Significance to the Nursery Industry

The low tolerance of retail nursery customers for American arborvitae defoliated by bagworm has strong implications for developing pest management strategies. Retail customers are discriminating shoppers. They will generally not purchase plants they recognize as damaged. A reasonable goal for nurserymen should be to minimize the defoliation on their plants during the period of sale. Prior to the time of sale higher levels of damage may be tolerated provided that the plant can recover before it is marketed.

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Clear and White Plastics for Freeze Protection of Landscape Plants in the Southern to Mid-Atlantic Region[1]

R.E. Young, J.L. Dunlap, Jr., D.J. Smith and S.A. Hale[2]
Agricultural Engineering Department
Clemson University
Clemson, SC 29634

Abstract

Rapid, wide fluctuations in winter temperatures in Mid-Atlantic and Southern states can result in severe damage to container grown landscape plants. Freezes on Christmas Day, 1983 and January 21, 1985 left nurserymen in this region with multimillion dollar losses and an interest in low-cost freeze protection methods. This study examines the cold protection properties of white copolymer and clear poly 6 mil plastics for covering unheated propagation hoop houses and for wrapping container growing beds. Soil, canopy, house ambient and outside temperatures were collected by computer on 15 minute intervals for a 3 month period. Diurnal temperature fluctuations were 1.5 to 2 times greater in clear poly than white copolymer. Double layer plastic coverings maintained minimum soil and canopy temperatures significantly higher than single layer structures. White copolymer wrapping of growing beds afforded root protection to Asian jasmine (*Trachelospermum asiaticum* Lem.) and Burford holly (*Ilex cornuta* Lindl 'Burford Nana') with some border damage; Wiltonii juniper (*Juniperus horizontalis* Moench. 'Wiltonii') did not need covering. White copolymer offers greater freeze protection at a lower cost.

Index words: freeze protection, clear plastic, white plastic, landscape plants, single layer, double layer, plastic coverings, overwintering, cold protection

Introduction

Increasing inventories of container grown nursery stock have occurred because of greater plant densities, lower labor costs per plant, and better control of media composition to optimize plant growth. Weather, however, has proved challenging to producers of container plants, particularly during record cold events like that which occurred January 21-22, 1985 (11, 16, 17). Above-ground roots in nursery containers are vulnerable to freezing, particularly in Southern to Mid-Atlantic climates where cold days may be immediately preceded by relatively warm days during winter months. In response to multi-million dollar losses of plant materials from the 1983 and 1985 freezes (3, 9, 16), Southern and Mid-Atlantic nurserymen are eagerly seeking low-cost freeze protection methods. In cooperation with Carolina Nurseries of Moncks Corner, South Carolina, Clemson University conducted a comparative study of clear and white plastic films as freeze protection devices for container grown plants.

The clear disadvantage of container grown landscape plants over field grown stock, however, is increased susceptibility to root damage from cold weather exposure. Roots of most plants do not develop the same level of root hardiness as the shoots (10). Yet, in containers, roots are also exposed to lower, above-ground temperatures during a freeze.

Havis (7) published a list of minimum safe root temperatures and killing root temperatures for 30 woody species commonly produced in containers. In 1976, Havis (8) extended his list to show root killing tempera-

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[2] Professor, Instrument Supervisor, Meteorologist, Visiting Instructor, resp.

tures of 38 woody landscape plants. He found roots of *Ilex crenata* to be killed at -7°C (19°F), and *Juniperus horizontalis* killed at -18°C (0°F). Studer, et al., (14), published root killing temperatures for an extended list of approximately 50 commonly container grown landscape plants. After artificial acclimation in a controlled growth chamber, killing root temperatures were observed at approximately -4°C (25°F) for *Ilex cornuta,* -5°C (23°F) for *Ilex crenata,* and -11 to -20°C (12 to -4°F) for *Juniperus horizontalis.*

Smith (1, 13) stressed the importance of enhancing the natural acclimation of container grown plants for freeze protection. Autumn acclimation and spring deacclimation need to be properly synchronized to minimize freeze injury. Excessive fertilization and irrigation in early fall must be avoided to prevent prolonging the growing season, yet plants entering winter protection must be in good health and not underfertilized or underwatered. Smith (12, 13, 14) also recommended use of white or milky poly film over clear or painted clear films for winter protection structures. Moreover, he stated that double layer structures with a forced air layer between offered more effective protection than a single layer structure.

