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STEFAN BIAŁOBOK, PAWEŁ PUKACKI

Relationship between measurements of electrical admittance of shoots and frost hardiness of *Viburnum* species*

The methods used so far for the determination of resistance of exotic woody plants to low temperatures depended on observations over many years, particularily following severe winters, of the damages done to plant tissues (B u g a ł a and C h y l a r e c k i 1958, B i a ł o b o k 1958). Sometimes also relations were sought between these observations and data on phenological phases in these trees and shrubs, in order to judge the suitability of the introduced plants for the local climatic conditions (Ł a p i n 1967, C h y l a r e c k i and S t r a u s 1968).

With the advance of breeding work on trees and shrubs for their introduction into regions having severe climatic conditions there exists a need to utilize rapid laboratory methods of estimating resistance to low temperatures.

Studies on the resistance of fruit trees to low temperatures using the method of determining electrical conductivity and electrical resistance (impedance) have been conducted on a wide scale by W i l n e r (1955, 1967, 1964) on numerous varieties of fruit trees differing in their scale of resistance to low temperatures in the climatic conditions of southern Canada. That author has also employed the method of measuring the electrical impedance of one-year-old shoots for the estimation of resistance to low temperatures in some ornamental trees and shrubs (W i l n e r and B r a c h 1970). By measuring electrical impendance there exists also the possibility of evaluating the cold resistance of trees and shrubs growing in situ (W i l n e r 1962). W i l n e r (1965) has also shown that the estimate of resistance to low temperatures in fruit trees is inherited by generative progeny.

The resistance of forest trees to low temperatures is being studied by G l e r u m (1973) in Canada, and in Europe this problem was under investigation by a group of scientists at the Institute of Forest Tree Breeding in Graupa, DDR. S c h e u m a n n and B ö r l i t z (1965) and S c h e u m a n n and H o f f m a n n (1967) have studied the resistance to low

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temperatures of *Picea abies* seedlings, trying to select them in this respect and Scheumann and Schönbach (1968) have compared 25 provenances of *Larix leptolepis* in their resistance to low temperatures, while Scheumann (1962) has also investigated the resistance of *Pseudotsuga menziesii* to low temperatures. Schönbach and Bellman (1967) have studied the resistance to low temperatures of Douglas fir hybrids, having crossed the more susceptible *viridis* variety with the more resistant *glauca* variety. On the example of the hybrids between these two forms of Douglas fir, they have shown that resistance to low temperatures hereditary and linked to a considerable extent with other similarities to the glauca parent.

Sakai (1968) has studied the damage done by low temperatures to the main shoot of seedlings of some tree species the introduction of which into Hokkaido island, with its severe winter climate, is of economic importance.

The laboratory methods of studying resistance of indiginous North American trees to low temperatures of —80°C have been employed by Sakai and Weiser (1973). They have shown that resistance to low temperatures of trees was related to their geographic location and elevation. Studies of this type are of importance in order to become acquainted with their ecology as well as to provide material for the needs of selecting populations resistant to low temperatures.

MATERIALS AND METHODS

In the Kórnik Arboretum observations were being made on resistance of trees and shrubs to winter injury following the five severe winters from the 1939/40 winter onwards. Severe winters have occurred later in the years 1955/56, 1962/63, 1969/70 and 1970/71, they were characterized by various patterns of the weather conditions. They were long, cold winters of the Siberian type with rich snow fall (1939/40, 1962/63 and 1969/70), steppe type of winters, cold but without snow (1955/56) and Atlantic type of winters generally warm but with sudden returns of the low temperatures (1970/71). The lowest air temperatures for Kórnik during these winters are presented in Table 12. They characterize well the severe conditions for woody plants during that time.

The temperature pattern was exceptionally unfavourable in the 1970/71 winter. It was quite unlike anything observed earlier therefore one can assume that this is the reason why in spite of its rather mild course it has caused so many damages to collections of exotic trees and shrubs.

