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WINTER HARDINESS OF TREES AND SHRUBS
GROWING IN THE ARNOLD ARBORETUM

I

THE WINTER OF 1933-34 ranks as one of the severest ever experienced in New England and other portions of northeastern North America. With its passing, evidences of damage to trees and shrubs from the unusual conditions began to appear and these became increasingly apparent as the season of growth progressed. Full appraisal of resultant injury was not immediately possible because in addition to outright killing of plants or obvious parts of them, it was uncertain to just what extent root systems and the vegetative tissues of stems has been affected. Even now, an estimate cannot be complete and secondary results due to inhibitory effects on buds, reduction of nutritional organs and the attacks of disease-causing organisms that find their way in through injured parts will continue to express themselves for some time. However, a considerable part of the picture is now clear and the purposes of this article are to sketch its outlines, present such detailed data as have been assembled, offer suggestions as to how woody plants should be made ready for winter and advise as to the treatment of winter-injured trees and shrubs.

Still fresh in the memories of most readers of the BULLETIN, little need be said concerning the rigors of the winter of 1933-34. The records of the Weather Bureau for all the years of its existence do not show more severe and long-continued cold throughout the greater part of northeastern North America. Winter began early and persisted well into the following spring. As for New England, the monthly mean temperatures from November to March inclusive, January excepted, were below the averages of the last 47 years. The official figures for the deviation from the means are: November 5.4° F. below the average,

December 5.8° below, January 0.1° above, February 10.7° below, March 1.8° below. Very low temperatures featured especially the last week in December and the entire month of February. Referring to the latter the U.S. Weather Bureau in its "Climatological Data for New England" (Vol. 46, p. 7) remarked – "The coldest month ever recorded, since the compilation of Section averages, passes into New England history as the temperatures during February, 1934, are brought into comparison with earlier occurrences." It is also pertinent to add that the cold was sometimes accompanied by strong winds. In fact, the winds from November to March inclusive were of more than normal mean intensity.

Important as these official records are when considering the effects of the winter on plant life, or in drawing conclusions as to the hardiness of plants, it must be borne in mind that there are other critical meteorological data of which no account is taken. Reference is made particularly to the modifying influences of snow-cover and shelters, and local variations in temperatures as between those of the "cold pockets" of depressions and the various facies of elevations of land. Differences in snow-coverage or site often account for differences in winter damage to plants of the same kind proximately located.

Regarding the phenomenon of winter hardiness of plants, that is, their resistance to cold, much remains to be learned. Basically it is an inherited character and, as do all inherited characters, shows minor variations only among individuals of the same kind under identical conditions. Its stability is indicated by the fact that a hardy race cannot be evolved from a tender one or vice versa simply by changing the environment. Thus, the progeny of plants reared in a climate foreign to them retain unimpaired their natural hardiness on being restored to their native surroundings. On the other hand hardier or more tender races can be evolved by appropriate methods of breeding.

Although hardiness is inherent, it is subject, just as are other inherent characters, to considerable modification in the individual resulting from changes in the environment. Indeed, hardiness is in some instances so delicately attuned to a given environment that certain species desired for introduction elsewhere, even into regions of the same latitude, may prove satisfactory or otherwise according to whether they originate on one side or the other of a mountain range. Differences in temperature, altitude, rainfall, season of rainfall, snowfall, proximity to the sea, physical and chemical soil conditions and various other factors may be of dominant importance in their effect on hardiness. In determining the fitness with respect to this feature of a species or race for introduction no rule of thumb applies; the answer can be

learned only by actual test. Such experimentation is one of the many functions of the Arnold Arboretum and similar institutions.

Finally, it should be observed that even in the cases of plants, native or introduced, suited to a given regional area, their natural resistance to cold may be weakened by such controllable factors as unfavorable soil and water conditions, crowding, wounds, recent transplanting, unfavorable sites, propagation on tender rootstocks and unseasonable or otherwise injudicious fertilization. Conversely, hardiness can be fortified by providing conditions favorable to good growth in the summer and suitable preparation for timely dormancy in the fall.

