SOME OBSERVED RELATIONSHIPS OF ELECTRICAL RESISTANCE AMONG SELECTED ROSE CULTIVARS

by

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TABLE OF CONTENTS

INTRODUCTION

Roses are the most valuable florist crop in the world; the earliest flowers were found in the tomb of Egyptian Kings. A serious drawback to the successful outdoor culture of roses in the colder regions is the heavy loss that occurs because of winter injury.

The fundamental nature of cold resistance in horticultural plants has been studied for more than two hundred years and many papers have been published, but just a few of them are concerned with low temperatures and desiccation of the garden roses.

A direct reading method for determining low temperature injury to plants by using a Boyoucous Bridge was devised by Filinger and Cardwell (1941). This method was used to determine the electrical resistances of some plant parts which were subjected to different freezing temperatures and then gradually thawed to the room temperatures in experiments by Filinger, Campbell, and Machia (1941, 1957, 1963).

Carrier (1951, 1952, 1953) did considerable work concerning effects of low temperatures on outdoor roses. Allen and Asai (1943) reported that considerable difference was noted in the rate of drying in different parts of the cane. The tips dried more rapidly and consequently lost a greater percentage of water in a given time than the bases. As a result, the portions near the tips reached the critical moisture content and were killed before the basal portions were injured. Molish (1897) suggested that low temperature damage in the absence of freezing should be call chilling injury as opposed to frost injury. One of the physiological possibilities which may be involved in chilling injury is the excess water loss due to transpiration which exceeds water absorption by the roots. Such a case of injury by desiccation is common in overwintering species.

The objectives of this study were as follows:

1) To determine what effects different air temperatures and varieties had on observed electrical resistance of overwintering rose plants.
2) To compare the observed electrical resistance reading of bases and tips of the same plant.
3) To find if there were linear correlations between air temperatures and electrical resistance reading in plants of the same variety.
4) To investigate whether there were relationships between the electrical resistance reading and the physiological observations made.

REVIEW OF LITERATURE

Thorough literature reviews of cold resistance in plants have been published by Scarth (1944) and Levitt, who reviewed more than six hundred reports in one publication (1941) and eighty-one in another (1956). A plant's reactions may be classified according to the unfavorable environmental condition to which it is subjected. There are three distinct types -- hardiness to extreme low temperature, to chilling, and to frost. 1) low moisture or drought hardiness. 2) High temperature or heat hardiness. 3) Hardiness to miscellaneous harmful factors.

A series of changes may occur during hardening. Before any appreciable frost hardiness develops, growth stops and carbohydrates accumulate. An activation or accumulation of certain enzymes occur during late summer or early fall, perhaps as a result of progressively shorter photo period. Because of these enzymes, the insoluble carbohydrates increase their osmotic potentials. Water, therefore, moves into the enzymes from the protoplasm. In plants capable of becoming frost hardy, the dehydration of the protoplasm leads to a slow change in the proteins, resulting in an increased binding of water (Levitt, 1951). The inability of growing plants to harden is easily understood on this basis. The carbohydrates are used up so rapidly that the cell sap concentration remains very low and consequently the protoplasm has a high water content. As a consequence, the proteins do not bind much water.

Some Previous Research of Winter Hardiness and Outdoor Roses.

In an effort to determine satisfactory procedures that might be used to reduce winter killing, Moore (1942) tested the effect of different cultural practices in his research. Varietal differences were not considered important in the test. Liquid manure was found to be a good fertilizer for roses from the standpoint of inducing strong growth and heavy bloom production, even in the year of planting. Applications begun in mid-May and continued fortnightly to mid-July produced the best results. Waxing rose plants for winter protection gave promising results from the standpoint of protection from winter killing. The cellar-wintering method was not at all satisfactory, and the defoliation of the bushed plants produced a harmful effect; hence, these two practices could not be encouraged.

The most common causes of winter injury to woody plants are low temperatures and desiccation. A considerable difference was noted in the rate of drying in different parts of the cane. The tips dried more rapidly and consequently lost a greater percentage of water in a given time than the bases. As a result, the portions near the tips reached critical moisture content and were killed before the base portions were injured. Canes killed by desiccation were always badly shriveled and turned a dull gray-green color. This change was quite distinct from the brown color observed when canes were killed by other means. Different.tissues of the stem varied in their resistance to low temperatures. The pericycle and phloem rays were the first to be injured. The inner cortex, phloem, cambium, outer cortex, xylem and pith were injured in the order listed (Allen and Asai, 1942).

Among all of the horticulturists, Carrier has done the most work concerning the effect of low temperatures on outdoor roses. He found that temperatures of +2 to -5 degrees F caused severe injury to both canes and roots of budded Pink Radiance rose plants. A treatment of +5 degrees F produced less injury to canes. No injury to canes of plants subjected to temperatures of +8, +12, +16 and +20 degrees F was observed. Sixty days after treatment, measurements and weights were taken of the new growth of the surviving plants. In the +5 degrees F treatment, the canes were severely injured. The treatments of +8, +12, +16 and +20 degrees F produced no injury to canes and cuttings responded the same as did cuttings from plants that were not treated (Carrier and Snyder, 1951).