Observations on frost damages to trees and shrubs following these severe winters have been conducted employing almost the same procedure, and usually the same individuals. Thus it was possible to calculate

Table 1

Absolute minimal temperatures of air during severe winters

Year and month 1939/40	Lowest temperatures in °C
I	−28.0*
II	−31.0
III	−13.0
1955/56	
XII	−7.7
I	−22.5
II	−26.8
III	−7.8
1962/63	
XII	−18.4
I	−25.9
II	−27.1
III	−21.6
1969/70	
XII	−24.1
I	−18.2
II	−24.5
III	−10.9
1970/71	
XII	−11.9
I	−24.4
II	−10.9
III	−19.7

* Only whole numbers are given since because of the war conditions the readings may not have been every accurate

an average estimate of susceptibility to injury by frost over all these winters, for each species or variety. These observations provided a certain basis for the selection of introduced and indiginous trees and shrubs resistant to low temperatures. Average degree of frost injury to trees and shrubs in the Kórnik Arboretum over four severe winters, namely 1955/56, 1962/63, 1969/70, 1970/71 was estimated. Damage was graded according to the following scale:

1) plant undamaged,
2) flower-buds damaged,
3) damage to flower and leaf buds and also spurs,
4) one year old shoots damaged,
5) one and two-year old shoots damaged,
6) the entire plant frozen to the snow line.

This type of observations however are very time consuming and they concern only the special site conditions where the collection of woody plants under observation is located.

Basing on the studies of Wilner (1962) we have used in the years 1970/73 the method of measuring the electrical conductivity and electrical resistance (impedance) for the evaluation of trees and shrubs as regards their resistance to low temperatures (Pukacki 1973). The first proved impractical when screening large quantities of plant material. Also the use in our studies of measurements of electrical impedance with the help of Wheatstone's bridge was not satisfactory, because making hundreds of measurements each day, using the earphones, has had a tireing effect on the ears and as a result the later readings were less accurate.

Thus we have employed for our studies a Hungarian conductivity meter of the type OK 102/1 with a frequency of 80 cycles per second, produced by "Radelkis", Elektrochemische Messgeräte, Budapest II. The readings are taken directly off a scale in simens units. The scale has a range from 0.1 μS to 0.5 S. The electrical potential measured was 0.2 V. With the help of this apparatus we have evaluated the electrical admittance of one year old shoots of trees and shrubs, which have and have not been subjected to low temperatures. By comparing differences between these readings to admittance we were hoping to be able to evaluate the cold resistance of trees and shrubs growing in the Kórnik Arboretum, and later those from other parts of Poland. Since the influence of low temperatures on woody plant tissues is estimated in some European countries and particularily in USA with the help of the electrical impedance it is in order to explain here the difference between the concept of electrical admittance and electrical impedance.

Impedance is defined as the total resistance of the cells of woody plants, that is both the Ohm's resistance and capacitance (Teske 1965, Beier 1968, Hayden, Moyse, Calder et al 1969) and is expressed by the following formula:

$$\text{Impedance } Z = \frac{R}{\sqrt{1+R^2(\omega C)^2}},$$

in which R is the Ohm's resistance,

C is the capacitance,

$\omega = 2\pi f$, where f is the frequency of alternating current.

Impedance Z can be expressed as the sum of resistance R and reactance X. Its value is expressed in Ω units. The reciprocal of impedance is referred to as admittance and is obtained from the formula $Y=1/Z$ and it is measured in the units of simens, or ohm^{-1} (Cholewicki 1973).

Conductance G is the reciprocal of resistance $G=1/R$ and it is measured in the units of simens, while the reciprocal of reactance is referred to as susceptance $B=1/X$ also measured in simens.

The measurements of electrical admittance were made using special pliers equipped on one side with two nickel-plated steel needles as electrodes 0.5 mm in diameter and 3.2 mm in length. These needles were fixed in plexiglass plates at a distance of 6.8 mm apart.