Gouin and Link (5) concluded that Japanese holly (*Ilex crenata* Thumb.), cherry laurel (*Prunus laurocerasus* L.), and dense cotoneaster (*Cotoneaster congestus* Bak.) wrapped under microfoam thermo-blankets in Maryland overwintered better and grew larger the following growing season than plants in small shelters covered with single layer, 4 mil white poly film. Gouin (6) noted that premature flowering and early spring growth frequently experienced under structureless thermoblanket wrapping could be reduced by covering the micro-foam with black poly film. Black plastic covering, however, appeared to damage some plant varieties under microfoam. In Kentucky, Duncan and McNeil (4) observed that foam-type covers were superior to polycovered frames for overwintering protection of containers of nursery stock in central and northern climates expecting low temperatures between -10 to -20°C (14 to -4°F).

Bonaminio and Bir (2) found that single white copolymer film structures were more effective than single clear polyethylene film structures for over-winter survival of liners of false holly (*Osmanthus heterophyllus*), Andorra Compacta juniper (*Juniperus horizontalis* 'Plumosa Compacta'), Nellie R. Stevens holly (*Ilex x* 'Nellie R. Stevens'), Fraser's photinia (*Photinia fraseri*), and flowering dogwood (*Cornus florida*). No plant survival differences were observed between 4 mil and 6 mil thicknesses in either clear or white plastics. White copolymer was more effective than clear polyethylene in tempering variations between maximum and minimum soil and ambient temperatures.

Research reported in this paper consisted of two concurrent studies of freeze protection structures for propagation liners and for 3l (#1) containers. The objectives of each study were as follows:

- To compare the effectiveness of clear polyethylene and white copolymer, single and double layer plastics on hoop (quonset style) houses to protect propagation liners from freeze damage.
- To evaluate the freeze protection effectiveness of white copolymer plastic film wrapped around growing beds of three plant varieties in 3l (#1) containers.

Methods and Materials

Temperature, solar radiation, and root bioassay data were collected from hoop houses with propagation liners and from growing beds with 3l (#1) containers.

The hoop houses were 4.4 x 45.7m (14 x 150 ft) with a north-south orientation and a door in the south end. They were located among a larger grouping of parallel hoop houses spaced approximately 0.6m (2 ft) apart. Five adjacent houses were used for the experiments:

- The westerly-most Unit 1 was covered with a clear polyethylene tube (double layer) of 6 mil Visqueen Model 1504, UV inhibited plastic inflated by a forced air blower;
- Unit 2 was covered by double layer, 6 mil Visqueen Model 1504 white copolymer polyethylene film, also inflated by a forced air blower;
- Unit 3 was covered by a single layer, 6 mil clear poly; and
- Units 4 & 5 were covered by single layer, 6 mil white copolymer.

All units were stocked with flats of propagation liners. Crape myrtle (*Lagerstroemia indica*) rooted cuttings were used in Units 1-4. Unit 5 contained dwarf Burford holly (*Ilex cornuta* Lindl. 'Burford Nana') and roundleaf Japanese holly (*Ilex crenata* Thumb. 'Rotundifolia') rooted cuttings. An uncovered grouping of crape myrtle was placed outside the north end of one house for a test control. All plants were potted in a medium of pine bark and sand (4:1 by vol).

A separate, concurrent experiment was conducted in an east-west oriented, 12.2 x 54.9 m (40 x 180 ft) growing bed of 3l (#1) containers. A 0.6 m (2 ft) wide vacant aisle was left in the middle of this bed in the long direction. Single layer, white copolymer (Visqueen Model 1505), 6 mil plastic was wrapped directly over the canopy of the plants and rolled and staked along the perimeters of the beds. Gravel-filled containers were placed on top of the plastic in the center aisle to secure it. From east to west, respectively, approximately 12 m (40 ft) long groupings of 3 plant varieties were placed in this growing bed: Asian jasmine (*Trachelospermum asiaticum* Lem.), Wiltonii juniper (*Juniperus horizontalis* Moench. 'Wiltonii'), and dwarf Burford holly (*Ilex cornuta* Lindl. 'Burford Nana'). An uncovered section of single rows of all three varieties was placed at the east end of the bed for test controls. All plants were watered to field capacity before being covered. Plants in 3l (#1) containers were also in a medium of pine bark and sand (4:1 by vol).

A common microcomputer-based data acquisition system was designed to measure and record on 15 minute intervals output of 33 thermocouples in the hoop house experiment, 36 thermocouples from the growing beds study, and an outside temperature thermocouple. The main components of the system were the thermocouples, a thermocouple channel selector, a digital temperature indicator, two parallel input/output interface cards, and an IBM-PC microcomputer.