Carrier (1951) observed that Multiflora rose stems and roots could reduce the vital stain 2,3,5-triphenyltetrazolium chloride when alive but failed to reduce it when dead. In 1952, he found that the larger canes of the larger green seedlings showed significantly higher specific conductance values and exhibited a more than 25 per cent injury at higher temperatures than did the small canes of the same seedling, or any of the canes of the red, smaller growing plants. Basal and terminal segments of Frau Karl Druschki were killed or severely injured at higher temperatures than were segments taken from intermediate positions on the canes.

In 1953, Carrier did research concerning the environment in relation to rose hardiness. Complete defoliation, daylength of eighteen hours and high soil nitrogen levels significantly decreased hardiness of rose plants. None of the treatments altered the hardiness of the rose understocks.

Recent Research Works on Hardiness

Shih, Jung and Shelton (1967) investigated the effects of temperature and photoperiod on metabolic changes during development and maintenance of cold hardiness of two alfalfa varieties varying widely in inherent cold hardiness. Cold temperatures appeared to be of primary importance for development and maintenance of cold hardiness, whereas both temperature and photoperiod played important roles in the metabolic processes. The content of protein, RNA, or DNA was positively associated with development and maintenance of cold hardiness. The content of protein or RNA located in microsomes was more closely associated with cold hardiness than was the content of these constituents located in other subcellular fractions. Tissue pH was higher at the peaks of cold hardiness than at other times. The hardy 'Vernal' variety contained more protein, RNA, or DNA than the nonhardy 'Arizona Common' variety during development and maintenance of cold hardiness.

Irving and Lanphear (1967) showed that development and hardiness was a photoperiodic response. Following six weeks of short days, the rate of hardening in darkness at 5 degrees F was over twice that of plants previously exposed to long days. In another paper (1967), they recorded that the removal of leaves from plants exposed to long days at 5 degrees F brought about an accelerated rate of hardening. They suggested that the presence of a hardiness inhibitor in the leaves was counteracted by short days or removal of the leaves. The application of gibberellin to Acer negundo either during or after a short photoperiod strikingly lowered the amount of hardiness obtained after four weeks in darkness at 5 degrees F (1968).

Two Easy Methods to Determine the Hardiness of Plants

To measure low temperature injury in plants, a method proposed by Dexter et al. (1930) indicates that the degree of hardiness of plants of certain species can be determined by measuring the extent of exosmosis of electrolytes from suitably frozen tissue. The method had been applied with satisfactory results to a large group of varieties of small grains. Tissues grown under various conditions have been examined by this method and show there is a marked influence of environment upon the hardening process.

An alternate method for the determination of frost resistance is presented by Dexter et al. (1932), in which the electrical conductivity of the tissue itself is determined after freezing. With three varieties of alfalfa of known hardiness, wide varietal differences are shown, as well as marked differences in hardiness of individual plants within a given variety. The upper root tissue is shown to be decidedly more resistant to freezing injury than the more deeply buried parts. Little difference in hardiness of different parts of the root has been found in the case of the most tender strain. According to Dexter, the diffusion of electrolytes if more rapid from damaged than from undamaged tissues; hence one may assume the higher the conductivity the greater the injury.

A direct method utilizing electrical current to measure low temperature injury in plants was devised by Filinger and Cardwell (1941). Damaged tissues offered less resistance than did undamaged tissues to electrical currents. This method has the following advantages: 1) It is a rapid method. 2) A portable apparatus could be taken to the field and plants studied after each adverse weather period. 3) A plant need not be destroyed to make a determination.

A Boyoucous Model C Moisture Bridge was used by Campbell and Ghosheh (1957) to measure the electrical resistance of grape canes. This model emplcys a 1000-cycle alternating current. Earphones were used to detect the null point. They observed decreased resistance in grape canes exposed to low temperatures, liquid air, or boiling water. Treatments used produced no significant differences among varieties in electrical resistance of canes. Apparently all treatments killed the plant tissues.

The direct method based on the measured electrical resistance of twigs and the electrolytic procedure involving electrical conductance measurements were found by Machia and Campbell (1963) to be significantly correlated and equally accurate and reliable in testing for low temperature injury. There was no significant correlation between twig diameter and electrical readings measured by either the resistivity or conductivity methods. With each successive decrease in temperature, a consistent reduction in electrolytic resistance reading was indicated by both methods.

A refinement from earlier methods (Filinger and Cardwell, 1941) that sometimes destroyed the tissues was devised by the Canadian Department of Agriculture (1960). The distance between the electrodes was narrowed to ¼ of an inch and the electrodes were fixed on light aluminum handles weighing about 50 grams instead of having electrical contacts separated by a non-conductive fiber bar as suggested by Filinger.

MATERIALS AND METHODS

A Boyoucous Model C Moisture Bridge was used to determine the effects of winter temperatures on the electrical resistance of overwintering canes of eight rose cultivars, and to find if differences in electrical resistance existed between tips and bases of rose canes.

Electrolytic resistance measurements were taken with a Boyoucous Bridge following the method used by Filinger and Cardwell (1941). The Bridge was energized by a 1,000 cycle source. A vacum tube voltmeter, using a 6E5 (electric eye) vacuum tube, served as the detector. Contact with the cane under test was made by inserting two steel needles three inches apart through the cane.

