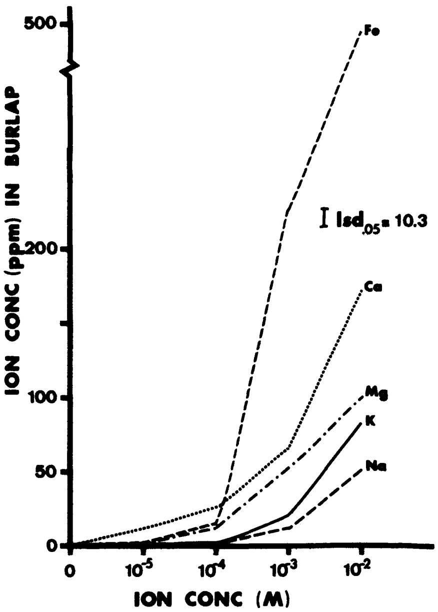

Fig. 2. Concn of 5 treatment cations in or on $CuSO_4$ treated burlap after leaching for 24 hr in solutions containing 5 concn of 5 chloride salts.

the results expected for an ion exchange situation. Burlap treated with $CuSO_4$ was acting primarily as an ion exchange medium, and H ions would be expected to behave as any other monovalent cation (1).

Of the 6 cations treated only Cu as the chloride or sulfate salt was able to protect burlap from decay during a 1 month soil burial (Table 2). Burlap whose Cu concn was reduced by ion replacement would thus be subject to deterioration when in contact with the soil.

The leachate from various holding media might also be expected to influence water quality in contact with the media. Table 3 shows the differences in water quality as influenced by leaching 12 media. Ranges for various ions in the leachates are as follows: Fe, 0–8 × 10^{-5}M (0 to 5 ppm); Ca, 7–770 × 10^{-5}M (3–308 ppm); Mg, 1–802 × 10^{-5}M (0.2–195 ppm); K, 2–612 × 10^{-5}M (1–240 ppm); and Na, 26–313 × 10^{-5}M (6–72 ppm). The ion concn of Ca and Mg were high enough (50 × 10^{-5}M) to displace Cu in the $CuSO_4$ treated burlap (Fig. 2). Copper was not at a detectable level in leachates from any of the tested media. Replacement of Cu in the burlap would be favored by low concn of end product (Cu ion in the leachate) (5). High levels of Ca, Mg and Fe in the leachate combined with low Cu levels imply the necessity of choosing the proper material to "heel in" plants in order to get the best results from the Cu treatment. River sand was the only medium tested which was low enough in Ca and Mg that the life expectancy of $CuSO_4$ treated burlap might not be adversely affected.

Our results indicate that many factors influence burlap life expectancy other than Cu source. Water quality, irrigation frequency and holding media all play roles as does temp which was previously reported (7).

Table 2. Break strength of 254 g/m² burlap treated with 0.2% cation solutions after soil burial for 1 month.

Source	Break strength^z (kg)
Control	1
$CaCl_2$	4
$CuCl_2$	33
$FeCl_3$	2
KCl	3
NaCl	4.5
$MgCl_2$	1
$CuSO_4$	27
$FeSO_4$	2
Na_2SO_4	3
$MgSO_4$	4
K_2SO_4	3

ᶻBreak strength of 4.5 kg is necessary for marginal effectiveness in holding a 40 cm root ball together.

Table 3. The concn of 6 cations in leachates of various holding media following a 24 hr leaching with 5 ml of double distilled H_2O per g of media.

	Ion concn (1 × 10^{-5}M) in leachate					
Treatment	Fe	Ca	Na	K	Mg	Cu
Control	0	0	0	0	0	0
River sand	2.44	7.11	25.88	2.37	0.93	0
Pine nuggets	0.18	61.81	26.10	175.82	34.45	0
Pine bark	1.66	117.76	40.24	191.81	72.60	0
Cypress mulch	0.42	59.26	54.81	103.58	48.33	0
Conifer shavings	0.44	95.37	201.18	173.26	39.49	0
Conifer sawdust	0	205.71	88.63	147.05	106.43	0
Hardwood chips	0.95	195.11	36.18	63.04	67.66	0
Hardwood sawdust	0	220.56	71.34	141.94	142.93	0
Undecayed leaves	1.24	574.47	813.18	612.50	802.59	0
Decayed leaves	0.77	770.96	32.19	372.10	428.29	0
Peat moss	7.89	118.08	44.80	63.04	104.06	0
LSD 5%	0.36	63.90	47.43	93.80	39.47	

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Root Hardiness of Woody Ornamentals[1]

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Additional index words. container plants

Abstract. **Root hardiness is reported for 38 container-grown woody ornamentals taken from commercial nursery storage in mid-winter. Lethal root temperature ranged from –5° to –23.3°C.**

Cold injury of roots is a serious problem in the over-wintering of plants in nursery containers and in raised planters in northern regions. Estimates of winter cold hardiness of the roots of woody ornamentals are needed by nurserymen for planning winter storage protection for container nursery stock and for selection of plants to be used in raised landscape planters. The root hardiness of relatively few woody species have been reported in the literature: *Ilex crenata* Thunb. (1), *Taxus cuspidata* Sieb. & Zucc. (2), *Lonicera tatarica* L., *Cotoneaster horizontalis* Decne., *Ligustrum obtusifolium* Sieb. & Zucc., *Euonymus europaeus* L. (3), *Forsythia intermedia* Zab., *Cornus alba* L. (4), *Juniperus chinensis* L. cv. Hetzi (5).