Thermocouples were made from Type T, copper-constantin, 24 AWG polyvinyl chloride insulated wire. For the hoop house experiment, 6 thermocouples were placed in each house, 3 in each of 2 locations. In both the center and the north ends of each house, a thermocouple was placed in each of the following positions: (1) approximately in the center of the soil in a liner, (2) in the canopy of the plant, and (3) approximately 0.9 m (3 ft) above the ground for house ambient readings. On the north end, the soil and canopy thermocouples were placed in liners in the northwest corner while the ambient thermocouple was placed in the center aisle. In the center of each house, all thermocouples were placed near the aisle. Four thermocouples were placed in the uncovered control flats—one each in the soil and canopy of a liner in the northwest corner and a liner in the center.

In the growing bed experiment, 8 thermocouples were placed in each of 3 plant varieties, 2 in each of 4 locations across the bed. One thermocouple was placed approximately 76 mm (3 in) deep in the soil near the center of the container and another in the canopy of the plant. These pairs of thermocouples were placed in a container in the outside row on the north side, in the center of the north half of the bed, in the aisle row of the south half of the bed, and in the outside row on the south side. For controls, soil and canopy pairs of thermocouples were placed in containers of each plant variety on the north edge and in the center of the uncovered block of containers.

A thermocouple, shielded from direct solar radiation, was mounted on a pole outside the hoop houses to measure outside temperatures for both experiments.

Thermocouple readings were multiplexed sequentially every 5 minutes through an Acromag channel selector control. Each reading of a thermocouple was converted from analog to BCD (binary coded decimal) form through a Thermo Electric digital temperature indicator Model ELPH-3. Two Metrabyte Model PI012, 24-bit parallel interface cards in the computer interpreted signals for temperature readings (from the temperature indicator) and for thermocouple numbers (from the Acromag channel selector). The IBM-PC computer refreshed its monitor screen with every 5 minute reading of thermocouples and recorded every third, or 15 minute, reading to a diskette. Diskette data were downloaded onto a mainframe computer for statistical analyses by SAS (Statistical Analysis Systems).

The amount of energy transmitted in through single and double layers of white copolymer was determined using daily direct solar radiation measurements. LI-200SB pyranometers were placed at a height of 1 m (3 ft) inside Unit 2 (double, white) and Unit 4 (single, white) and at a height of 2.5 m (8 ft) outside. Hourly average solar radiation measurements were taken using a Campbell Scientific CR-21 micrologger. Incident radiation from the two hoop houses was analyzed and compared to radiation observed outside to determine differences between single and double layer plastic coverings.

Root health of tagged plants in the experiments was evaluated for each treatment at the beginning of tests in December, 1985 and at the conclusion in March, 1986. In the hoop houses, 5 liners were tagged along the outside edges of plants in the northwest corner and 5 other liners in the center of the beds near the center of the house. Similarly, 10 plants were also tagged in the uncovered control liners. For the growing beds study using 3l (#1) containers, 5 plants each were tagged for the 3 varieties in the north edge, the center of the north half of the bed, the aisle, and the south edge. Similarly, 3 plants each were tagged for the 3 varieties in the north edge and the center of the north half of the beds for uncovered controls.

Root condition was assessed and rated by inspection of the root ball and by microscopic slide mounts of roots. The following subjective (visual) scale was used to rate root health:

1—Healthy, white roots
2—25% discoloration
3—50% discoloration
4—75% discoloration
5—100% discoloration; dead roots.

The most appropriate number was ascribed to each root sample inspected. Consequently, a higher number indicated greater freeze damage to the roots. To isolate freeze damage from pathogenic damage, root samples were subjected to an acid fuchsin-lactophenol stain and observed under a microscope.

Results and Discussion

Comparisons were made among means of daily minimum, maximum, mean and difference between maximum and minimum temperatures for all thermocouples in both the hoop house and growing bed experiments. Means of root ratings were also compared among treatments for both experiments.

Hoop Houses. Mean daily differences between maximum and minimum soil temperature were significantly greater by approximately 3-6°C (5-10°F) in the northwest corners than in the centers for all types of house coverings (Fig. 1). Average daily minimum soil temperatures were significantly lower by about 3-5°C (5-9°F) in the northwest corners than in the centers of all houses (Fig. 2). Although slightly significant at the 5 percent level, mean daily maximum soil temperature gradients were not consistently different between house locations within respective houses (Fig. 3). Since there were appreciable soil temperature gradients from edge to center in plastic covered hoop houses at low temperatures, perhaps one should consider additional insulation around the lower perimeters.

Further statistical observations of Figures 2 and 3 revealed that for both clear and white plastics, double layer coverings resulted in significantly higher minimum soil temperatures and significantly lower maximum soil temperatures. In addition to soil temperatures, canopy temperatures showed similarly significant differences for clear coverings, and both canopy and house ambient temperatures for white coverings. House ambient maximum temperatures were not significantly different between single and double layer, clear coverings, but house ambient minimum temperatures were significantly higher in the double layer units.