Electrical resistance readings were taken from the basal portions of canes, two inches above the ground, for the eight varieties, and also from the tips of canes of Summer Sunshine, and Europeana cultivars. All plants used in this study were vigorous and well-established in the garden. The following eight cultivars were selected because they were thought to represent a wide range in hardiness and are also commonly grown: Matterhorn, hybrid tea; Bewitched, hybrid tea; Summer Sunshine, hybrid tea; Queenie, floribunda; Saratoga, floribunda; Europeana, floribunda; Camelot, grandiflora; Scarlet Knight, grandiflora. Four plants, having canes that were nearly the same diameter, were chosen for each of these varieties; variable sized canes offered different resistance to electrical current (Carrier, 1952). The electrical resistance of one cane of each of these four plants represented one replication, so that there were four replications for each variety.

The readings were taken in the garden on the following dates (see Table 1). Temperatures records from October 1, 1967 to April 30, 1968 are presented in Figure 1.

Tip readings were taken only six times because the tips were withered and dried after November 16, and further readings could not be obtained.

Other observations included: time of leaf fall, bud development, and new leaf appearance. These observations were compared with the electrical resistance readings for possible correlation.

All statistical analyses were made as outlined by Fryer (1966).

Figure 1. Daily Temperature Records from October 1, 1967 to April 30, 1968.

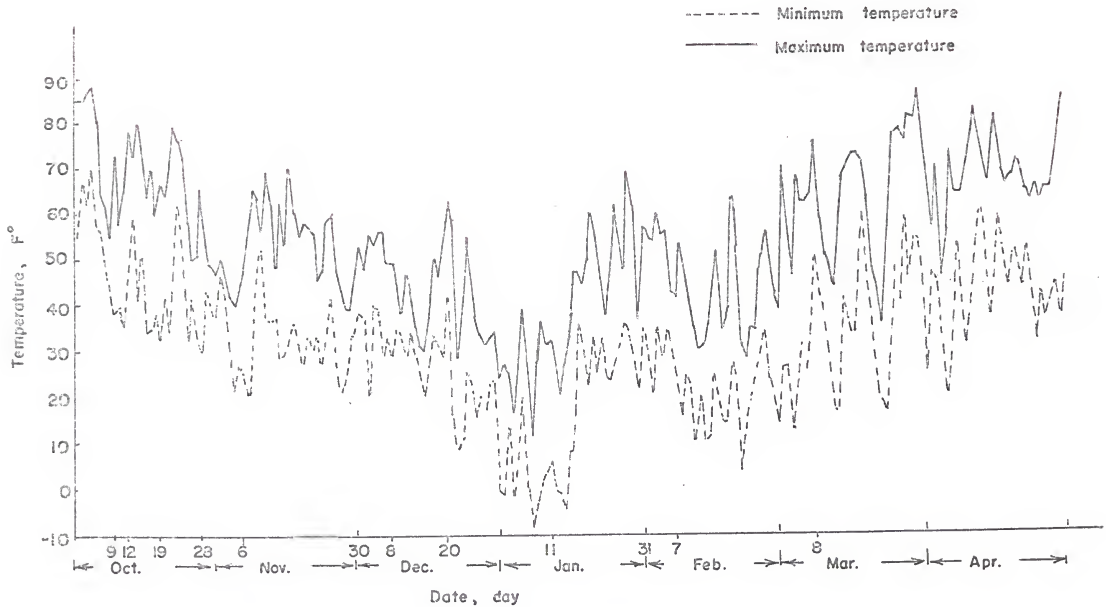

Fig. I. DAILY TEMPERATURE RECORDS FROM OCTOBER 1, 1967 TO APRIL 30, 1968.

Table 1. Dates and temperatures (F°) when electrical resistance readings were taken.

Date	Max	Min	Date	Max	Min	Date	Max	Min
Oct. 9	73	38	Oct. 12	78	47	Oct. 19	67	32
Oct. 28	66	30	Nov. 6	48	25	Nov. 12	62	36
Nov. 16	70	33	Nov. 30	49	34	Dec. 8	49	33
Dec. 20	63	43	Jan. 31	57	35	Feb. 7	41	24
Mar. 8	76	50	Mar. 14	68	41	Mar. 25	77	48
Apr. 4	46	29	Apr. 15	77	41			

RESULTS AND DISCUSSIONS

1. Results of Statistical Analyses:

The electrical resistance readings (ERRs) for eight different rose varieties on seventeen different dates were analyzed by a two-way analysis method (Table 2). The results show that the ERRs were affected by dates, varieties, and their interactions.

When dates of temperatures effects were considered, readings in the means' column were quite different. These can be separated into three groups for explanation:

A) Electrical resistance readings were taken from warm to colder weather, Oct. 9 to Dec. 20, when inner plant tissues were not frozen and plants had not been injured by low temperatures. The ERRs of the means' column showed a tendency to increase when temperatures decreased, with two exceptions namely Oct. 20 and Dec. 20, when temperatures increased and ERRs decreased. During this period, the temperatures were all above 8 degrees F. According to Carrier and Snyder's (1951) experiment, they could not find any injury to plants subjected to temperatures of +8, +12, +16 and +20 degrees F.

Chandler (1954) emphasized maturity to be the most important factor affecting the hardiness of plant tissues. He also mentioned that the more common criteria for testing seasonal maturity in plants were: declining water content, increasing osmotic pressure, accumulation of carbohydrates, declining rates of respiration, defoliation, formation of terminal bud. Wilner (1964) found that the resistance of twigs increased as the growing season advanced .

from summer to fall and appeared to reflect differences in the rate and time of development of autumn maturity. On the basis of ERRs of the eight cultivars sampled from Oct. 9 to Dec. 20, it appears that Europeana followed closely by Queenie and Saratoga are the earliest maturing of the varieties tested.