The most suitable period for these investigations in our climatic zone is from the beginning of November to about the middle of the winter. At this time, most of the native plants and a majority of those recently introduced have passed through an acclimation process during the nor-

mal autumn weather. A fully dormant state of the trees under investigation is an indispensable pre-condition for the application of the electrical admittance method of investigating the winter hardiness of one-year old shoots after exposure to artificial low temperatures.
We have measured the electrical admittance in the same cutting before and after freezing. For this reason we were able to calculate the difference in admittance for each cutting. The measurement of electrical admittance of a cutting have been made in three places in the middle and on both its ends. This was aimed at determining the best point at which the measurement of electrical admittance should be made.

An adequate number of 14 cm shoots from the apices of the trees and shrubs under investigation were cut. These shoots were put into plastic bags, their cut surfaces covered with moistened lignin to prevent drying. They were then placed in the phytotron chamber at a temperature of 1°C, where they were kept for 24 hours.

Then the shoots were divided into four groups of ten shoots each. Each group was placed in moistend plastic bags and put into a hermetically closed steropian box. One box of shoots, the control, was placed in the phytotron chamber at 1°C. The other three boxes were placed in a refrigerator, where the temperature was lowered at a rate of 3°C per hour, to —25°C. Then one of the boxes was transferred to a refrigerator at the same temperature and left there for 24 hours. The temperature in the first refrigerator was lowered down to —30°C. When the temperature reached —30°C, the next box was transferred to a next refrigerator at a constant temperature of —30°C, and left there for 24 hours. In the first refrigerator, where there was still one box, the temperature was lowered during the next 24 hours to —35°C. It was left at this temperature for 24 hours, then all the refrigerators were turned off and the temperature was allowed to rise gradually over a period of 12 hours.

We introduced a modification in the presentation of the experimental data. We do not compare the direct readings of electrical admittance in cuttings after treatment with low temperatures (expressed in μS), but the differences between the admittance of each cutting made before and after it was frozen.

In our statistical analyses we have introduced certain improvements using the method of Caliński and Wagner (1974) in which the grouping of the means has been performed by minimizing the within group sum of squares.

We were interested in employing such a method which would divide our species and varieties into such groups within which the difference in electrical admittance of shoots be similar. This method of tabulating the results facilitates the comparisons with the results of observations on frost damage of trees as with the results of observations on the survival duration of plants placed in the phytotron following a treatment with low temperatures.

To determine the best position on the cutting for the measurement of admittance in one-year old shoots before and after freezing we have employed the method of contrasts (Elandt 1964) in evaluating the results.

The use of more accurate statistical methods when sorting out the data from that period was also associated with the necessity of analysing the results in greater detail particularily in the cases when the results were close for various species or variaties in the same genus. These calculations were performed on a Polish computer Odra 1204.

THE VISUAL METHOD OF ESTIMATING DAMAGE TO CUTTINGS BY LOW TEMPERATURES ON THE BASIS OF TISSUE DISCOLORATION

The degree of tissue damage after exposure to low temperatures was estimated visually in this research as a control on the results of measurements of the electrical admittance. These observations included the discoloration of the tissue, which is taken to be an indication of the total decay of the cutting. The number of days after freezing when the first discoloration occurred was recorded. These observations were made in a phytotron chamber at a temperature of 25°C and a relative humidity of 75%, with a daylength of 12 hours. The experiment was performed under sterile conditions. The plant cuttings were placed in plastic flower-pots in sand sterilized by a quartz lamp, in a phytotron chamber irradiated for 30 minutes by a quartz lamp before each experiment. Before the cuttings were put into the flower-pots in damp sand, the lower 1 cm of each was cut off. The cuttings were watered with distilled water.

Observations were made at three-day intervals for 21 do 30 days; changes in the colour of the cutting tissues were checked by inicisions. Control cuttings provided the pattern for color changes. Those plant cuttings whose tissues had turned yellow or brown were considered inanimate. After the observations were finished, the average number of days the cuttings retained green tissue was calculated. The numbers shown in the tables for this experiment are averages for 10 cuttings, graded on the following scale: 1 — 0 - 4 days, 2 — 5 - 8 days, 3 — 9 - 12 days, 4 — 13 - 16 days, 5 — 16 days and above.