Greater freeze injury was observed on roots of plants in the northwest corners of the hoop houses (Fig. 4). Only in the double, clear poly unit were root injuries approximately equal between the northwest corner and the center of the house. Root deterioration in the double, clear poly unit was greater in the centers and less in the northwest corners than for all other house coverings. The cause of this particular response is not apparent but may have been a combination of high temperatures and low air movement. Clearly, our data indicates that all house coverings prevented root damage levels as high as those experienced in the uncovered control plants. Perimeter root damage, indicated by the high "end" root ratings in the northwest corners, could perhaps be reduced by use of insulating materials, empty containers, or containers of more resistant plants around the lower inside wall of each unit.

The coldest day during the experiment occurred on January 28, 1986 when the outside temperature dropped to -10.5 °C (13 °F) (Fig. 5). All coverings maintained minimum soil temperatures above the outside temperature by 2.5-9.5 °C (4.5-17 °F) (Fig. 5). The lowest soil temperature in the white, single layer unit was approximately 0.7 °C (1.3 °F) higher than the clear, single layer unit and approximately 0.7 °C (1.3 °F) lower than the clear, double layer unit. The white, double layer unit, however, maintained approximately 5 °C (9 °F) warmer soil temperatures than the clear, double layer unit. In fact, minimum soil temperatures in the white, double layer unit were approximately 9.5 °C (17 °F) warmer than the minimum outside temperature. Consequently, the white, double layer covering afforded substantially greater root injury protection than any of the other coverings on the coldest day of the experiment.

The highest outside temperature during the experiment occurred on February 20, 1986 (Fig. 6). Both clear (single and double layer) coverings maintained maximum soil temperatures considerably above outside temperatures. Soil maximum temperatures in the white, single layer unit generally approximated outside temperatures while those of white, double layer were appreciably lower during this 10-day period (February 15-25, 1986). Soil temperature differences (Fig. 1) were approximately 1.5 to 2 times greater under clear plastic than white plastic (double and single layer) and more highly correlated to maximum temperatures than mini-

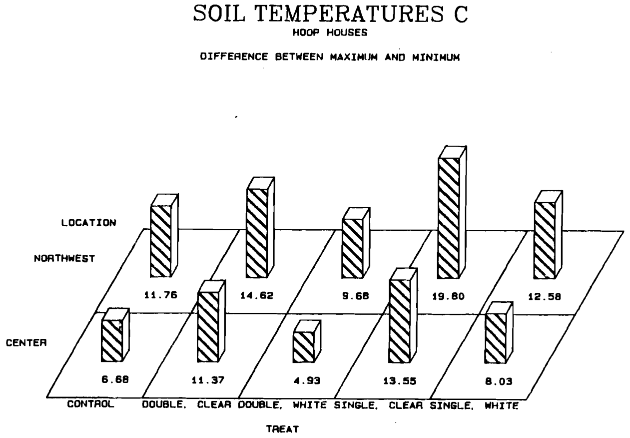

Fig. 1. Mean of daily differences between maximum and minimum soil temperatures in hoop houses at Carolina Nurseries, December 6, 1985 to March 4, 1986.

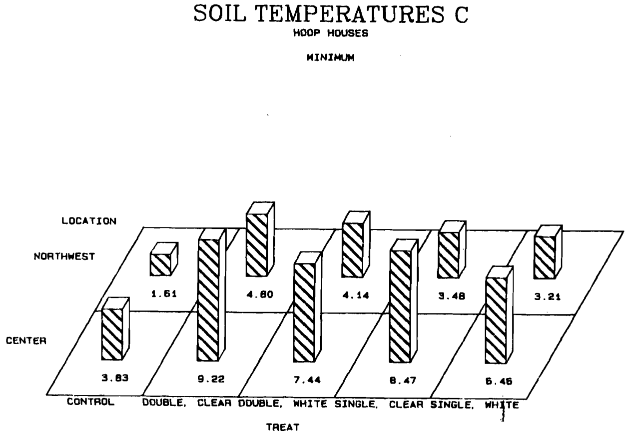

Fig. 2. Means of daily minimum soil temperatures in hoop houses at Carolina Nurseries, December 6, 1985 to March 4, 1986.