B) Electrical resistance readings on Jan. 31 were greatly reduced when compared with those observed on Dec. 20. Minimum temperatures from Dec. 21 to Jan. 16 were below freezing constantly (Figure 1). From Jan. 17 to Feb. 7 minimum temperatures increased nearly to the freezing point and were quite stable. Only small changes in electrical resistance readings were observed between Jan. 31 and Feb. 7. At this time, inner plant tissues were thawed and ERRs decreased. Reduction in electrical resistance for the period Dec. 20 to Jan. 31 are presented in Table 3.

C) Readings on Jan. 31 and Apr. 15 were not significantly different for the varieties: Matterhorn, Bewitched, Summer Sunshine, Queenie and Scarlet Knight, but significantly different for the varieties Saratoga, Europeana and Camelot.

Table 2. Analysis of variance of the electrical resistance readings (ohms x 100) of eight different rose varieties on seventeen different dates. (Two-way analysis)

MEANS OF COLUMNS, ROWS, AND CELLS

DATE	MAT	BEW	SUM	QUE	SAR	EUR	CAM	SCA	MEAN*
10-9-67	375.0	307.5	375.0	487.5	402.5	655.0	345.0	475.0	427.8 hi
10-12-67	352.5	265.0	345.0	422.5	362.5	675.0	365.0	302.5	386.2 j
10-19-67	332.5	310.0	307.5	537.5	455.5	745.0	475.0	265.0	428.4 hi
10-28-67	375.0	395.0	410.0	632.5	515.0	785.0	500.0	335.0	493.4 ef
11-6-67	430.0	467.5	495.0	725.0	552.5	807.5	665.0	537.5	585.0 de
11-12-67	587.5	552.5	562.5	740.0	697.5	862.5	580.0	647.5	653.7 c
11-16-67	420.0	407.5	415.5	530.0	475.0	672.5	495.0	480.0	486.8 f
11-30-67	610.0	665.0	610.0	805.0	722.5	932.5	722.5	645.0	714.0 b
12-8-67	615.0	730.0	737.5	940.0	760.0	1040.0	740.0	780.0	792.8 a
12-20-67	560.0	610.0	472.5	632.5	637.5	1040.0	572.5	580.0	638.1 cd
1-31-68	425.0	437.5	400.0	400.0	362.5	362.5	362.5	387.5	392.1 j
2-7-68	450.0	437.5	412.5	412.5	375.5	337.5	362.5	387.5	395.8 ij
3-8-68	475.0	512.5	475.0	475.0	487.5	425.0	412.5	462.5	465.6 fg
3-14-68	500.0	500.0	462.5	500.0	475.0	462.5	425.0	462.5	473.4 fg
3-25-68	425.0	400.0	387.5	437.5	412.5	400.0	412.5	400.0	409.3 ij
4-4-68	462.5	437.5	437.5	475.0	450.0	475.0	400.0	400.0	442.1 eh
4-15-68	437.5	412.5	400.0	387.5	412.5	450.0	400.0	400.0	412.5 ij
MEAN*	460.7 DE	461.6 DE	453.2 E	561.1 B	503.2 C	654.5 A	484.4 CD	467.5 DE	

Table 2. (continued)

ANALYSIS OF VARIANCE

SOURCES	DF	SUM OF SQUARES	MEAN SQUARE	F RATIO	$LSD_{0.01}$
DATES	16	7928770	495548.13	171.55**	34.80
VARIETIES	7	2303340	329048.57	113.91**	23.87
INTERACTION	112	2686580	23987.32	8.30**	
ERROR	408	1178560	2888.62		
TOTAL	543	14097250			

*Values within the same column or row designated by the same letter are not significantly different at 1% level as determined by Fisher's LSD procedure.

** All F ratio are significant at 1% and 5% levels.

From Table 3, it can be seen that the reductive percentages for these three varieties and for Queenie were greater than for the other varieties.

There were some fluctuations both in temperature and ERRs during this period, however in general an increase in mean temperature and a decrease in electrical resistance was noted. These two factors appeared to be related.

Wilner (1967) reported that with the advent of spring weather, the electrical resistance of all injured shoots greatly increased dur to desiccation, whereas the resistance of healthy shoots decreased with their resumption of growth.

When varieties effects were considered, the different values in the means' row (Table 2) indicated that the varieties in the floribunda group, Queenie, Saratoga and Europena differed significantly at 1% and 5% levels from the other varieties in electrical resistance. However there was no significant difference in ERRs for varieties within or between the hybrid tea or grandiflora groups.

Many ganeticists have shown that crosses between varieties differing in frost hardiness might result in progeny that was either hardier or less hardy than either parent (Anderson 1935, Worzella 1942). They explained these results by the existence of two or more hardiness factors. Shih, Jung and Shelton (1967) reported that different alfalfa varieties varied widely in inherent cold hardiness.

Table 3. Reductive percentages in electrical resistance readings (ohms x 10) of eight different varieties.

