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STEFAN BIAŁOBOK, HENRYK CHYLARECKI, PAWEŁ PUKACKI

Studies on the resistance of forsythias to low temperatures*

The interest in Poland in the breeding of forsythias (Suszka, 1959, 1965; Seneta, 1973) is associated with the high decorative value of these plants but also with the high sensitivity to low temperatures, in the eastern and northeastern parts of the country. For this reason search for quick laboratory methods of evaluating the frost resistance of the introduced species and variaties of these shrubs as well as of those new forsythia hybrids that have been raised for their high decorative value is necessary to facilite selection of forms that could be cultivated throughout the country.

Popularization of the methods of evaluating the resistance of woody plants to low temperatures with the help of the estimation of electrical conductivity and electrical resistance (impedance) of one-year old shoots has been achieved by Wilner (1962, 1970 in his work on fruit trees and ornamental shrubs. As was shown by Wilner (1962) the measurement of electrical impedance in one year old shoots of trees and shrubs permits an estimation of their resistance to low temperatures, even with respect to individuals already growing in the field.

MATERIALS AND METHODS

In Kórnik Arboretum observations were being made on resistance of shrubs to winter injury following the five severe winters 1939/40, 1955/56, 1962/63, 1969/70 and 1970/71. The absolute minimal temperatures during these severe winters in Kórnik were respectively −31.0°C, −26.8°C, −27.1°C, −24.5°C and −24.4°C. A more accurate description of the weather conditions during these winters has been presented in the paper of Białobok and Pukacki (1974). Here we give only very general informations on the subject.

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 an average estimate of

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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 five severe winters, 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 alsc 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 observations is located.

Thus we have employed for our studies of cold resistance a Hungarian conductivity meter of the type OK 102/1 with a frequency of 80 cycles per second, produced by „Radelkis", Elektrochemische Messgerate, Budapest II. The readings are taken directly off a scale in S (ohm^{-1}) 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.

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 electrical admittance of each cutting was measured at the top, middle, and bottom of each shoot. The temperature of shoots during measurements was 19° - 21°C.

By comparing differences between these readings of admittance we were hoping to be able to evaluate the cold resistance of 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 conductance and electrical impedance. Impedance Z can be expressed as the sum of resistance R and reactance X:

$$Z = R+X$$

Its value is expressed in ohm units. The reciprocal of impedance is referred to as admittance and is obtained from the formula $Y = \frac{1}{Z}$ and it is measured in the units of simens (Cholewicki, 1973).

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

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 normal 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. Forsythia shoots growing in the Kórnik Arboretum have been collected on the 7th of February 1972 and the forsythias growing in other parts of the country on the 1st - 3rd December 1971.

Forty shoots, each 14 cm long were cut from the apices of the trees and shrubs under investigation. Then the shoots were divided into four groups of ten shoots each. 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. Each group of shoots was placed in moistened plastic bags and put into a hermentically closed steropian box. The cuttings were frozen in refrigerators, in lots of 10, at temperatures of −25°C, −30°C and −35°C, while the rate of temperature drop was maintained at 3°C per hour. Control cuttings were held at a temperature of 1°C. The cuttings were maintained in the said temperatures for 24 hours after which they were defrosted slowly over 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 cuttings made before and after it was frozen. It appears that this method of evaluating the degree of tissue damage by low temperatures is very useful for these studies.

Several experiments were run in order to investigate the influence of the water content of a cutting on its sensitivity to the electrical current. The visual method of estimating damage to cutting by low temperatures was employed.

The not frozen control cuttings have been moved to the phytotron to a temperature of 25°C and 75% of relative humidity with a 12 hour day-length, positioning each one into a plastic flower pot with sand sterilized under a quartz lamp.

Observations were made at three-day intervals for 21 to 30 days; changes in the colour of the cuttings tissues were checked by incisions. 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.

STATISTICAL CALCULATIONS

As large quantities of data were collected during our investigations of species and varieties of trees and shrubs resistant to low temperatures, statistical analysis was necessary to determine the significance of the effects obtained. This was particularly necessary because of the varying origins of our plant material, which introduced another discriminating factor.