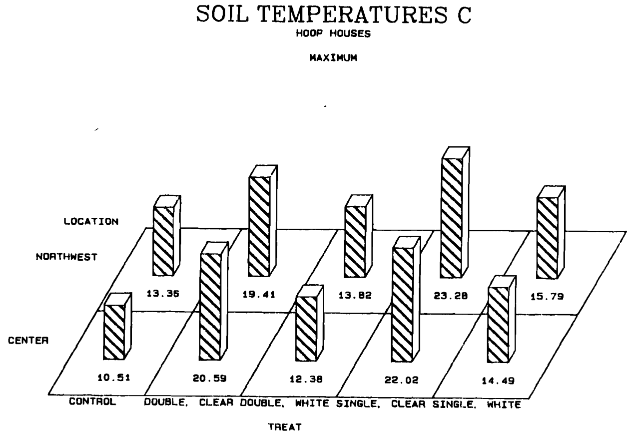

Fig. 3. Means of daily maximum soil temperatures in hoop houses at Carolina Nurseries, December 6, 1985 to March 4, 1986.

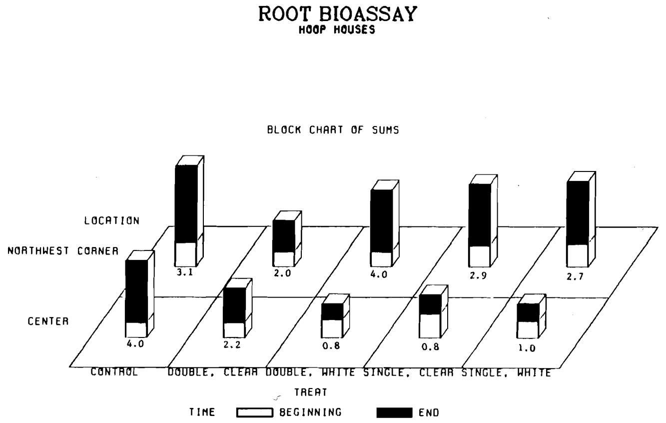

Fig. 4. Comparative root bioassays for crape myrtles in liners in hoop houses at the initiation and completion of the Carolina Nurseries study. (Ratio of bioassays scale "end" rating to "beginning" rating is shown in each square.)

mum temperatures. Similar ratios also existed for mean daily differences in canopy and house ambient temperatures in clear versus white plastic coverings. Average maximum soil temperatures were significantly greater in the centers of clear versus white plastic units by about 7.5 °C (13.5 °F) in single layer and 8 °C (14.5 °F) in double layer coverings (Fig. 3). Maximum canopy and house ambient temperatures ranged up to 15 °C (27 °F) higher in clear than in white plastic units with the greatest differences between clear, single layer and white, double layer.

Solar radiation recordings in Figure 7 for two periods during the tests reveal how the opaque white copolymer reduced maximum temperatures and tempered wide swings in differences between maximum and minimum temperatures. Three pyranometer recordings show outside solar radiation and inside solar radiation under single and double layer white coverings. Transmitted radiation under single layer white copolymer averaged about 24% and under double layer about 16% of outside radiation. Transmitted solar radiation through the double layer, white copolymer was about 66% of that through the single layer, white copolymer. Some transmissivity reduction in white copolymer may have been

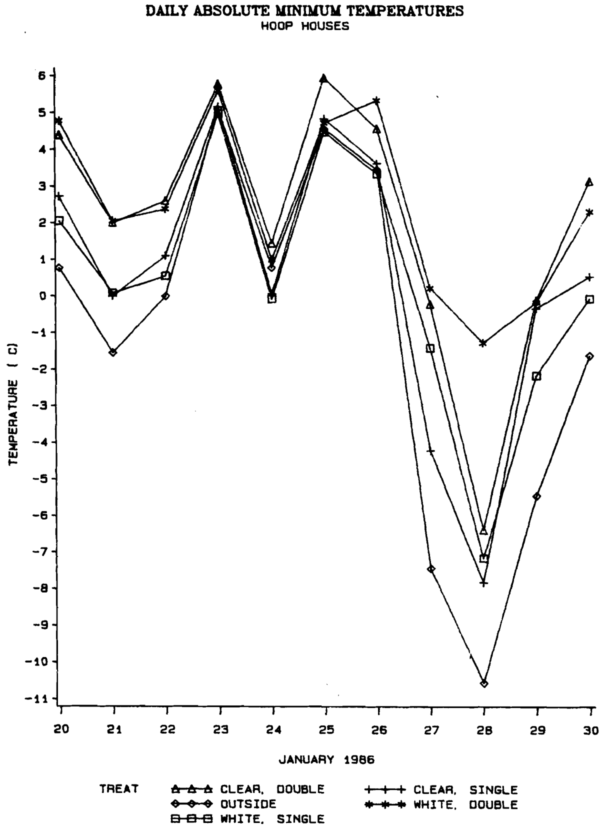

Fig. 5. **Daily minimum outside temperatures and soil temperatures for hoop houses including the coldest day of the test, January 28, 1986.**