	MAT	BEW	SUM	QUE	SAR	EUR	CAM	SCA
DEC.20	5600	6100	4725	6325	6375	10400	5725	5800
JAN.31	4250	4375	4000	4000	3625	3625	3625	3875
REDUCTIVE PERCENTAGE	24.1	28.3	15.3	36.8	43.1	65.1	36.1	33.2

Filinger and Cardwell (1941) concluded that when plants were injured or killed by freezing temperatures, they offered less resistance than undamaged tissues to electrical currents. The ERRs taken on Dec. 20 (max 63, min 43) were compared with those on Jan. 31 (max 57, min 35) in Table 3. The temperatures between this period were very los, plant tissues were frozen and the ERRs could not be recorded. After being frozen, plants thawed gradually, and the ERRs on Jan 31 were reduced greatly for the three floribunda varieties, Queenie, Saratoga, and Europeana. The ERRs of the hybrid tea varieties, Matterhorn, Bewitched and Summer Sunshine were reduced the least for varieties of the three groups. In Wilner's experiments (1960), he found that generally no injury occured in hardened twigs when the resistance readings were above 35000 ohms, but resistance below 8000 to 10000ohms usually indicated severe injury to tissues. Every kind of plant has a low limit of ERRs to cold weather. In this study, Europeana was the only variety tested that appeared to be severely injured by low temperatures.

Table 4. Analysis of variance of electrical resistance readings (ohms x 100) of eight different rose varieties on the same day (One-way analysis).

VARIETY	MEAN ELECTRICAL RESISTANCE READINGS								
	OCT.9	OCT.12	OCT.19	OCT.28	NOV.6	NOV.12	NOV.16	NOV.30	DEC.8
MATTER	375.0^{bc}	352.5^{bc}	332.5^{e}	375.0^{e}	430.0^{e}	587.5^{cd}	420.0^{bc}	610.0^{c}	615.0^{c}
BEWITC	307.5^{c}	265.0^{c}	310.0^{c}	395.0^{de}	467.5^{de}	552.5^{d}	407.5^{c}	665.0^{bc}	730.0^{bc}
SUMMER	375.0^{bc}	345.0^{bc}	307.5^{c}	410.0^{cde}	495.0^{de}	562.5^{d}	415.0^{bc}	610.0^{c}	737.5^{bc}
QUEENI	587.5^{b}	422.5^{b}	537.5^{b}	632.5^{b}	725.0^{ab}	740.0^{ab}	530.0^{b}	805.0^{ab}	940.0^{a}
SARATO	402.5^{bc}	362.5^{bc}	455.0^{b}	515.0^{c}	552.5^{cd}	697.5^{bc}	475.0^{bc}	722.5^{bc}	760.0^{bc}
EUROPE	655.0^{a}	675.0^{a}	745.0^{a}	785.0^{a}	807.5^{a}	862.5^{a}	672.5^{a}	932.5^{a}	1040.0^{a}
CAMELO	520.0^{b}	302.5^{bc}	265.0^{c}	335.0^{e}	537.5^{de}	647.5^{bcd}	480.0^{bc}	645.0^{c}	780.0^{b}
SCARLE	345.0^{bc}	365.0^{bc}	475.0^{b}	500.0^{cd}	665.0^{bc}	580.0^{cd}	495.0^{bc}	722.5^{bc}	740.0^{bc}
F-RATIO	6.91**	16.00**	45.75**	32.22**	19.27**	10.07**	8.35**	7.72**	11.78**
$LSD_{0.01}$	166.0	124.2	93.7	105.6	120.4	134.5	118.6	157.0	154.4

Table 4. (continued)

	MEAN ELECTRICAL RESISTANCE READINGS							
VARIETY	DEC.20	JAN.31	FEB.7	MAR.8	MAR.14	MAR.25	APR.4	APR.15
MATTER	$560.^{bc}$	425.0	450.0^{a}	475.0^{ab}	500.0^{a}	425.0	462.5^{a}	437.5^{ab}
BEWITC	610.0^{b}	437.5	437.5^{ab}	512.5^{a}	500.0^{a}	400.0	437.5^{ab}	412.5^{bc}
SUMMER	472.5^{c}	400.0	412.5^{abc}	475.0^{ab}	462.5^{ab}	387.5	437.5^{ab}	400.0^{c}
QUEENI	632.5^{b}	400.0	412.5^{abc}	475.0^{ab}	500.0^{a}	437.5	475.0^{a}	387.5^{c}
SARATO	632.5^{b}	362.5	375.0^{bcd}	487.5^{a}	475.0^{ab}	412.5	450.0^{ab}	412.5^{bc}
EUROPE	1040.0^{a}	362.5	337.5^{d}	425.0^{bc}	462.5^{ab}	400.0	475.0^{a}	450.0^{a}
CAMELO	580.0^{bc}	387.5	387.5^{abcd}	462.5^{abc}	462.5^{ab}	400.0	400.0^{b}	400.0^{c}
SCARLE	572.5^{bc}	362.5	362.5^{cd}	412.5^{c}	425.0^{b}	412.5	400.0^{b}	400.0^{c}
F-RATIO	38.08**	1.94*	4.88**	5.82**	4.23**	2.46*	5.47**	5.71**
LSD 0.01	109.4		68.5	53.4	50.5		50.5	35.0

* F-ratio is not significant at 1% level,

** Values within the same column designated by the same letter are not significantly different at 1% level as determined by Fisher's procedures.

Table 5. Linear correlations between the temperatures and the electrical resistance readings (ohms x 100) of the same variety.