On the basis of our results the following statistical calculations were made:

1. Linear, quadratic and cubic regressions of: A) the average differences in electrical admittance of shoots frozen at three temperatures on the average degree of damage by frost to trees and shrubs in the Kórnik Arboretum during severe winters; B) the average length of the period during which shoot damage did not appear after exposure to three different temperatures (survival duration) on average degree of damage to individuals during severe winters; C) the average differences in electrical admittance of shoots frozen at three temperatures on the length of the period during which no sign of tissue damage appeared (survival duration).

2. Multiple regressions of the difference in electrical admittance before and after freezing on the average degree of damage in the Kórnik Arboretum during severe winters and on the water content.

3. Correlation coefficients.
4. The F tests for significance of the linear, quadratic, and cubic regressions were also calculated.
5. Where presenting the results use was made of the average from the 10 cuttings.

At present, statistical calculations are being conducted for the purpose of selecting those shrubs and trees in Kórnik Arboretum and in other places in Poland which are most resistant to low temperatures.

These calculations are being performed on a Polish computer Odra 1204.

RESULTS

The results of statistical analysis on the measurement of electrical admittance of forsythia shoots are presented in table 1. This table presents the results of several years of observations of damages to forsythias during severe winters in the Kórnik Arboretum, the results of measurements of electrical admittance and the indices of survival of shoots after freezing. From the values in this table, it can be seen that in general high frost resistance of forsythias growing in the Kórnik Arboretum corresponds to small differences in the electrical admittance of shoots and a long survival period of shoots after freezing. For hybrids produced in the Institute of Dendrology in Kórnik, by doc. dr. B. Suszka, only the measurements on the admittance of the shoots and the period of survival after freezing are included.

The forsythias most resistant to low temperatures as can be seen from the data presented in Table 1 are: *Forsythia ovata* no. 4778 from the Forest Experiment Station in Korea, *F. japonica saxatilis* no. 10518 obtained from Kew Garden and *F. japonica* no. 7549 also obtained from Kew Garden. These shrubs have low differences in the electrical admittance, and *F. japonica* and *F. japonica saxatilis* have the longest survivals of the cuttings after being subjected to the action of low temperatures.

Differences in electrical admittance of the known forsythia cultivars are much greater for the studied temperatures than of the hybrids bred in Kórnik. This clearly indicates that the former are less resistant to low temperatures than the latter. Also the survival duration of the frozen shoots of forsythia cultivars is shorter than that of the individuals bred in Kórnik.

Anatomical studies of the cortex, cambium and pith (Tab. 4) following injury by low temperatures indicated that the Kórnik varieties have generally more resistant tissues than the ones already known in cultivation. In some cases the cambium is more sensitive to low temperatures than the bark. However, in the studied forsythias it was frequently found that the bark is more resistant than the pith.

Further results of the statistical evaluations presented in Tables 2

Table 1

Mean values of electrical admittance (in μS) in shoots from forsythia 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 on their mean susceptibility to injury during severe winters