THE DETERMINATION OF THE WATER CONTENT OF CUTTINGS

Several expiremnts were run in order to investigate the influence of the water content of a cutting on its sensitivity to low temperatures. Five cuttings 10 - 14 cm long were taken for each analysis. These cuttings were dehydrated to a constant weight at a temperature of 105°C in drying apparatus for one week.

METHODS OF PREPARING PLANT CUTTINGS GATHERED FROM THE COUNTRY AND INTENDED FOR EXAMINATION IN THE KÓRNIK LABORATORY ON RESISTANCE TO LOW TEMPERATURES

During the season of investigations, lasting from about the middle of October to the end of December in 1971, and including March, 1972, plant cuttings were gathered from field specimens which our visual evaluations had suggested as particularly resistant to frost. Most of the experimental material was collected from mother trees. In collecting these shoots, attention was paid to the selection of shoots representative of each individual plant.

The cuttings were put into damp plastic bags, then placed in 15-liter thermal containers with ice, to secure them adjustment conditions in all cases during the transportation by car, which lasted several days. When the materials arrived at the Kórnik laboratory for examination, the cuttings were wrapped in damp lignin and placed in plastic bags, where they were stored for one week at a temperature of 1°C. The plant cuttings were kept in the phytotron in order that the measurement of their electrical admittance before and after freezing be made at the same temperature and humidity. After the cuttings were removed from the phytotron chamber they were divided into four groups of 10 cuttings each for tests of frost resistance as described above.

RESULTS

With the help of the statistical analyses we have grouped the individuals on the basis of the electrical admittance difference (table 2). In the table we have also shown the survival duration and the water content of the shoots.

The *Viburnum* shrubs are relatively resistant to our climatic conditions, which is indicated by the large group of species and varieties that are to be found in the first group, that is the one having the lowest admittance difference. Among the most susceptible *Viburnum* varieties as evidenced by injury during severe winters and the high electrical admittance difference, there are *Viburnum dasyanthum* and to a lesser extent *V. sieboldii* and *V. fragrans*.

A high degree of correlation was observed at the studied temperatures between the difference in electrical admittance and the frost damage of *Viburnum* varieties as observed over the years in Kórnik Arboretum.

Table 3 (4, 5) presents correlation coefficients for the cubic and quadratic regression and linear correlation coefficients for the linear regression. The significance of the correlation coefficient for linear regression as well as the F-test of significance, confirmed the relation between the differences in electrical admittance of shoots exposed to −25°C and −35°C and the average damage to individuals in the Kórnik Arboretum

Table 2

Mean value of electrical admittance in shoots from *Viburnum* growing in the Kórnik Arboretum subjected to the action of low temperatures as related to their water content, observations on the damage to tissues in laboratory conditions and data of their mean susceptibility to injury during severe winters