DATES	TEMP (F)	VARIETIES MAT	BEW	SUM	QUE	SAR	EUR	CAM	SCA
OCT.9	73	375.0	307.5	375.0	487.5	402.5	655.0	475.0	345.0
OCT.12	78	352.5	265.0	345.0	422.5	362.5	675.0	302.5	365.0
OCT.19	67	332.5	310.0	307.5	537.5	455.0	745.0	265.0	475.0
OCT.28	66	375.0	395.0	410.0	632.5	515.0	785.0	335.0	500.0
NOV.6	48	430.0	467.5	495.0	725.0	552.5	807.5	537.5	665.0
NOV.12	62	587.5	552.5	562.5	740.0	697.5	862.5	647.5	580.0
NOV.16	70	420.0	407.5	415.0	530.0	475.0	672.5	480.0	495.0
NOV.30	49	610.0	665.0	610.0	805.0	722.5	932.5	645.0	722.0
DEC.8	49	615.0	730.0	737.5	940.0	760.0	1040.0	730.0	740.0
DEC.20	63	560.0	610.0	472.5	632.5	637.5	1040.0	580.0	572.5
JAN.31	57	425.0	437.5	400.0	400.0	362.5	362.5	587.5	362.5
FEB.7	41	450.0	437.5	412.5	412.5	375.0	337.5	387.5	362.5
MAR.8	76	475.0	512.5	475.0	475.0	487.5	425.0	462.5	412.5
MAR.14	68	500.0	500.0	462.5	500.0	475.0	462.5	462.5	425.0
MAR.25	77	425.0	400.0	387.5	437.5	412.5	400.0	400.0	412.5
APR.4	46	462.5	437.5	437.5	475.0	450.0	475.0	400.0	400.0
APR.15	77	437.5	412.5	400.0	387.5	412.5	450.0	400.0	400.0
PRODUCT-MOMENT COEFFICIENT		-0.44*	-0.50**	-0.51**	-0.48*	-0.38*	-0.20*	-0.36*	-0.46*

* Non-significant at both 1% and 5% levels

** Significant at 5% level

Table 6. Analysis of variance of the electrical resistance readings (ohms x 100) between tip and base of the rose variety - - Summer Sunshine.

	MEAN RESISTANCE READINGS						
	OCT.12	OCT.19	OCT.28	NOV.6	NOV.12	NOV.16	SUM(MEANS)
TIP	827.5	867.5	982.5	1185.0	1320.0	1097.5	6280.0
BASE	345.0	307.5	410.0	495.0	562.5	415.0	2535.0
SUM (MEANS)	1172.5	1175.0	1392.5	1680.0	1882.5	1512.5	

ANALYSIS OF VARIANCE

SOURCE	DE	SUM OF SQUARE	MEAN SQUARE	F-RATIO
DATE	5	795191.6	159038.3	23.3832*
PART	1	4675008.3	4675008.3	687.3608*
INTERACTION	5	104741.6	20948.3	3.0800**
ERROR	36	244850.0	6801.3	
TOTAL	47	5819791.6		

* Significant at 1% and 5% levels.

** Significant at 5% level, but non-significant at 1%level.

Table 7. Analysis of variance of the electrical resistance readings (ohms x 100) between tip and base of the rose variety - - Europeana.

	MEAN RESISTANCE READINGS						
	OCT.12	OCT.19	OCT.28	NOV.6	NOV.12	NOV.16	SUM(MEANS)
TIP	1202.5	1365.0	1370.0	1892.5	2365.0	1735.0	9930.0
BASE	675.0	745.0	785.0	807.5	862.5	672.5	4547.5
SUM (MEAN)	1877.5	2110.0	2155.0	2700.0	3227.5	2407.5	14477.5

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARE	MEAN SQUARE	F-RATIO
DATE	5	2381885.5	476377.1	28.2262*
PART	1	9657102.1	9657102.1	572.2020*
INTERACTION	5	1479935.4	295987.0	17.5378*
ERROR	35	607575.0	16877.0	
TOTAL	47	14126498.0		

* All significant at 1% and 5% levels.

When the electrical resistance readings of all eight rose varieties each on the same day was subjected to a one-way analysis, readings for nearly all varieties were significantly different at the same temperatures, except on January 31 and March 25 (Table 4). No quantitative analysis of the plant tissue components were made; hence a comparison of the different abilities of electrical resistance by varieties is not available.

Machis and Campbell (1963) reported that with each successive decrease in temperature, a consistent reduction in electrolytic resistance would be offered by the injured or killed plants. The question arises whether the temperatures and the ERRs appear as linear correlations. Two varieties, Bewitched and Summer Sumshine, show a linear correlation at the 5% level. Their minus product moment coefficient can also indicate that the higher the temperatures, the lower the electrical resistance readings, and vice versa. The other six varieties do not show any linear correlation (Table 5).

The electrical resistance readings between two different parts, tip and base, of the same variety are quite different (Table 6,7). These differences may be due to three factors: temperatures, positions, and temperatures by positions interactions. These reactions are the same as Machia and Campbell (1963) indicated in the methods they used to determine injury to peach trees. From Oct. 9 to Nov. 16, at any time of taking the ERRs, values for the bases were always lower than those of the tip's. This means that the cane bases have much more electrical resistance than do the tips of the same variety. A considerable difference was noted in the rate of drying in different parts of the cane; tips dried more rapidly and consequently lost a greater percentage of water in a given time than did the bases (Allen and Asai, 1943). As a result, the portions near the tips reached the critical moisture content and were killed before the basal portions were injured.