Inventory No.	Variety and hybrids	Mean injury over 5 severe winters	Diff. in electrical admittance before and after freezing			Survival duration after freezing			Moisture content % of fresh wt.
			−25°C	−30°C	−35°C	−25°C	−30°C	−35°C	
1	2	3	4	5	6	7	8	9	10
4778	*F. ovata*	1.2	2.5	6.2	6.6	5	1	1	50.1
7549	*F. japonica*	3.4	1.1	3.9	15.8	5	2	1	53.9
1078	*F. viridissima v. koreana*	4.0	0.7	6.4	10.6	4	1	1	54.6
7748	*F. giraldiana*	4.0	2.6	10.7	14.4	4	1	1	57.0
2488	*F. 'Variegata'*	4.2	6.3	8.3	10.6	2	1	1	53.8
2489	*F. suspensa v. sieboldii*	4.2	5.9	10.6	14.6	1	1	1	52.6
8430	*F.* × *intermedia*	4.2	2.2	7.8	13.2	5	1	1	52.1
2485	*F. 'Primulina'*	4.2	3.0	10.1	9.1	5	1	1	54.9
2484	*F. 'Densiflora'*	4.2	0.8	6.5	9.6	5	1	1	55.8
2486	*F. 'Vitellina'*	4.2	2.6	13.4	12.1	4	1	1	58.5
10518	*F. japonica var. saxatilis*	–	2.1	1.5	1.8	2	3	2	52.4
	F. H.-203-17	–	0.2	1.4	2.1	5	3	1	47.8
	F. H.-145-1	–	2.0	1.6	4.4	3	3	1	54.5
	F. H.-205-11	–	1.7	3.1	3.6	4	3	1	53.9
	F. H.-204-46	–	1.5	3.3	4.3	5	1	1	50.5
	F. H.-86-94	–	0.0	4.2	5.2	2	1	1	54,1
	F. H.-205-12	–	2.4	3.8	3.8	2	3	1	57.4
	F. H.-142-4	–	0.6	4.4	5.3	3	3	1	01.5
	F. H.-86-90	–	1.3	4.6	4.6	5	1	1	54.1
	F. 'Maluch' H.-87-60	–	3.5	3.8	4.1	2	3	1	53.7
	F. H.-91-1	–	2.6	3.7	5.4	1	1	1	51.2
	F. H.-86-71	–	3.4	3.2	6.8	3	3	1	55.2
	F. H.-86-100	–	2.1	6.9	5.9	4	1	1	56.2
	F. H.-144-1	–	0.6	7.1	7.4	5	1	1	52.7
	F. H.-94-1	–	2.3	5.2	8.1	3	1	1	53.6
	F. H.-89-3	–	0.5	5.3	9.9	5	5	3	56.5
12269	*F. 'Lynwood'*	–	4.3	19.3	10.6	5	1	1	54.6
12268	*F. 'Spring Glory'*	–	22.0	16.9	–	5	1	1	51.0

and 3 concern only species and varieties known in cultivation, since only for these we had a full documentation of the observations. For the studies on the resistance to low temperatures of the known varieties of forsythias, a freezing temperature of −30°C (Tab. 1, 2) appeared to be most characteristic. A temperature of −25° is still too high for an evaluation of the resistance, while a temperature of −35°C is too low for the varieties long under cultivation in the Kórnik Arboretum. However the temperature of −35°C (Tab. 1) proved satisfactory for the evaluation of resistance of the Kórnik bred hybrids to low temperatures as well as for the species *Forsythia ovata*.

The relation was estimated between the difference in electrical admittance in one year old shoots of forsythias measured in the laboratory and the mean degree of injury to these shrubs growing in the Kórnik Arboretum during several severe winters (A). Significance of this relationship

Table 2

Regression coefficients and *F*-test for difference in electrical admittance, survival duration and injury during severe winters in shoots of *Forsythia* species

	Regression	Correlation coefficient −25°C	−30°C	−35°C	*F*−test −25°C	−30°C	−35°C	$F_{0.05}$	$F_{0.01}$
					1) 0.19	1.95	3.31	5.99	13.7
	Cubic	0.24	0.44	0.59	2) 1.35	2.74	5.39		
					3) 0.40	0.14	0.06		
					1) 0.21	2.22	3.82	5.59	12.2
A	Quadratic	0.19	0.43	0.59$^{\times}$	2) 1.47	3.12	6.22$^{\times}$		
	Linear	0.16	0.42	0.47	1) 0.20	1.75	2.31	5.32	11.2
					1) 0.71	–	–	5.99	13.7
	Cubic	0.15	–	–	2) 0.33	–	–		
					3) 0.00	–	–		
					1) 0.82	0.85	–	5.59	12.2
B	Quadratic	0.15	0.83$^{\times\times}$	–	2) 0.38	34.65$^{\times\times}$	–		
	Linear	−0.32	−0·14	–	1) 0.89	0.16	–	5.32	11.2
					1) 5.59$^{\times}$	8.98$^{\times\times}$	0.03	4.28	7.88
	Cubic	0.22	0.35$^{\times}$	0.09	2) 1.02	3.36	2.50		
					3) 0.07	0.02	0.00		
					1) 5.82$^{\times}$	9.36$^{\times\times}$	0.04	4.26	7.82
C	Quadratic	0.22$^{\times}$	0.35$^{\times\times}$	0.09	2) 1.06	3.50	2.61		
	Linear	−0.43$^{\times}$	−0.50$^{\times\times}$	−0.04	1) 5.80$^{\times}$	8.58$^{\times\times}$	0.03	4.24	7.77

