to be ample shading to eliminate the leaf yellowing and leaf dehydration caused by the winter sun.

Root kill had not been a problem for the past 15 years until the winter of 1977. There have been winters with lower temperatures (−3°F) but none with as long a period when the roots were frozen. Few times have the root balls frozen solid. In 1977 they were frozen for 10 consecutive weeks. I have no solution for this problem without going to plastic house protection or mulching around the containers. Both are costly and are contrary to my method of operation.

Frost protection is provided by Rainbird sprinklers. At the Florida nursery the pump is actuated by a heating thermostat set at 33°F. During the winter of 1977 this functioned several times. During the worst freeze, the temperature was 27°F for 10 hours and 1/2 inch of ice was formed on the plants with no observable damage. In North Carolina the pumps are operated manually for frost protection.

Last year we also tried covering the plants with burlap. However, this was not too successful. We may have been late putting it on or may have left it on too long (mid-March). At any rate, it was not as effective as we had expected.

One additional problem we seem to have is that of hiring people who are conscientious about helping implement some of our procedures. Unfortunately, none of our methods prevented serious losses last winter.

WINTER PROTECTION OF NURSERY PLANTS: 1956-1977 SUMMARY

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Disastrous effects of freezes in the South in 1950, 1962-1963, and 1977, have stimulated research at the Ornamental Horticulture Field Station in Mobile. Results have often been skimpy due to lack of freezes. Usually, the experiments have been set up hastily when severe freezes were predicated or immediately thereafter.

The results of numerous laboratory and field tests have revealed the following facts regarding protection of container-grown plants from freeze injury:

1. The freeze rate varies with the type of potting mixture ingredients. The rate of freeze is fastest for sandy clay, inter-

mediate for spent wood (charcoal and sand from burned pine stumps), and slowest for German peat moss. By incorporating generous quantities of peat moss or charcoal with the potting mixture, many additional hours of freeze protection can be built into a potting mixture (6). The mixtures that freeze fastest also thaw fastest, causing undue rupturing of roots, which kills the plants (8).

2. Freeze and thaw is fastest inside the can, near the top and at the outer edges, and slowest in the center of the can near the bottom (7).

3. The rate of thaw following a freeze is affected by the color of the container. *Ilex crenata* 'Helleri' liners were grown from July, 1959, to August, 1960. Plants in white cans had the greatest survival, followed closely by aluminum and green cans. Survival was poorest in black cans with half of the plants being lost to cold injury. The percent increase in growth over that of plants in black cans for each of the other colors was as follows: white, 87; aluminum, 57; and green, 36 (4). In a previous test from September, 1958 through spring, 1959, root injury was greater on *Ilex crenata* 'Rotundifolia' growing in black cans set on 3 inches of shavings, than on those set directly on the ground. Greatest winter injury occurred in black cans, followed by green, aluminum, and least in white (3).

One-year loquat seedlings grown in green, black, and unpainted cans under nursery conditions in the field indicated container temperatures were affected by can color, position of can in beds, exposure to solar radiation, and soil moisture content. The highest soil temperatures occurred in the western side of cans that were in the outer rows of beds and in the rows having western and southwestern exposures. Soil temperatures in cans in the middle of the beds and in outer rows facing north were near air temperatures or several degrees cooler. Soil temperatures on the western side of fully-exposed cans were highest (10° to 15°C above air temperatures) in black containers, lowest (2° to 5°C above air temperatures) in unpainted containers, and intermediate (4° to 10°C above air temperatures) in green containers. Temperatures in dry soils were 4° to 7°C warmer than temperatures in soils of optimum moisture content (12).

A test in the summer of 1972 revealed soil temperatures were influenced by color, composition, and size of the container. A black plastic Lerio 7-in. can was 9.3°F cooler on the hot side in the a.m. and 1.4° hotter in the p.m. than a comparable 6-in. can. In the a.m., a white 6-in. metal can was 7° cooler than a green, and 11.4° cooler than a black metal can. The coolest pots were 8-in. Pullen papermache pots, which were

8.3° cooler for a light brown pot and 6.6° cooler for a dark brown pot (11).

4. Polystyrene liners used inside the can retarded both freezing and thawing of the root ball of plants. In a field test, the liners increased survival by 17.8, 24.4, and 31 percent, respectively, for *Ilex crenata* 'Rotundifolia', *I. cornuta* 'Burfordii', and *I. crenata* 'Helleri'.

5. Shavings mulches under the containers were responsible for much of the freeze injury to nursery stock during the 1961-1962 freezes. A 3-inch shavings mulch on a morning when the low was only 25°F reduced the soil temperature at the bottom of the can to that of the air temperature, whereas the temperature under the cans sitting directly on the soil was 36°F, or 11°F higher than the temperature under the cans sitting on shavings. A 3-inch shavings mulch inside a double-lined plastic house lowered the temperature 5°F below that in an identical house having no shavings mulch (3). Plastic or roofing paper also serves as a barrier.

