment with non labelled KJ.

The results of several other authors also indicate that the uptake of different substances by leaves is very fast. Ebetullaev (1968) showed that rinsing the plants 3 hours after treating them with a mixture of calcium chloride and calcium chlorate did not diminish the defoliation effect of the treatment. Stonov (1973) reported that magnesium chlorate and the preparates Butifos and Merfos are taken up by cotton leaves during 60 minutes in sufficient amounts to cause defoliation. Hartman et al. (1970), however, found that rain which took place the next day after treating olive trees with ethephon markedly diminished the effectiveness of this preparate.

What seemed surprising in our experiment was that the difference in the rate of KJ absorption between the two years was so great: about 9 fold in the case of both species. The temperature at the day of treatment was very similar in both years (Table 2), but later, during the 3 days following the treatment there were rainfalls in the second year of experiment, whereas in the first year the weather was dry. Posibly high air humidity connected with rainfalls increased markedly the penetration of KJ into the leaf during the second year of experiment.

The presented results show that the uptake of defoliants by the lower surface of the privet leaf is much faster than by the upper one. Similar results were obtained by Green and Bukovac (1971), Souty

Table 2
Temperatures during the experiments on defoliation

	1973 date	max	min	24 h mean	1974 date	max	min	24 h mean
Day of treatment	15 Sept.	19,6	3,7	11,5	21 Sept.	17,4	7,4	11,1
Frist 6-day period after treatment	16-21	19,1	6,0	11,8	22-27	15,1	8,2	11,2
Second 6-day period after treatment	22-27	15,3	7,6	10,7	Sept. 28-3 Oct.	11,5	4,0	7,4

and Guennelon (1974), Franke (1975), with, other substances and plant species. Our results indicate that the differences in the uptake of KJ by the upper and lower sides of the leaf are great enough to be taken into consideration in working up the spraying technique for defoliants: a strong stream of air must be used to shake the leaves vigorously in order to cover both sides with droplets. Such a technique will save the defoliant and will permit spraying several rows of trees simultaneously.

The presented data indicate that the iodide ion penetrates leaves much faster in conditions of high humidity than in conditions of low humidity. These data corroborate earlier data obtained with other substances. Better hydration of hydrophilic groups in the cuticle makes penetration of inorganic ions in to the leaf easier (Bukovac 1973).

A marked effect of temperature on iodide ion uptake was found in this experiment. A considerable influence of temperature on the penetration of several other substances into the leaves of different plant species was also found by other workers (Green and Bukovac 1971; Bukovac 1973; Hull et al. 1975). It is stated that temperature directly influences the permeability of the cuticle and concomitantly influences the uptake by changing the rate of metabolic processes in the leaf (Green and Bukovac 1971).

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Wnikanie i transport znakowanego jonu jodu w krzewach ligustru (*Ligustrum vulgare L.*) w związku z jego aktywnością defoliacyjną

Streszczenie

Jon $^{131}J^-$ podany na liść w roztworze KJ w miejscu otoczonym lanolinowym pierścieniem przemieszczał się szybko do innych części liścia, natomiast jego transport do pędu i sąsiadującego z liściem pąka był bardzo słaby. Jon $^{131}J^-$ z jodku potasu bardzo szybko wnikał do liści ligustru (*Ligustrum vulgare* L.). Prawie połowa zastosowanego jodku była pochłonięta po około 45 min. Ten wynik został potwierdzony, gdy stosowano roztwór nieradioaktywnego KJ w warunkach polowych. W warunkach wysokiej wilgotności powietrza (95% w.w.) dużo więcej $^{131}J^-$ było zaabsorbowane niż przy niskiej wilgotności (50%), przy zachowaniu tej samej temperatury (23°C). Podobnie w stosunkowo wysokiej temperaturze (23°) wnikanie było dużo bardziej intensywne niż w niskiej temperaturze (4°C) przy wilgotności względnej 95%. Wnikanie przez dolną powierzchnię liścia było znacznie intensywniejsze niż przez górną.