ABC – explanation in the methodical part 1) – linear effect, 2 – quadratic effect, 3) – cubic effect
$^{\times\times}$ – significant at 0.01 level, $^{\times}$ – significant at 0.05 level

Table 3

Regression coefficients and *F*-test for difference in electrical admittance and survival duration of *Forsythia* species shoots

Regression	Correlation coefficient −25°C	−30°C	−35°C	*F*−test −25°C	−30°C	−35°C	$F_{0.05}$	$F_{0.01}$
				1) 85.00$^{\times\times}$	0.0	0.0	5.32	11.26
Cubic	0.913$^{\times\times}$	–	–	2) 0.0	0.0	0.0		
				3) 0.0	0.0	0.0		
Quadratic	0.913$^{\times\times}$	–	–	1) 0.0	0.0	0.0	5.12	10.56
				2) 0.0	0.0	0.0		
Linear	−0.956$^{\times\times}$	0.224	–	1) 106.25$^{\times\times}$	0.531	0.0	4.96	10.04

1) linear effect, 2) quadratic effect, 3) cubic effect
$^{\times\times}$ significant at 0.01 level, $^{\times}$ significant at 0.05 level

was established only in the case of quadratic regression for the freezing treatment with −35°C.

The next calculated relationship (B) was between the survival duration (the time during which there were no visible necrotic colour changes in tissues of shoots that have been freeze treated) and the mean degree of injury to shrubs growing in the Kórnik Arboretum during several severe winters. A significant value of this relation was only obtained in the case of quadratic regression for the freezing treatment with −30°C.

Relationship (C), between the difference in electrical admittance of shoots and the survival duration (time during which no necrotic colour changes were observed in tissues) following freezing of the shoots in a

Table 4

Mean values of electrical admittance (in μS) in shoots from forsythia shrubs growing in the Kórnik Arboretum subjected to the action of low temperatures, as related to observations on the damage to tissues in laboratory conditions

Inventory No.	Variety and hybrids	Diff. in electrical admittance before and after freezing			Freezing resistance [°C]		
		−25°C	−30°C	−35°C	Cortex	Cambium	Pith
1	2	3	4	5	6	7	8
10518	*F. japonica var. saxatilis*	2.1	1.5	1.8	−35	−30	−35×
4778	*F. ovata*	2.5	6.2	6.6	−30×	−25	−25
2484	*F. 'Densiflora'*	0.8	6.5	9.6	−30	−25	−25
7549	*F. japonica*	1.1	3.9	15.8	−30	−25	−30
2485	*F. 'Primulina'*	3.0	10.1	9.1	−25	−25	−25
2486	*F. 'Vitellina'*	2.6	13.4	12.1	−25	−25	−25×
2489	*F. suspensa v. Sieboldii*	5.9	10.6	14.6	−25	−25ª	−25
12269	*F. 'Lynwood'*	4.3	19.3	10.6	−25	−25	−25
12268	*F. 'Spring Glory'*	22.0	16.9	—	−25	−25	−25
	F.H.-203-17	0.2	1.4	2.1	−35	−35×	−30×
	F.H.-145-1	2.0	1.6	4.4	−30	−30×	−30
	F.H.-205-11	1.7	3.1	3.6	−35	−30×	−35×
	F.H.-204-46	1.5	3.3	4.3	−35	−30×	−30×
	F.H.-205-12	2.4	3.8	3.8	−35	−25	−35
	F.H.-142-4	0.6	4.4	5.3	−35	−30×	−25
	F.H.-86-90	1.3	4.6	4.6	−30×	−30×	−30
	F.H.-87-60	3.5	3.8	4.1	−35	−30×	−35×
	F.H.-91-1	2.6	3.7	5.4	−35	−25	−25
	F.H.-86-71	3.4	3.2	6.8	−35	−30	−30
	F.H.-86-100	2.1	6.9	5.9	−35×	−30×	−30
	F.H.-144-1	0.6	7.1	7.4	−30×	−30×	−30×
	F.H.-94-1	2.3	5.2	8.1	−35×	−30×	−30×
	F.H.-89-3	0.5	5.3	9.9	−35	−30	−35×