The results mentioned above are just opposite to those of Carrier's (1952). He found that the segments from the basal region showed lack of hardiness because of their lower osmotic concentration (near the source of water).

2. Phenological Observations:

A. Leaf Color Change and Leaf Fall:

a. November 6, 1967:

Leaves of Matterhorn, Bewitched and Scarlet Knight were still green and no leaf fall had occured; leaves of Summer Sunshine were green, but some leaves had begun to fall off; leaves had turned to reddish green and had begun to fall off for Queenie, Saratoga and Europeana; some leaves of Camelot had turned brown, but no leaf fall had occured. These observations are reflected in Table 4, November 6, where no ERRs difference were noted among the varieties Matterhorn, Bewitched, Scarlet Knight and Summer Sunshine which still had green leaves; furthermore the ERRs of these four varieties were lower than for the other varieties. These four varieties seem to be more resistant to the low temperature at that time.

b. November 12, 1967:

Most leaves of Matterhorn, Bewitched and Scarlet Knight were green; just a few of them had become red and no leaves had fallen; leaves of Summer Sunshine appeared brownish green and some of them had fallen off; leaves of Camelot had become yellowish brown, but still no leaf fall had occurred . When these results are compared to ERRs in Table 4, column of November 12, the varieties which had green leaves like Matterhorn, Bewitched and Scarlet Knight, and those which had discolored leaves but no leaf fall such as Camelot did not show significant differences among their ERRs, and the values are lower than those of the other varieties. The varieties which show discoloring and leaf fall have higher ERRs and possible less winter hardiness. These results are in accordance with Carrier's (1953) study showing that complete early defoliation significantly decreased the hardiness of the canes of the rose bushes. Discoloring or even falling leaves will affect photosynthesis, and hence affect starch formation. Levitt (1956) found that sugar accumulation is the cause of the increased cell sap concentration in hardening. The decreasing of starch formation will result in less sugar assimilation, and hence reduce the ability to be winter hardy.

B. Observe Dates of Buds Development:

The buds of Summer Sunshine, Queenie, Saratoga and Scarlet Knight developed on March 8; Europeana and Camelot on March 14; Bewitched on April 4; and Matterhorn on April 15. A comparison of bud development with results shown in Tables 2 and 4 does not show a relationship to electrical resistance of any variety. According to Allen and Asai's (1943) observation very often in the early spring canes would appear to be green and healthy, but the buds would fail to develop or would grow for only a short time. Finding a good method such as using chemical treatment to delay early bud development is very important.

C. New Leaf Appearance:

On March 25, new leaves of Summer Sunshine, Queenie and Scarlet Knight appeared; new leaves of Europeana appeared on April 15; Matterhorn, Bewitched, Saratoga and Camelot did not have new leaves until April 24.

3. Discussion:

It is easy to test the different abilities of electrical resistance among different varieties, but it is difficult to use quantitative analysis to analyze the components of inner plant tissues when they offer different ERRs. If the amounts of each component can be analyzed during the winter hardening process, the factors affecting cold hardiness could be determined, and suitable methods to decrease cold injury may be found. After temperatures increase or decrease, some components will raise and some lower. In Levitt's book "The Hardiness of Plant", many different results were observed by many different researchers, and it is evident that any one physiologist can find different phenomena in different experiments.

In this study, the electrical resistance method was utilized to take readings in order to compare them with the changing temperatures to find which variety if more sensitive to lower temperatures. However quantitative analysis of the factors which may affect electrical resistance in plant tissues was not done. How to improve the varietal cold hardiness if an important problem waiting to be solved.

SUMMARY

A study of the relationships in electrical resistance among eight selected rose varieties: Matterhorn, Bewitched, Summer Sunshine (hybrid tea); Queenie, Saratoga, Europeana (floribunda); Camelot, Scarlet Knight (grandiflora); was made by using the Boyoucous Model C Bridge. Four canes of nearly the same size from four different plants of one variety were chosen for taking electrical resistance readings (ERRs).

Steel needles were inserted into the canes two inches above ground to determine ERRs of the basal parts, and two inches from the tip of the canes to represent ERRs of the tips. The ERRs of the bases were taken for all eight varieties; however only Europeana and Summer Sunshine were selected in order to compare their ERRs differences between tips and bases for the same variety.

The ERRs were taken on the following dates: Oct. 9, Oct. 12, Oct. 19, Oct. 28, Nov. 6, Nov. 12, Nov. 16, Nov. 30, Dec. 8, Dec. 20, Jan. 11, Jan. 31, Feb. 7, Mar. 8, Mar. 14, Mar. 25, Apr. 4, Apr. 15, and Apr. 24. Nineteen readings of the basal parts for every variety were collected in this experiment. But, on January 11, the temperatures were very low, and inner plant tissues were frozen. The sounds from the earphones were too loud to make it possible to take ERRs; on April 24, new plants replaced all old canes; hence, the ERRs can not represent the old ones. In all the statistical analyses, seventeen readings for each variety were considered. Only six readings were collected from the tips of Summer Sunshine and Europeana, due to withering and drying of tips. Also, on November 30, the plants were tied

together for protection and readings could not be taken.