From all that has been said above it is apparent that the explanation of instances of winter injury and the passing of judgment on the normal hardiness of any kind of plant involves a wide range of considerations.

Just what it is in the organization of a plant that makes it winter hardy, just what happens when its tissues "ripen" for dormancy in the fall and ensures dormancy until the insistent call of spring comes are phenomena not yet fully understood. They have been studied, however, from many angles and much of interest has been learned even though the riddles evade solution. Among these studies, some on the action of cold and frost on living cells, have resulted at least in producing plausible theories. Various theories, some more or less fanciful, others based on reasonable experiment, have been advanced in explanation of the nature of frost injury. Formerly it was believed that cell walls were ruptured by the formation of ice crystals, but observations show that generally this is not the case. It is now commonly believed that the ice crystals permanently disturb the organization of the living substance within the cells to such an extent as to render them incapable of retaining water. Inferentially then "water retention is the basis of hardiness." One investigator, (W. Stiles) in a recent paper summarizes his views as follows – "In case of frost resistant plants, however, it is probable that water is bound to hydrophile colloids of the protoplasm and is non-freezable, so that the formation of ice crystals and the consequences of their formation to which the death of the cells is attributed do not take place."

The extent and the kind of winter injury to woody plants present many aspects, some obvious and readily diagnosable, others insidious and difficult to diagnose unless the full history of the case is known. In all instances observations should be made as early as possible after winter closes because later on confusion may result from the inroads of destroying fungi or other disturbing agents, or from the similarity of symptoms that follow causes other than frost. The extent and the

kinds of winter injury vary from complete killing, immediate or delayed, to localized affections as expressed by twig, bud, bark or root injury, dieback of crown, frost cracks and discoloration of internal tissues. Akin to these, but not included in this presentation, is the damage by early fall frosts to stems not yet fully hardened, and to premature growths by late spring frosts; nor are included "heaving" and so-called "winter-browning," a browning on evergreen foliage on the sun-exposed sides of crowns that takes place in late winter or early spring, the result of excessive loss of water from the leaves while the ground is still frozen and the roots are inactive.

Turning now to the compiled lists that follow under self-explanatory headings, it should be stated that a classification free from some overlapping and some likelihood of modification is impossible. A perusal of this introductory section, in which attention is called to natural variations and to the many ponderable and imponderable influences that affect hardiness, will afford explanations of why that is so. Further, there are examples in which injury may appear to be so much greater or so much less at the outset, than eventually materializes that incorrect initial listing results. Thus, what may seem at first to be simply a non-fatal dieback or a temporary inhibition of buds may be of such a nature that subsequent growth is never satisfactory and a year or two hence the plant dies. Indeed, especially with introduced species, experience alone over a long period of years is essential before one knows their reactions and can unfailingly interpret their manifestations under the various conditions and treatments in their new environment. Another difficulty arises from the circumstance that a species recognized under a commonly accepted name may actually comprise several unrecognized or unnamed strains differing inherently from one another in hardiness. The history of at least some of these would probably reveal that they represent strains of dissimilar geographical origin. Not so perplexing, yet worthy of mention, are those woody plants, both native and introduced, that die back more or less every winter because of their habit of continuing growth until checked by frost; in the course of the winter these always die back to the "ripened" wood. It is planned to extend and perfect these above mentioned lists as opportunity affords.

A third section of this article is devoted to advice on the treatment of winter-injured plants and to a discussion of practical procedures in preparing and in protecting trees and shrubs so as to enable them best to resist the inclemencies of winter.