× – partly injured
ª – complete injured

refrigerator, is significant: 1) for the linear effect of the cubic regression at a temperature treatment of −30°C, 2) for the linear effect of the quadratic regression at temperature treatments of −25°C and −30°C and 3) for the linear regression at temperature treatments of −25°C and −30°C.

Multiple regressions were analysed for the three variables: differences in admittance, dependent variable (1), frost damage in the Arboretum, independent variable (2), and water content, dependent variable (3). Only the multiple correlation coefficient R was significant for the three temperatures examined (Tab. 5).

Table 5

Coefficients of multiple regression of the difference in electrical admittance (1), on the mean injury during winter freezing (2) and the moisture content (3) in *Forsythia* species shoots

Temperature °C	R	$r_{23.1}$	$r_{12.3}$	$r_{31.2}$
−25	0.8633××	0.6579	0.3604	−0.3802
−30	0.9677××	0.4909	0.1445	0.3970
−35	0.9796××	0.5674	0.4152	−0.0451

×× – significant at 0.01 level
× – significant at 0.05 level

Table 6

Mean values of electrical admittance (in μS) in shoots from forsythia from Poland subjected to the action of low temperatures, as related to their water content and observations on the damage to tissues in laboratory conditions

Date of shoots collecting Nov. 28 – Dec. 2, 1971

Variety		Place	Diff. in electrical admittance before and after freezing			Survival duration of shoots after freezing			Moisture content % of fresh wt.
			−25°C	−30°C	−35°C	−25°C	−30°C	−35°C	
1		2	3	4	5	6	7	8	9
F. sp.	(1)	Ciechocinek	2.7	8.7	31.7	5	1	1	58.8
F. sp.		Toruń	3.0	15.0	31.7	5	1	1	57.6
F. sp.	(1)	Bydgoszcz	2.0	19.2	41.8	5	1	1	56.8
F. sp.	(2)	Ciechocinek	3.0	27.5	55.9	5	1	1	60.7
F. sp.	(1)	Inowrocław	3.0	16.5	35.2	5	1	1	58.5
F. sp.	(3)	Ciechocinek	2.9	17.7	40.0	5	1	1	59.8
F. sp.	(2)	Inowrocław	5.7	19.2	36.7	5	1	1	58.7
F. suspensa		Bydgoszcz	3.1	22.1	36.6	5	1	1	62.1
F. sp.	(3)	Inowrocław	4.5	22.0	39.2	5	1	1	61.1
F. sp.	(2)	Bydgoszcz	10.9	27.4	97.4	4	1	1	60.4
F. sp.	(4)	Inowrocław	11.8	23.3	53.0	4	3	1	60.2
F. sp.	(3)	Bydgoszcz	3.1	13.3	31.1	5	1	1	59.9

Most commonly cultivated in Poland are the attractive varieties of *F. intermedia 'Vitellina', 'Primulina', 'Densiflora'* and *'Spectabilis'*. These are characterized however by susceptibility to frost which is indicated by the serious damages primarily to flowers buds, 60 - 100% of which have been affected, and to one year old shoots as well as to some older ones. These damages were most severe in the regions of Warsaw, Białystok, Kraków and Poznań. Of the 309 specimens of this species under observation only 22 (7%) have not suffered winter injury. The most valuable specimens for us have been selected in Warsaw and Poznań.

Also common in various parts of the country are susceptible varieties of *F. suspensa* var. *sieboldii* and var. *fortunei*, in which a similar though perhaps not so severe a frost damage to flower buds has been observed. Within these varieties note was also taken of the several frost resistant specimens from the collection of the Botanical Garden in Warsaw.