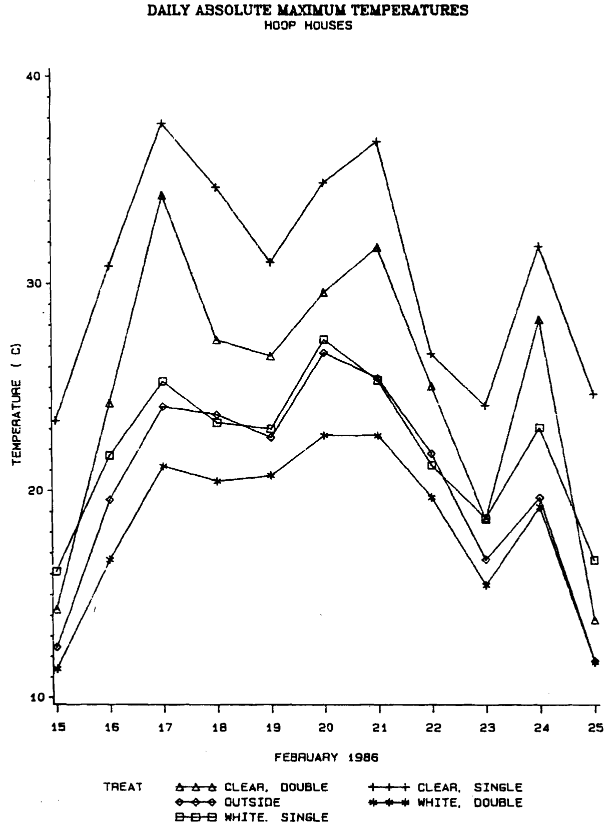

Fig. 6. **Daily maximum outside temperatures and soil temperatures for hoop houses including the warmest day of the test, February 20, 1986.**

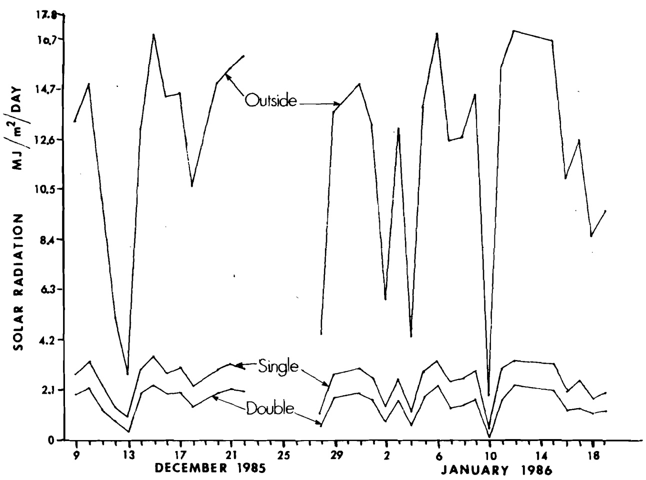

Fig. 7. **Total daily solar radiation for outdoors and inside single and double-walled, 6 mil white plastic hoop houses at Carolina Nurseries, December 9, 1985 to January 19, 1986.**

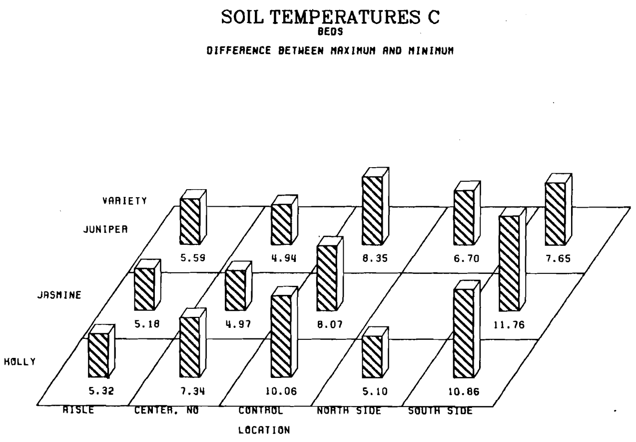

Fig. 8. **Means of daily differences between maximum and minimum soil temperatures in growing beds, covered and uncovered, at Carolina Nurseries, December 6, 1985 to March 4, 1986.**

attributed to condensation after crops were irrigated. Restrained growth from moderated temperatures of crape myrtle in early spring was visually observable under white copolymer as compared to clear poly, particularly in the single layer units. White copolymer, however, afforded greater root freeze protection (Fig. 4).