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II

1. Plants killed at the Arnold Arboretum in the winter of 1933-34.

<i>Acanthopanax Simonii</i>	<i>Helianthemum glaucum</i>
<i>Berberis atrocarpa</i>	<i>Stoechadifolium</i>
<i>Berberis pruinosa longifolia</i>	<i>Hypericum Hookerianum</i>
<i>Chaenomeles lagenaria cathayensis</i>	<i>Juglans regia</i>
<i>Cladrastis Wilsonii</i>	<i>Ligustrum Quihoui</i>
<i>Colutea arborescens bullata</i>	<i>Picrasma quassioides</i>
<i>Cytisus multiflorus</i>	<i>Platycarya strobilacea</i>
<i>Cytisus scoparius</i>	<i>Polygonum Auberti</i>
<i>Cytisus scoparius Andreanus</i>	<i>Prunus avium plena</i>
“ <i>Compacta</i> ”	<i>Prunus Lannesiana affinis</i>
<i>Euptelea Franchetii</i>	<i>Prunus Padus Purdomii</i>
<i>Exochorda macrantha</i>	<i>Prunus serrulata horinji</i>
<i>Helianthemum alpestre</i>	<i>Sinowilsonia Henryi</i>
<i>Helianthemum nummularium</i>	<i>Sorbaronia Dippelii</i>
“ <i>Carmine Queen</i> ”	<i>Viburnum ovatifolium</i>

2. Plants killed to the ground at the Arnold Arboretum in the winter of 1933-34.

<i>Abelia Engleriana</i>	<i>Berberis Wilsonae Stapfiana</i>
<i>Acanthopanax setchuenensis</i>	<i>Berberis Wilsonae subcaulialata</i>
<i>Actinidia melanandra</i>	<i>Berchemia racemosa</i>
<i>Akebia trifoliata</i>	<i>Callicarpa Bodinieri Giralddii</i>
<i>Ampelopsis brevipedunculata elegans</i>	<i>Callicarpa dichotoma</i>
<i>Baccharis halimifolia</i>	<i>Callicarpa japonica</i>
<i>Benzoin praecox</i>	<i>Campsis chinensis</i>
<i>Berberis aemulans</i>	<i>Caragana Boisii</i>
<i>Berberis aggregata</i>	<i>Ceanothus americanus</i>
<i>Berberis aggregata Prattii</i>	<i>Ceanothus Fendleri</i>
<i>Berberis aggregata recurvata</i>	<i>Ceanothus pallidus roseus</i>
<i>Berberis candidula</i>	<i>Celastrus hypoleuca</i>
<i>Berberis dictyophylla</i>	<i>Celastrus Loeseneri</i>
<i>Berberis Francisci-Ferdinandi</i>	<i>Celastrus Rosthorniana</i>
<i>Berberis Gagnepainii</i>	<i>Celastrus rugosa</i>
<i>Berberis Julianae</i>	<i>Clematis paniculata</i>
<i>Berberis polyantha</i>	<i>Clerodendron trichotomum</i>
<i>Berberis sanguinea</i>	<i>Colutea arborescens</i>
<i>Berberis Soulieana</i>	<i>Colutea cilicica</i>
	<i>Colutea media</i>