Within the group of *Forsythia sp.* the most valuable ones are 60-year old, very viable and luxuriant shrubs of forsythia found in the park around a monastry in southeastern Poland, in Jarosław and in the castle park in Przemyśl. These are adapted to the severe winter conditions typical for this part of the country and have not had any sings of winter injuries. Similarily valuable frost resistant specimens have been selected in the cold climate of northeastern Poland, in the region of Olsztyn, around the Szczytno castle.

Material for investigations was collected in parks on the lower Vistula River and in the towns (listed in Table 6). From the measurements of differences in admittance and survival duration after freezing, it is clear that all of the individuals in these parks have higher differences in admittance than the *F. ovata* growing in the Kórnik Arboretum, which means that they are less frost resistant than this *F. ovata*.

DISCUSSION

Observations on the frost injuries to forsythias conducted over 32 years represent a valuable material to be utilized when evaluating laboratory methods of estimating the effect of low temperatures on these shrubs. It appears that not only in the Kórnik Arboretum, but also throughout the country it is possible to find individuals of forsythias which are very resistant to low temperatures. These are possibly generative offspring of the species and varieties cultivated by us. This property of the shrubs has been confirmed by the laboratory tests using the difference in electrical admittance of the shoots before and after freezing.

Field observations and laboratory studies have shown that a great resistance to low temperatures is demonstrable in *Forsythia ovata*, *F. japonica* and *F. japonica* var. *saxatilis*. For this reason Suszka (1959) has used *F. ovata* in his breeding work on forsythias resistant to low temperatures. Many of the hybrid individuals he has obtained are characterized by greater resistance to low temperatures than the maternal *Forsythia ovata*. Long term studies on the possibility of cultivating these in eastern and northeastern Poland that have been conducted by Suszka have confirmed that it is possible to breed ornamental forsythia varieties more resistant than the maternal forms. In this way a possibility resulted of extending their cultivation into regions of our country where so far the shrub has not been used.

In our studies a temperature of $-30°C$ proved sufficiently selective for the forsythias so far under cultivation, however the breeding value of *Forsythia ovata* and of its hybrids bred in Kórnik is best demonstrated at a freezing temperature of $-35°C$.

The breeding of forsythia varieties resistant to low temperatures can represent only the first stage of cultivation of these shrubs. It will be the responsibility of breeders later on to increase the decorative value of these varieties while maintaining their high resistance to low temperatures.

In the case of exceptionally high resistance of *Forsythia ovata* to low temperatures, compared to other cultivars studied by us, we were obtaining significant correlations for the linear effect as well as for the quadratic effect of the quadratic regression. This result gives a simple method of utilizing the variation in the degree of resistance to low temperatures for the needs of breeding new varieties.

From the studies on the effect of low temperatures on the differences in electrical admittance of shoots subjected to the action of low temperatures we have found that within the genus *Forsythia:*

1. The species and varieties under cultivation in Kórnik Arboretum and in other parts of Poland differ substancially in cold resistance.

2. There exist in Poland numerous individuals of *Forsythia* highly resistant to low temperatures.

3. Utilization of the individuals resistant to low temperatures as maternal plants in a breeding program can lead to the selection of highly resistant hybrids.

4. The method of evaluating the electrical admittance can be successfully utilized for the screening of forsythia individuals for resistance to low temperatures.

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Institute of Dendrology
Kórnik nr. Poznań

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STEFAN BIAŁOBOK, HENRYK CHYLARECKI, PAWEŁ PUKACKI

Badania nad odpornością forsycji na niskie temperatury

Streszczenie

Forsycja należy do krzewów cenionych w Polsce. U gatunków i odmian powszechnie u nas uprawianych są uszkadzane przez mrozy, w czasie surowych zim, pędy i pączki kwiatowe, głównie w Polsce wschodniej, północno-wschodniej i środkowej. Odmiany o wysokich wartościach ozdobnych, które mogą być uprawiane na

terenie całego kraju można otrzymać przez selekcję osobników odpornych na mrozy rosnących w starych parkach i ogrodach lub przez hodowlę nowych mieszańców. We wspomnianych częściach Polski prowadzono selekcję forsycji i stwierdzono, że na 309 osobników tylko 22 nie ucierpiało od mrozów. Jako wskaźnik odporności na niskie temperatury w badaniach laboratoryjnych przyjęto pomiary admitancji elektrycznej pędów (odwrotność impedancji), którą mierzy się w simensach. Do tych pomiarów został użyty węgierski konduktometr OK 102/1. Częstość prądu pomiarowego wynosiła 80 Hz.