Beds. In Figure 8, soil temperatures for jasmine on the north side of the growing beds were not available because the thermocouple came out of the soil after the beds were covered. Mean daily differences between maximum and minimum soil temperatures were significantly higher on the south side than in other positions across the growing beds for all plant varieties. Mean daily differences in canopy temperatures on the south side had similar significantly higher values. Solar radiation significantly increased means of daily maximum soil temperatures on the south side over the other bed positions by 2.7 to 6.8 °C (5 to 12 °F). Means of temperature differences were highly correlated to maximum temperatures. When the white copolymer was removed from the growing beds at the end of the experiment, the south side row of containers was observed to be much drier than other rows of containers. Apparently higher south-exposure temperatures desiccated these containers by condensing moisture from the plant containers onto the lower side of the plastic covering where it flowed by surface tension down to the ground. Values with respect to bed positions of daily means of both soil and canopy temperatures ranked, from highest to lowest, as south side, center of north half of growing bed, aisle, and north side, respectively. Mean daily soil and canopy temperatures were not significantly different on the north side from the uncovered control plants. Perhaps a border of some type of insulating materials is advisable for both the north and south sides of the growing beds to moderate temperature extremes.

Wiltonii juniper displayed a general improvement of root health in all covered positions and maintained health in the uncovered control bed. Since juniper withstands root temperatures as low as -18 °C (0 °F) according to Havis (8), our test results indicated no need for covering this hardy variety in Moncks Corner, South Carolina, where minimum outside temperatures reached -10.5 °C (13 °F) in 1986. For dwarf Burford holly and Asian jasmine, however, benefits of bed wrapping by white copolymer were observed, especially for interior bed positions (aisle and center of north half). Holly and jasmine roots were all 75% or greater discolored in the uncovered controls at the conclusion of the tests. Roots of these latter two plants were 0-25% discolored in interior bed positions and 25-50% discolored in border positions (north and south sides). Although white copolymer clearly protected root health of holly and jasmine, it appeared that further insulation of north and south edges may be merited.

The same temperature moderating effects of white copolymer observed in the hoop house study were also evident with the single, 6 mil, white copolymer wrapping of the 3l (#1) containers in the growing beds. Minimum soil temperatures for holly and juniper were generally the same during the coldest outside temperatures of -10.5 °C(13 °F) on January 28, 1986 (Fig. 10). At the same time, minimum soil temperatures in north side containers did not drop below 0 °C (32 °F). The warmest outside temperature of about 26.5 °C (80 °F) was reached on February 20, 1986 (Fig. 11). On this date, the maximum soil temperature of the north side juniper containers was about 21.5 °C (71 °F) and of holly was about 17.5 °C (64 °F). The 4 °C (7 °F) cooler soil temperature of holly probably resulted from buffering of its more upright canopy as compared to the prostrate canopy of Wiltonii juniper.

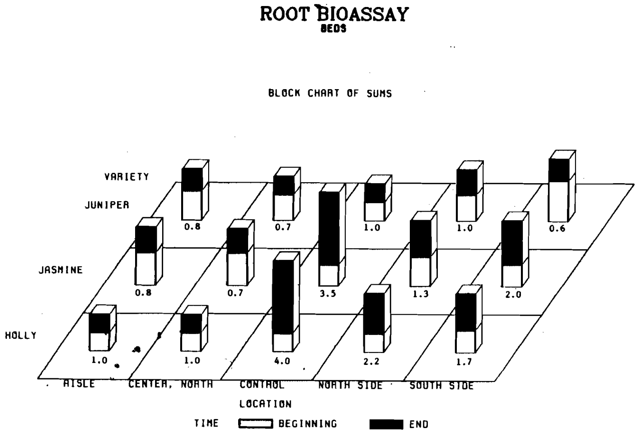

Fig. 9. Comparative root bioassays for three plant varieties in 3l (#1) containers in covered and uncovered growing beds at the initiation and completion of the Carolina Nurseries study. (Radio of "end" rating to "beginning" rating is shown in each square.)