The root hardiness tests were conducted over a 5-year period using plants in mid-winter from storages of local nurserymen. All plants were dormant and had been exposed to near freezing or below freezing temp. Most were in 2-liter containers; ground covers were in approx 200 ml containers. Deciduous plants and ground covers were 1 or 2

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year, evergreens 2 or 3 years from rooted cuttings or liners. Five plants in containers were tested at each of several temp, generally at 2.8°C intervals between −3.9° and −15.0°, in darkness in a 1.26 m^3 growth chamber, using a YSI Thermistemp Model 63RC temp controller. The cooling rate was 0.7°/hr after the media was frozen. For tests below −15.0°, root balls were shifted to solid containers and immersed in a circulating methanol-water bath where media cooled at 1.5°/hr. Copper-constantan thermocouples were inserted in the center of the container for monitering media temp, which was assumed to equal root temp. The media were held at each test temp 4 hr, thawed at approx 2.5°, requiring 15 to 20 hr, and transferred to a greenhouse for growth. After 4 to 6 weeks, injury was estimated from condition of tops and roots. Root kill was estimated from the proportion of decaying roots. Five unfrozen control plants provided a basis for comparison and to assure that roots had not been injured prior to the tests. Killing temp (Table 1) was the highest that killed more than 50% of the total root system and reduced top growth in 3 or more plants. Temp 1.7° to 2.8°C higher than that listed killed less than 50% of the root system, and top growth was not affected.

Mityga and Lanphear (2) classified *Taxus* roots starting from the stem as primary mature, secondary mature and young roots, and concluded that young roots were not capable of significant cold acclimation. We saw a similar root classification on most plants in these tests. Observations of many plants indicated that young roots at the media-container interface could be lost without adverse affect on top growth. The killing temp in Table 1 was generally that which killed secondary mature roots.

These root hardiness estimates were obtained over several seasons with plants from different environmental exposure. It is quite possible that plants of different age or different pre-conditioning would have different root killing temp than reported here. For example, Pellett (3) found that *Cotoneaster* and *Euonymus* dug from the field and stored bare root 15 weeks at −7°C had hardier roots than plants stored at 2°. We are not aware of similar results with plants in containers. We have not been able to increase root hardiness of dormant *Magnolia, Ilex, Cornus* or *Cotoneaster* in containers by holding 1 or 2 weeks in darkness at 2° to 3° above their killing temp. In spite of the possibility of variations in root hardiness due to storage conditions, these estimates can be valuable to nurserymen as a guide to the degree of winter protection required to avoid low temp root kill.

Table 1. Root killing temp[z] of woody ornamentals.

Species	°C
Magnolia X *soulangeana* Soul.	−5.0
Magnolia stellata Maxim.	−5.0
Cornus florida L.	−6.7
Daphne cneorum L.	−6.7
Ilex crenata Thunb. Cv. Convexa	−6.7
Ilex crenata cv. Hetzi	−6.7
Ilex opaca Ait.	−6.7
Ilex crenata cv. Stokes	−6.7
Pyracantha coccinea Roem.	−7.8
Cryptomeria japonica D. Don	−8.9
Cotoneaster horizontalis Decne.	−9.4
Viburnum carlesii Hemsl.	−9.4
Cytisus X *praecox* Bean	−9.4
Buxus sempervirens L.	−9.4
Ilex glabra Gray	−9.4
Euonymus fortunei Hand.-Mazz. cv. Carrieri	−9.4
Euonymus fortunei cv. Argenteo-marginatus	−9.4
Hedera helix L. cv. Baltica	−9.4
Pachysandra terminalis Sieb. & Zucc.	−9.4
Vinca minor L.	−9.4
Pieris japonica D. Don cv. Compacta	−9.4
Acer palmatum Thunb. cv. Atropurpureum	−10.0
Cotoneaster adpressa praecox Bois & Berth.	−12.2
Taxus X *media* Rehd. cv. Nigra	−12.2
Rhododendron cv. Gibraltar (an Exbury Hyb. azalea)	−12.2
Rhododendron cv. Hinodegiri (azalea)	−12.2
Pieris japonica	−12.2
Leucothoe fontanesiana Sleum.	−15.0
Pieris floribunda Benth. & Hook.	−15.0
Euonymus fortunei cv. Colorata	−15.0
Juniperus horizontalis Moench. cv. Plumosa	−17.8
Juniperus horizontalis cv. Douglasii	−17.8
Rhododendron carolinianum Rehd.	−17.8
Rhododendron catawbiense Pursh.	−17.8
Rhododendron P.J.M. Hybrids	−23.3
Potentilla fruticosa L.	−23.3
Picea glauca Voss.	−23.3
Picea omorika Purkyne.	−23.3

[z] Highest temp that killed more than 50% of root system and reduced top growth.

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Surface Characteristics of American Elm Clones for Identification by Scanning Electron Microscopy[1]

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Additional index words. clonal identification, plant fingerprinting *Ulmus americana.*

Abstract. **Two clones of American elm (*Ulmus americana* L.), which could not be distinguished by conventional identification techniques were differentiated on the basis of combined microtopographical characteristics using scanning electron microscopy. Intraclonal variation due to environmental influences was negligible.**

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