Jednoroczne pędy poddawano przez 24 godziny działaniu temperatur: −25°C, −30°C i −35°C. Temperaturę obniżano o 3°C na godzinę. Pędy odmrażane przez 12 godzin przenoszono do fitotronu, gdzie w ciągu 16 dni określano stopień uszkodzenia ich tkanek według skali pięciostopniowej. Jako wskaźnik odporności na niskie temperatury przyjęto różnice admitancji elektrycznej między nieprzemrożonymi a przemrożonymi pędami, co bardzo ułatwiło opracowanie wniosków w zakresie oceny tej metody do masowych badań odporności roślin drzewiastych na niskie temperatury. Decydujący wpływ na dalsze badania miało porównanie obserwacji odporności forsycji, rosnącej w Arboretum Kórnickim, na mrozy w okresie 1939-1971 r. z pomiarami admitancji.

Do najbardziej odpornych na mrozy w Arboretum Kórnickim należy *Forsythia ovata*, u której stwierdzono też małą różnicę admitancji w temperaturze −35°C. Znacznie mniejszą różnicę admitancji elektrycznej pędów jak u *F. ovata* stwierdzono u *F. japonica* var. *saxatilis*. Również *F. japonica* jest odporna na mrozy i dopiero w temperaturze −35°C pędy jej są silnie uszkadzane.

Inne gatunki i odmiany forsycji (tab. 1) okazały się nieodporne na mrozy podczas surowych zim. Stwierdzono też u nich wysoką różnicę elektrycznej admitancji nie tylko po przemrożeniu pędów w −35°C. O wysokiej odporności na niskie temperatury tych trzech forsycji świadczy dłuższy okres przeżywania przemrożonych pędów.

U kórnickich mieszańców forsycji stwierdzono na ogół mniejszą różnicę admitancji pędów niż u uprawianych w Polsce gatunków i odmian forsycji (tab. 1), co wskazuje na ich większą odporność na niskie temperatury. Również obserwacje uszkodzeń przez niskie temperatury tkanek kory, miazgi i rdzenia (tab. 4) wskazują, że mieszańce kórnickie są na ogół odporniejsze niż dotychczas znane u nas w uprawie gatunki i odmiany forsycji. Nieodporne na mrozy okazały się odmiany amerykańskie 'Lynwood' i 'Spring Glory'.

Temperatura −30°C dobrze segreguje badane forsycje (tab. 1 i 2) pod względem ich odporności na niskie temperatury, natomiast dla oceny mieszańców kórnickich bardziej odpowiednia jest temperatura −35°C. Temperatura −25°C jest za niska dla selekcji forsycji odpornej na mrozy.

Z wyników tych badań obliczono współczynniki regresji i test *F* Fishera dla: a) zależności średniej różnicy admitancji pędów w 3 temperaturach a średnim stopniem uszkodzenia krzewów przez mrozy w Arboretum, b) zależności między okresem przeżycia pędów przemrożonych a stopniem uszkodzenia krzewów w Arboretum, c) zależności między różnicą admitancji pędów a przeżywaniem przemrożonych pędów.

W poszukiwaniach forsycji odpornych na mrozy w obszarze dolnej Wisły nie znaleziono osobników mających mniejszą różnicę admitancji elektrycznej pędów niż *Forsythia ovata*.

W wyniku badań wpływu niskich temperatur na różnicę admitancji pędów forsycji należy stwierdzić, że przy pomocy tej metody można przeprowadzić selekcję osobników odpornych na mrozy. Można również rozwinąć hodowlę mieszańców forsycji odpornej na niskie temperatury i wykorzystać opisywaną metodę do szybkiej ich oceny pod względem tej cechy.