6. A mulch over the cans retains ground heat and gives some winter protection. However, this same mulch results in increased frost damage on clear nights when the air temperature is in the neighborhood at 32°F. The mulch prevents upward radiation of heat from the soil to replace that lost from above the shavings (9).

7. Leafdrop of azaleas and other ornamentals was prevented with monthly applications of 6-8-8 complete fertilizer into the winter, and resulted in no winter injury (2).

8. Dolomitic lime at 6 pounds per cubic yard improved growth and winter hardiness of 8 species of plants treated; 12 pounds had no apparent ill effect on azaleas. Omission of lime resulted in tip burn of *Ilex crenata* 'Rotundifolia' and complete kill of *Buxus* sp., *Cornus florida*, *Gardenia* sp., *Pittsporum* sp., *Podocarpus* sp., and *Rhododendron* sp. (5). The newer slow-release fertilizers, plus complete preplant mix, should be the best approach.

9. Cold damage to camellias was greater in mixes of 3 bark: 1 shale amended with soil rather than sand (13).

10. Ten pounds of Osmocote 18-5-11, plus a potting soil mix (Special 8) containing 10 pounds dolomite, 2 pounds gypsum, 1/4 pound of 008 micronutrients, and 1/4 pound of Chlordane 10G, gave adequate growth and comparable cold protection to camellias in the mixes containing 15 and 20 pounds of 18-5-11 (13).

11. Antitranspirants (antidessicants) have given variable results when used for winter protection under mild winter condi-

tions. Responses have varied from slight retardation of growth to increases up to 50 percent with 12.5% WiltPruf. They have given considerable protection from severe, sudden freezes or from the after-effects of these freezes resulting from top dessication before new roots can be regenerated.

Several other antidessicants improved growth of *Photinia* × *fraseri* from 10 to 60% when applied 3 weeks before a sudden freeze (10).

In 1977, Exhalt 800 (1:10), WiltPruf (1:10), and Exhault 410 (1:5) all gave protection of the tops of dwarf burford holly until new roots could be regenerated. Best results were associated with transplanting to larger containers (14).

12. Chemical treatments other than antitranspirants have given some winter protection. Effects of a particular treatment have varied with the plant species. A combination of potassium bromide, calcium chloride, and potassium nitrate, plus naphthaleneacetic acid and Cycocel sprays, increased top growth of Coral Bell azalea 60 and 20%, respectively. B-9, KNO_3, and Sul-Po-Mag gave increases of 50, 50, and 66.6% on Pink Supreme azalea. Additional research is needed on the possible winter protection from various chemical treatments (1).

13. The best approach to winter protection of container plants appears to be to jam the cans together, put a protective border (soil-filled container, paper or plastic barrier, shavings, or straw mulch) around them, treat with one of the antidessicants, transplant to larger containers if plants are extremely root-bound, preferably before a freeze. Transplanting after the freeze will allow regeneration of new roots from within the old rootball (14). Fertilize adequately, but not excessively, as excess amounts burn the roots, and shade the plants if at all practical. Wind barriers are also very beneficial.

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QUESTION BOX

The Southern Region Question Box was moderated by Dr. Richard Stadtherr.

MODERATOR STADTHERR: Which is more harmful to plants after a 6°F temperature, a fast thaw or a slow thaw?

DR. JAKE TINGA: If the root ball is frozen, slow thawing of the shoots would be more compatible with the slow thaw of the roots. If you could thaw the roots as fast as the shoots, there would be no problem. Slow thawing of the shoots would reduce transpiration. Turn the water on before freezing starts; keep the water on until all ice has melted. This layer keeps the surface at 32°F (cell damage begins at 28°F) and also prevents dessication. If the sun hits a dry leaf and it transpires, and there is no available liquid water to come through the frozen root and stem, the leaf dessicates and dies. However, I do not think you can hold a plant at 6°F. I think the limit is about 20°.

CHARLIE PARKERSON: Dr. Robert Wright told us today that roots freeze before the tops. How can roots freeze first?

MODERATOR STADTHERR: Roots do not have the ability to go into rest. They do not withstand as low temperatures as the tops, but in the ground they have protection from the soil warmth. Roots of canned plants have less protection.

GARY HUTT: Is it better to leave plants jammed or leave them apart to thaw out quickly?

KERMIT NORRIS: In the Mobile area the temperature went down to 10°F. I didn't jam anything except young material that was potted up early in the fall. Winter damage was noted on this young material. Other plants that were left spaced came