ERRs of eight varieties on seventeen different dates were analyzed in Table 2 with the following conclusions: a) Different varieties of the same group do not have the same ability to resist cold injury. Though Matterhorn, Bewitched and Summer Sunshine in the hybrid tea group, and Scarlet Knight and Camelot in the grandiflora group show no significant differences in their ERRs, the ERRs of Queenie, Saratoga and Europeana in the floribunda group are all significantly different at both 1% and 5% levels. Many geneticists have shown that crosses between varieties differing in frost hardiness may result in progeny that are either hardier or less hardy than either parent (Andersson 1935, Worzella 1942).
b) Queenie, Saratoga and Europeana in the floribunda group appeared more sensitive to the changing temperatures; winter protective care should be provided earlier for these varieties. Matterhorn, Bewitched, Summer Sunshine, Scarlet Knight and Camelot show lower electrical resistance readings and more cold hardiness.

ERRs of eight varieties subjected to the same temperatures were analyzed in Table 4 and only on Jan. 31 and Mar. 25 did the ERRs show no significant difference among these varieties under the same temperature. The others are all significantly different.

On January 31, after the plants thawed, the ERRs, except for three varieties in the floribunda group, did not differ much in comparison with those of the ERRs taken before they were frozen. Machia and Campbell (1963) reported that with each successive decrease in temperature, a consistent reduction in electrolytic resistance would be offered by an injured or killed plant. All the varieties used, except those in the floribunda group, can grow very vigorously in areas which have weather conditions like those of Manhattan.

From Table 5, two varieties, Bewitched and Summer Sunshine appear to have significant linear correlations between temperatures and ERRs at 5% levels. The product moment coefficients of the other six varieties are minus, but may appear as linear correlation with smaller confidence intervals.

The basal portion of Bewitched and Summer Sunshine appear to be able to resist much lower temperatures than the tip. These results are in accordance with Allen and Asai's conclusion (1943). They found that the tips dried more quickly and consequently lost a greater percentage of water time than did the bases; hence the portion near tips reached the critical moisture content and were killed before the basal portions were injured.

From the observations made, on November 6, it was observed the leaves of Queenie, Saratoga and Europeana had turned dark-red and had begun to fall. Using these results to compare with their ERRs (Table 4, column of Nov. 6), it is evident that the ERRs of these three varieties were higher than for the others. It means that the earlier leaf color change and leaf fall usually occur on those varieties which have higher electrical resistance readings and less abilities to withstand winter injury.

Leaf fall has no correlation with bud development. Bud development for these eight varieties does not show any relationship to the ERRs. Leaves of Summer Sunshine and Queenie and Saratoga had fallen off on November 6, and their new buds developed on March 8. Leaves of Scarlet Knight and Camelot did not fall off on November 12, but their new buds developed on March 8 and March 14 separately. Leaves of Europeana began to fall off on November 6, but new leaves appeared on March 14.

Allen and Asai (1943) reported that very often in the early spring, canes would appear very green and healthy, but that buds would fail to develop or would grow for only a short time. From the observations made, the earlier the buds occur, the earlier the new leaves appear. Finding a good method to prevent buds appearing too early in the cold spring is very important in improving the cold resistance.

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SOME OBSERVED RELATIONSHIPS IN ELECTRICAL RESISTANCE AMONG SELECTED ROSE CULTIVARS

by

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In this study, a Boyoucous Model C Bridge was used to take electrical resistance readings from rose canes. This method was devised by Filinger and Cardwell in 1941. Contact with the cane under test was made by inserting steel needles 3 inches apart through the cane. Earphones were used to detect the null point.

Eight rose varieties in three different groups were selected for this study: Matterhorn, Bewitched, and Summer Sunshine in hybrid tea group; Queenie, Saratoga, and Europeana in floribunda group; Camelot and Scarlet Knight in grandiflora group.

All plants used were all vigorous and well-established in the garden. Four plants having canes that were nearly of the same diameter were chosen for each of these varieties. The electrical resistance of one cane of each of these four plants represented one replication so that there were four replications for each variety. The readings were taken from the basal parts of the canes, two or three inches above the ground, for these eight varieties; and also taken from the cane tips of Summer Sunshine and Europeana.

Resistance readings from the basal cane position were collected from each variety and analyzed statistically. Data was collected for the period October 9, 1967, to April 15, 1968. Measurement of resistance readings of cane tips were discontinued after November 16.

In addition to taking the electrical resistance measurement, dates of leaf color change, leaf fall, bud development and new leaf appearance were also observed. Some relationships were found when these observations were compared with the electrical resistance readings.

Electrical resistance readings were affected by dates, varieties, and their interactions. Resistance increased as the growing seasons advanced from fall to the early winter. After plant tissues thawed on January 31, the resistance readings were reduced. Electrical resistance for the variety Europeana was reduced the most of the eight varieties studied.

Different varieties in the same group were found not to have the same ability to resist cold injury. For the floribunda group, the resistance readings of Queenie, Saratoga and Europeana were all significantly different.

In general, temperature and electrical resistance should have a linear relationship. In this study, two varieties; Bewitched and Summer Sunshine, showed a linear correlation at 95 percent confidence intervals.

Resistance readings taken from the tips and the bases of the same plant were significantly different. Values for the tips were higher than for those of the bases.

Plants with green leaves were found to have lower electrical resistance readings than those on which leaf color had changed.