Inventory No.	Variety	Mean injury over 4 severe winters	Differences in electrical admittance before and after freezing and hardiness group						Survival duration of shoots after freezing						Moisture content % of fresh wt.
			−25°C		−30°C		−35°C		−25°C		−30°C		−35°C		
			group	diff.	group	diff.	group	diff.	re	days	re	days	re	days	
10078	*V. americanum*	3.5		2.6		6.1		2.5	5	28	5	28	3	12	55.19
7316	*V. microphyllum*	1.0		2.5		5.1		4.2	4	15	5	18	3	11	51.70
5885	*V. veitchii*	1.0		2.7		5.5		7.8	5	28	3	12	3	8	55.19
213	*V. lantana*	1.0		3.8		4.5		4.8	5	28	5	20	4	14	56.48
2616	*V. prunifolium*	2.7		1.7		6.4		8.1	5	28	5	22	3	12	56.74
6645	*V. panciflorum*	1.6		3.6		6.6		8.0	5	28	5	28	2	5	56.01
2772	*V. lentago*	1.0		3.5		7.8		9.0	4	15	4	15	4	13	48.75
2771	*V. dentatum*	2.5		4.0		6.2		10.2	5	18	3	12	2	5	55.28
8892	*V. carlesii*	1.0		4.0		6.7	I	11.9	2	8	2	5	2	5	51.61
1983	*V. scabrellum*	2.5	I	2.9	I	6.0		15.0	5	28	3	12	2	5	55.18
2605	*V. opulus*	1.7		2.9		10.5		11.9	3	12	2	5	2	5	53.16
5882	*V. burejaeticum*	1.0		1.0		5.0		12.6	5	25	3	11	3	10	55.46
5272	*V. bitchiuense*	2.2		4.4		8.7		17.2	4	14	2	5	1	0	48.54
3896	*V. ×kurnicense*	2.6		3.5		8.1		19.2	4	13	3	12	1	0	53.18
6348	*V. orientale*	1.0		4.2		10.9		18.7	3	10	2	5	1	3	56.24
5146	*V. sargentii*	2.0		6.5		12.5		21.2	3	12	3	12	3	12	54.51
3894	*V. zamoyskianum*	2.0		3.8		10.9		31.0	4	15	2	5	1	0	52.68
2621	*V. tomentosum*	3.5		5.8		12.8		28.3	5	16	1	0	1	0	57.89
7460	*V. burkwoodii*	4.0		7.6		22.2		33.2	3	8	1	0	1	0	51.40
2619	*V. sargentii*	2.0		7.6		18.3	II	47.1	2	5	1	4	1	0	56.79
8971	*V. lantanophyllum*	3.0		5.5		15.5	III	54.5	4	15	2	5	1	0	69.67
2619	*V. sargentii*	2.0		11.8	II	28.9	I	39.5	2	6	1	4	1	0	57.50
5278	*V. fragrans*	4.0	II	11.1	I	6.8	IV	67.2	2	5	2	5	1	0	55.44
5288	*V. setigerum*	3.5	I	9.2	III	37.5		56.3	2	5	1	0	1	0	56.01
5279	*V. fragrans*	4.0	IV	18.2	V	52.1	III	60.0	2	7	2	8	1	0	57.29
8969	*V. dasyantum*	4.7	V	26.8		50.2		55.3	1	0	1	0	1	0	57.48
7461	*V. sieboldii*	3.7	III	15.1	IV	44.4	V	89.7	1	0	1	0	1	0	56.86

Table 3

Regression coefficient and *F* − test for difference in electrical admittance and freezing injury during severe winters in shoots of *Viburnum* species

Regression curve	Effect	Correlation coefficient			*F* − test			Level of significance		
		−25°C	−30°C	−35°C	−25°C	−30°C	−35°C	−25°C	−30°C	−35°C
Cubic	linear	0.87	0.71	0.68	44.45	19.05	19.79	0.00001	0.0002	0.0002
	quadratic				17.83	3.44	0.28	0.0003	0.07	0.6
	cubic				10.93	1.09	0.03	0.003	0.3	0.9
Quadratic	linear	0.80	0.69	0.68	31.43	18.98	20.62	0.00001	0.0002	0.0001
	quadratic				12.61	3.43	0.30	0.002	0.08	0.6
Linear	linear	0.67	0.63	0.67	21.46	17.30	21.22	0.0001	0.0003	0.0001

Table 4

Regression coefficient and F – test for survival duration and difference in electrical admittance in shoots of *Viburnum* species

Regression curve	Effect	Correlation coefficient			F – test			Level of significance		
		–25°C	–30°C	–35°C	–25°C	–30°C	–35°C	–25°C	–30°C	–35°C
Cubic	linear				33.74	0.52	38.00	0.00001	0.5	0.00001
	quadratic	0.81	0.30	0.84	9.25	0.75	13.19	0.006	0.4	0.001
	cubic				2.62	1.08	4.00	0.1	0.3	0.06
Quadratic	linear	0.79	0.21	0.80	31.60	0.52	33.78	0.00001	0.5	0.00001
	quadratic				8.68	0.75	11.72	0.007	0.4	0.002
Linear	linear	0.70	0.14	0.69	24.18	0.52	23.64	0.00005	0.5	0.00005

Table 5

Regression coefficient and F – test for difference in electrical admittance and moisture content, of *Viburnum* species shoots