<i>Colutea orientalis</i>	<i>Deutzia magnifica eburnea</i>
<i>Cornus kousa</i> . Younger plants were uninjured.	<i>Deutzia magnifica erecta</i>
<i>Cornus kousa chinensis</i>	<i>Deutzia magnifica gracillima</i>
<i>Cornus paucinervis</i>	<i>Deutzia magnifica latiflora</i>
<i>Coronilla emeroides</i>	<i>Deutzia maliflora</i> "Avalanche"
<i>Coronilla Emerus</i>	<i>Deutzia mollis</i>
<i>Corylopsis platypetala</i>	<i>Deutzia myriantha</i>
<i>Corylopsis spicata</i>	<i>Deutzia reflexa</i>
<i>Corylopsis Veitchiana</i>	<i>Deutzia rosea</i>
<i>Cotoneaster affinis bacillaris</i>	<i>Deutzia rosea campanulata</i>
<i>Cotoneaster bullata macrophylla</i>	<i>Deutzia rosea eximia</i>
<i>Cotoneaster glabrata</i>	<i>Deutzia rosea floribunda</i>
<i>Cotoneaster microphylla</i>	<i>Deutzia scabra crenata</i>
<i>Cotoneaster salicifolia floccosa</i>	<i>Deutzia scabra eminens</i>
<i>Cytisus albus</i>	<i>Deutzia scabra Fortunei</i>
<i>Cytisus albus pallidus</i>	<i>Deutzia scabra</i> "John Richardson"
<i>Cytisus multiflorus</i>	<i>Deutzia scabra macrothyrsa</i>
<i>Cytisus sessilifolius</i>	<i>Deutzia scabra plena</i>
<i>Davidia involucrata</i>	<i>Deutzia scabra</i> Pride of "Roch- ester"
<i>Davidia involucrata Vilmorin- iana</i>	<i>Deutzia scabra suspensa</i>
<i>Decaisnea Fargesii</i>	<i>Deutzia scabra Watereri</i>
<i>Deutzia candida</i>	<i>Deutzia Schneideriana laxiflora</i>
<i>Deutzia carnea</i>	<i>Deutzia Sieboldiana Dippeliana</i>
<i>Deutzia carnea densiflora</i>	<i>Deutzia Vilmorinae</i>
<i>Deutzia carnea stellata</i>	<i>Deutzia Wilsonii</i>
<i>Deutzia discolor</i>	<i>Diervilla hortensis</i>
<i>Deutzia discolor major</i>	<i>Diervilla praecox</i> "Avant- garde"
<i>Deutzia elegantissima</i>	<i>Dipelta floribunda</i>
<i>Deutzia elegantissima fascicu- lata</i>	<i>Dipelta floribunda parviflora</i>
<i>Deutzia glomeruliflora</i>	<i>Dipelta ventricosa</i>
<i>Deutzia hybrida</i> "Contraste"	<i>Evonymus patens</i>
<i>Deutzia hybrida</i> "Magicien"	<i>Evonymus Wilsonii</i>
<i>Deutzia kalmiaeflora</i>	<i>Forsythia suspensa atrocaulis</i>
<i>Deutzia longifolia</i>	<i>Forsythia suspensa Fortunei</i>
<i>Deutzia longifolia Veitchii</i>	<i>Forsythia viridissima</i>
<i>Deutzia longipetala</i>	<i>Genista cinerea</i>
<i>Deutzia macrocephala</i>	<i>Genista hispanica</i>
<i>Deutzia magnifica</i>	<i>Genista pilosa</i>