СТЕФАН БЯЛОБОК, ГЕНРЫК ХИЛЯРЕЦКИ, ПАВЕЛ ПУКАЦКИ

Исследования морозостойкости видов Forsythia

Резюме

Форзиция принадлежит к кустарникам, высоко ценнимым в Польше. У повсеместно культивируемых здесь видов и разновидностей во время суровых зим, особенно в восточной, северо-восточной и центральной Польше, побеги и цветочные почки повреждаются морозами. Формы, обладающие высокими декоративными достоинствами и приспособленные для культивирования на территории всей страны, могут быть получены путем отбора морозостойких экземпляров, растущих в старых парках и садах, или же путем селекции новых гибридов. В упомянутых районах Польши проводилась селекция форзиций и было установлено, что из 309 экземпляров только 22 не пострадало от морозов. В качестве показателя морозостойкости в лабораторных условиях вы использовали полную электропроводимость побегов (величина, обратная полному сопротивлению), определяемую в сименсах. Для измерения ее употреблялся венгерский кондуктометр ОК 102/1. Частота тока составляла 80 герцов.

Годичные побеги подвергались в течение суток воздействию температур −25°С, −30°С, −35°С. Температура снижалась на 3°С в час. После их размораживания (в течение 12 часов) побеги переносились в фитотрон, где на протяжении 16 дней определялась степень повреждения тканей по пятистепенной шкале. Показателем морозостойкости служила разность электропроводимости, определенной у промороженных и непромороженных побегов. Полученные данные облегчили оценку значения этого метода при массовом изучении устойчивости древесных растений к низким температурам. Решающее значение для дальнейших исследований имело опоставление наблюдений 1939 - 1971 гг. за морозостойкостью *Forsythia,* культивируемой в Арборетуме Курника, с измерением электропроводности.

К наиболее морозостойким растениям в условиях нашего арборетума относится *F. ovata,* у которой установлены также небольшие изменения электропроводимости под воздействием температуры −35°С. Значительно меньшие изменения электропроводимости, чем у *F. ovata,* обнаружены у *F. japonica* var. *saxatilis,* но этот вид также морозостоек и побеги у него сильно повреждаются только при −35°С.

Другие виды и разновидности *Forsythia* (табл. 1) оказались неустойчивыми к морозам суровых зим. У них выявлены большие изменения электропроводимости при промораживании побегов не только до −35°С. О высокой устойчивости к низким температурам этих трех форзиций свидетельствует большая продолжительность переживания промороженных побегов.

У курницких гибридов форзиций установлены в целом меньше различия в электропроводимости промороженных и непромороженных побегов, чем у видов и разновидностей, культивируемых в Польше (табл. 1), что указывает на их большую устойчивость к низким температурам. Наблюдения за повреждениями тканей коры, камбия и сердцевины, вызванными низкими температурами (табл. 4), также указывают, что курницкие гибриды в целом более устойчивы, чем до сих пор известные у нас в культуре виды и разновидности форзиций. Не морозостойкими оказались американские сорта 'Lynwood' и 'Spring Glory'.

Температура −30°С (Табл. 1 и 2) хорошо разделяет исследованные формы Forsythia по их устойчивости и морозу; но для курницких гибридов более пригодна температура −35°С. Температура −25°С слишком низка для проведения отбора форзиций на морозостойкость.

По результатам этих исследований вычислены коэффициенты регрессии и тест F Фишера для: а) средней разности электропроводимости побегов при трех темпе-

ратурах и среднего уровня повреждения кустарников морозом в арборетуме, б) зависимости между периодом выживания промороженных побегов и степенью повреждения кустарников в арборетуме, в) зависимости между изменениями электропроводимости и выживанием промороженных побегов.

Для этих зависимостей получена не линейная регрессия, а криволинейно-кубическая и квадратная. В поисках морозостойких форм форзиций в районе нижней Вислы не найдено таких, которые бы имели меньшие изменения электропроводимости побегов, чем F. ovata.

В результате изучения влияния низских температур на электропроводимость побегов форзиции можно утверждать, что этот метод может быть использован для отбора морозостойких особей. Он пригоден также при селекции гибридов для быстрой оценки их устойчивости к низким температурам.