Regression curve	Effect	Correlation coefficient			F – test			Level of significance		
		–25°C	–30°C	–35°C	–25°C	–30°C	–35°C	–25°C	–30°C	–35°C
Cubic	linear				1.87	2.17	5.34	0.2	0.1	0.03
	quadratic	0.52	0.50	0.48	1.89	1.45	0.18	0.2	0.2	0.7
	cubic				5.00	4.21	1.56	0.03	0.05	0.2
Quadratic	linear	0.34	0.34	0.42	1.60	1.91	5.22	0.2	0.2	0.03
	quadratic				1.61	1.28	0.17	0.2	0.3	0.7
Linear	linear	0.24	0.26	0.42	1.56	1.89	5.4	0.2	0.2	0.03

Table 6

F values from variance analysis including selected contrasts, for electrical admittance difference in *Viburnum* shoots

Source of variation	Degree of freedom	F		
		–25°C	–30°C	–35°C
V	26	12.00**	30.00**	16.32**
P	2	2.91	3.45*	0.75
C_1	1	5.82**	0.00	1.41
C_2	1	0.00	6.89**	0.08
$V \times P$	52	0.97	1.67	1.46
$C_1 \times A$	26	1.03	1.08	1.91**
$C_2 \times A$	26	0.92	2.26**	1.00

V – varieties, P – testing position on shoot (apex – A, mid-point – M, base – B) C_1 – contrast A/B, C_2 – contrast $2M/A+B$.

* – significant at 0.05 level,

** – significant at 0.01 level.

during severe winters. This statistical analysis also presents a high correlation coefficient for the curvilinear regression and high F – test of significance for linear effect of cubic regression.

The significance of the linear effect in the quadratic regression for the dependence of these variables was also high. Calculation of the curvilinear correlation coefficient showed that the relation between the differences in electrical admittance and the survival duration of the frozen shoots to a temperature of -25°C and -35°C was significant (table 4).

No relation was found between the water content in the shoots of *Viburnum* and the admittance difference (table 5).

The analysis of variance of the results was performed using orthogonal contrasts (table 6) in order to study the interaction between the point of measurement of the electrical admittance on the cuttings (measured before and after freezing to three temperatures) and the *Viburnum* species. *V.* — refers to the species of *Viburnum*, *P* — to the site of admittance measurements on a shoot, C_1 — is the contrast of cutting base with the cutting apex and C_2 — is the contrast 2 $\times$ mid-point against the sum of the base and the apex.

DISCUSSION

Many authors, who have sought laboratory methods of determining the resistance of trees and shrubs to low temperatures have been comparing the obtained results with the observations made on the subject in the field conditions. This was done by Wilner (1967) when evaluating the usefulness of various methods for the study of resistance to low temperatures of apple varieties Antonówka, Northern Spy and Mc Intosh characterized by a considerable scale of resistance to low temperatures. Also Schönbach and Bellman (1967) was comparing the resistance to low temperatures of a susceptible green Douglas fir with the more resistant blue variety.

In our studies on the effect of low temperatures on trees and shrubs we have used the observations of winter injuries that have been made in the Kórnik Arboretum after 5 or four severe winters that we had in the years 1939 - 1972. We have observed the winter injuries to introduced trees and shrubs in the Kórnik Arboretum from the following genera: *Malus, Magnolia, Ilex, Viburnum* and others covering several hundreds of individuals from various species and varieties. It appears that to-date such extensive comparisons of the results of laboratory observations with the field observations on damage by low temperatures to trees and shrubs have not been undertaken.

Over the 17 years of observations in the Kórnik Arboretum the most resistant to winter injury under extreme conditions (table 2) were the following species: *Viburnum lantana, V. lentago, V. microphyllum, V. veitchii, V. carlesii, V. burejaeticum* and *V. orientale,* which have not been damaged during severe winters.

A very high resistance to frost is shown also by the following species of *Viburnum*: *V. opulus, V. pauciflorum.* Intermediate values of resistance to injury during severe winters with an index value between 2-3.4 is shown by several species of *Viburnum* listed in table 2.