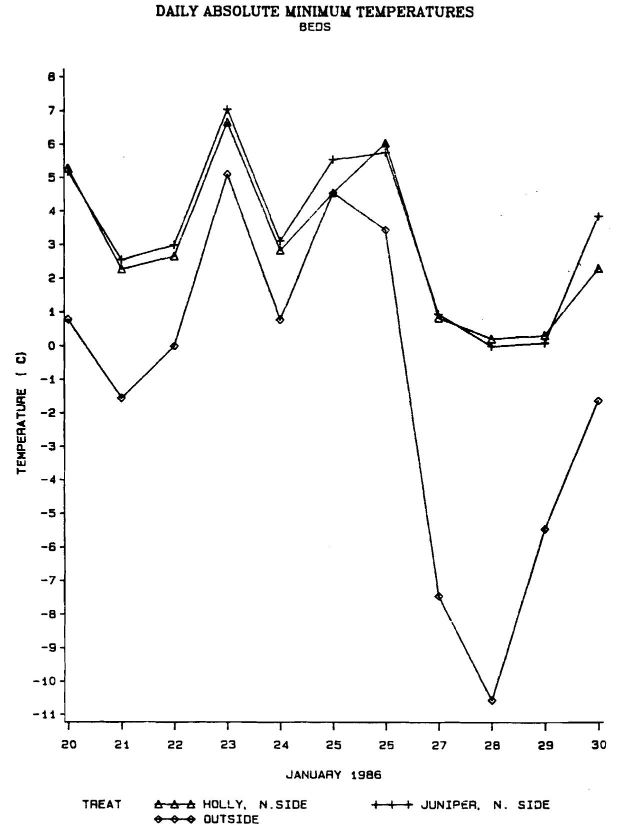

Fig. 10. Daily minimum outside temperature and north side soil temperatures for covered growing beds including the coldest day of the test, January 28, 1986.

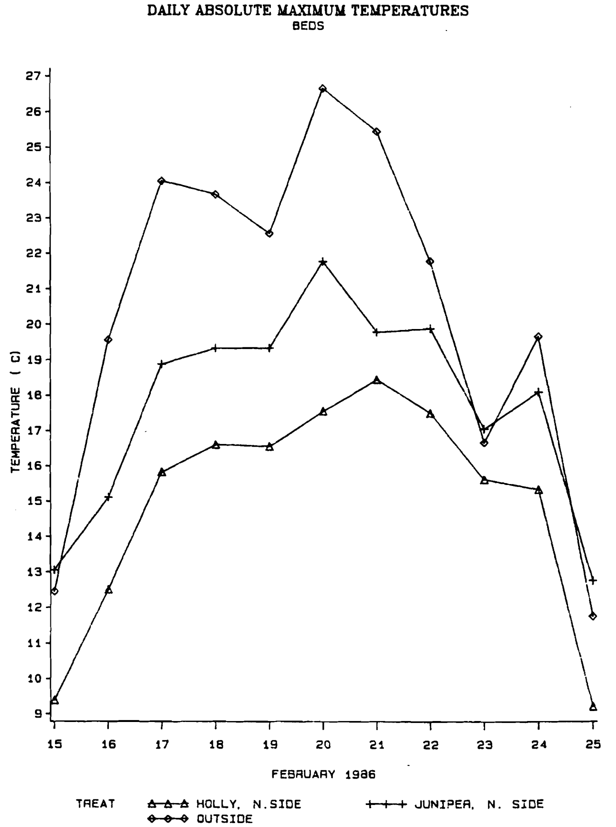

Fig. 11. Daily maximum outside temperature and north side soil temperatures for covered growing beds including the warmest day of the test, February 20, 1986.

Economics of Plastic Films. Visqueen Model 1504 clear polyethylene, 6 mil plastic film costs approximately \$0.45/m^2 (\$0.042/ft^2). It is treated with an ultraviolet (UV) inhibitor and may last up to three seasons if not damaged during installation and/or removal.

Visqueen Model 1505 white copolymer polyethylene, 6 mil plastic film costs approximately \$0.27/m^2 (\$0.025/ft^2). Currently it is not sold with a UV inhibitor, although experimental white plastics with UV inhibitors are being tested. For freeze protection during shorter days of winter months, however, UV deterioration may be minimal. The supplier is, nevertheless, reluctant to claim longevity beyond a single season.

Whether a nurseryman can successfully install and remove plastic films without excessive damage over multiple seasons is questionable, particularly where staples are used extensively on hoop houses. If plastic longevity in a practical sense is not appreciably different, white copolymer is a stronger performer for moderating temperatures in a freeze protection application and is more cost effective.

Significance to the Nursery Industry

This study of clear and white plastics for nursery crops freeze protection in Moncks Corner, South Carolina leads to the following conclusions which are particularly significant to overwintering in Southern to Mid-Atlantic climates.

- White copolymer greatly moderates temperature extremes in hoop houses, particularly at higher temperatures. Temperature differences between daily maximum and minimum are 1.5 to 2 times greater in clear poly than white copolymer structures.
- Border plants in both hoop houses and wrapped growing beds experience temperature extremes that increase root injury. Perhaps additional perimeter insulation is needed, or more cold tolerant plants should be placed as borders for more susceptible plants.
- Double layer plastic coverings significantly increase minimum soil and canopy temperatures over single layer coverings, thereby affording greater freeze protection of plants.
- In growing beds, white copolymer wrapping provides root freeze protection for Asian jasmine and Burford holly. Wiltonii juniper did not need plastic covering at Moncks Corner, South Carolina during the 1985-86 winter.
- For single season use, white copolymer offers greater freeze protection of plants at a lower cost.

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