<i>Grewia parviflora</i>	<i>Lonicera trichosantha acutius-</i> <i>cula</i>
<i>Helwingia japonica</i>	<i>Lonicera Vilmorinii</i>
<i>Holodiscus discolor</i>	<i>Lycium chinense</i>
<i>Holodiscus discolor ariaefolius</i>	<i>Meliosma Beaniana</i>
<i>Hovenia dulcis</i>	<i>Neillia affinis</i>
<i>Hydrangea quercifolia</i>	<i>Neillia sinensis</i>
<i>Hypericum arnoldianum</i>	<i>Neillia thibetica</i>
<i>Hypericum Kalmianum</i>	<i>Parrotiopsis Jacquemontiana</i>
<i>Indigofera amblyantha</i>	<i>Periploca graeca angustifolia</i>
<i>Indigofera decora alba</i>	<i>Philadelphus argyrocalyx</i>
<i>Indigofera Gerardiana</i>	<i>Philadelphus Lemoinei</i>
<i>Indigofera Kirilowii</i>	<i>Philadelphus subcanus</i>
<i>Itea virginiana</i>	<i>Physocarpus capitatus</i>
<i>Kerria japonica</i>	<i>Physocarpus glabratus</i>
<i>Kerria japonica picta</i>	<i>Physocarpus malvaceus</i>
<i>Kerria japonica pleniflora</i>	<i>Poncirus trifoliata</i> . Killed to the ground in some places, else- where uninjured.
<i>Leptodermis oblonga</i>	<i>Prunus mira</i>
<i>Lespedeza Buergeri praecox</i>	<i>Pterocarya hupehensis</i>
<i>Lespedeza cyrtobotrya</i>	<i>Rhododendron</i> "Album splen- dens"
<i>Lespedeza formosa</i>	<i>Rhodotypus scandens</i>
<i>Ligustrum acuminatum</i>	<i>Ribes Vilmorinii</i>
<i>Ligustrum ovalifolium</i>	<i>Rosa arnoldiana</i>
<i>Lonicera chaetocarpa</i>	<i>Rosa caudata</i>
<i>Lonicera deflexicalyx</i>	<i>Rosa centifolia cristata</i>
<i>Lonicera discolor</i>	<i>Rosa centifolia muscosa</i>
<i>Lonicera fragrantissima</i>	<i>Rosa centifolia muscosa</i> "Salet"
<i>Lonicera Giraldii</i>	<i>Rosa damascena trigintipetala</i>
<i>Lonicera gracilipes</i>	<i>Rosa damascena versicolor</i>
<i>Lonicera gynochlamydea</i>	<i>Rosa dumetorum Deseglisei</i>
<i>Lonicera Henryi</i>	<i>Rosa filipes</i>
<i>Lonicera involucrata flavescens</i>	<i>Rosa gallica officinalis</i>
<i>Lonicera involucrata serotina</i>	<i>Rosa Gentiliana</i>
<i>Lonicera Ledebourii</i>	<i>Rosa Helenae</i>
<i>Lonicera Myrtillus</i>	<i>Rosa Lheritierana</i>
<i>Lonicera Periclymenum</i>	<i>Rosa mollis arduensis</i>
<i>Lonicera Periclymenum belgica</i>	<i>Rosa multibracteata</i>
<i>Lonicera quinquelocularis trans-</i> <i>lucens</i>	<i>Rosa multiflora cathayensis</i>
<i>Lonicera saccata</i>	
<i>Lonicera Standishii lancifolia</i>	
<i>Lonicera subdentata</i>	

Rosa Noisettiana	Spiraea japonica acuminata
Rosa omeiensis	Spiraea Miyabei glabrata
Rosa Pouzinii	Spiraea revirescens
Rosa rugosa Chamissonis	Spiraea Rosthornii
Rosa rugosa "New Century"	Spiraea Sargentiana
Rosa rugosa "Nova Zembla"	Spiraea semperflorens
Rosa rugosa "Parfum de l'Hay"	Spiraea Veitchii
Rosa rugosa Schweinitzii	Spiraea Zabeliana
Rosa "Ruskin"	Staphylea colchica
Rosa sericea	Staphylea colchica Coulombieri
Rosa spinosissima "Dominie Sampson"	Staphylea holocarpa
Rosa spinosissima "Iris"	Stephanandra incisa
Rosa spinosissima "King of the Scots"	Stephanandra Tanakae
Rosa spinosissima "Plato"	Symphoricarpus Chenaultii
Rosa spinosissima "Pythagoras"	Viburnum betulifolium
Rosa tomentella obtusifolia	Viburnum erubescens
Rosa villosa	Viburnum hupehense
Rosa villosa duplex	Viburnum ichangense
Rosa villosa recondita	Viburnum mongolicum
Rosa Waitziana macrantha	Viburnum ovatifolium
Rosa Watsoniana	Viburnum rhytidophyllum
Sorbaria arborea subtomentosa	Viburnum tomentosum grandi- florum
Spiraea Billiardii	Viburnum Veitchii
Spiraea blanda	Vitis Champini
Spiraea brachybotrys	Vitis Davidi
Spiraea fontenaysii alba	Vitis Piasezkii Pagnuccii
Spiraea Henryi. Some not in- jured, others more or less so.	Vitis pulchra
	Zanthoxylum schinifolium
	Zanthoxylum simulans

(*To be continued*)



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