Results of statistical analyses of the difference in electrical admittance and of the observations conducted over many years in the Kórnik Arboretum were to clarify the most important question from the point of view of plant introduction, namely to what extent the observations conducted following severe winters in the climatic conditions of Kórnik Arboretum were reproduced by the laboratory investigations.

For the purpose a variance analysis was performed, with the help of which the studied species of *Viburnum* were divided into 5 groups depending on the basis of the value of the difference of electrical admittance (table 2). From the data it can be seen that in the first group one can find the *Viburnum* species most resistant to winter injury as judged from the observations in the Kórnik Arboretum and having the lowest value of the difference in electrical admittance and longest period of survival following freezing in the phytotron. On the other hand the most susceptible species, as well as those having the highest values of the difference in the electrical admittance are to be found in the fourth and fifth groups.

In view of the fact that the relations between F values from the variance analysis, including the contrast for electrical admittance differences in *Viburnum* shoots are very complicated, it seems most appropriate to make measurements of the difference at all the three points on the cuttings, namely at the base, in the middle and at the top.

CONCLUSIONS

As a result of studies of the effect of low temperatures on the electrical conductance of frozen shoots of various *Viburnum* species the following relationships were established:

1. A high degree of correlation between the effect of low temperatures on the shoots of various species from the genus *Viburnum* and the electrical admittance.

2. A high degree of correlation between observations on winter injury to Viburnum shrubs following several severe winters and the difference in electrical admittance of shoots subjected to various low temperatures.

3. There exists the possibility of employing the described method for the screening of many *Viburnum* individuals for their resistance to low temperatures.

4. Regardless of the site of measurement of admittance on the cutting, the properties of the studied species in response to low temperatures are alike. Only in the case of measuring admittance difference following freezing at —30°C is the position of measurement on the cutting of importance.

5. The values of the calculated contrast C_1 is only significant for the −25°C and C_2 only for temperature −30°C, thus for other temperatures

the conductance was not dependent on the position of measurement on a shoot.

6. Lack of $V \times P$ interaction indicates that the measurement of electrical admittance in different species of *Viburnum* is independent of the position of making the measurement on the cutting. On the other hand the interaction $C_1 \times V$ indicates that it is only significant at the temperature $-35°C$ which signifies that under the influence of this temperature probably far going changes took place in the *Viburnum* shoots, which have resulted in a disapperance of their typical biological reactions. For other temperatures this interaction is not significant. We also obtained a significant value for the interaction $C_2 \times V$ at a temperature of $-30°C$ which indicated that there is a relation between site of electrical admittance measurement and the physiological properties of cuttings of different varieties.

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STEFAN BIAŁOBOK I PAWEŁ PUKACKI

Zależność między admitancją elektryczną pędów a odpornością na niskie temperatury krzewów z rodzaju Viburnum

Streszczenie

Stopień odporności na niskie temperatury krzewów z rodzaju Viburnum określano metodą pomiaru admitancji elektrycznej (odwrotność impedancji). Badania te przeprowadzano na trzydziestu osobnikach kalin rosnących w Arboretum Kórnickim.

Stwierdzono, że różnice admitancji elektrycznej pędów obliczone z wartości otrzymanych z pomiarów przed i po ich przemrożeniu są odwrotnie proporcjonalne do odporności kalin na niskie temperatury. Najsilniejsze zróżnicowanie w odporności kalin nastąpiło po przemrożeniu pędów w temperaturze —30 i —35°C.

Wyniki pomiarów admitancji elektrycznej wykazały istotną ujemną korelację z długością zachowania zdrowotności przemrożonych tkanek pędów umieszczonych w fitotronie. Przemrożone pędy osobników odpornych posiadały niskie wartości różnicy admitancji elektrycznej oraz długi okres niewystępowania zmian nekrotycznych pędów. Nie stwierdzono też istotnej zależności między miejscem pomiaru na pędzie a różnicą admitancji elektrycznej.

Najbardziej odpornymi kalinami na działanie niskich temperatur okazały się: Viburnum lantana, V.lentago, V.microphyllum, V.veitchi, V.carlesii, V.burejaeticum oraz V.orientale.