freezing stops, the temperature of the plant drops to that of its surroundings. This implies a system in which the output can be varied considerably. These systems do not exist.

Secondly, the system must be designed in such a way that the water is not blown away from the plants if the cold is associated with wind.

Also, wind increases the evaporation rate of water, which is a heat consuming process. As the wind velocity increases the evaporation rate and the amount of water required also increase.

Another problem with overhead irrigation is that the nozzles freeze, adequate coverage is not obtained, and severe damage occurs.

Thorough and continuous cover of water is essential, for wet plant tissue freezes at a higher temperature than dry tissue. For example, dry citrus leaves freeze around −6°C (21°F) while wet ones freeze at −2°C (28°F). Although I do not know a definite reason for this, it could be because we have filled all the pores with water and have a continuous conductive surface. At any rate, if the wind shifts or the water supply is inadequate so that the freezing action is not occurring, the situation has been made worse by wetting the plants.

In spite of the problems with overhead irrigation, we have successfully protected low growing crops down to a temperature of −9°C (16°F). Thus, it works in both principle and practice.

In using this system, it is a good idea to continue sprinkling until all the ice has melted from the plants. Also, the soil must be very well drained. If it is not, water-logging will occur and plants will usually die.

In summary, then, we can see that a great deal of heat can be retained by using simple measures to reduce radiation loss. Furthermore, there are inexpensive ways to add heat to a protective structure on a short term basis. And, finally, overhead irrigation can help under certain conditions, but liquid water must remain on the plants until the danger is past.

THE MAJOR DISEASES OF HOLLY IN THE NURSERY

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Holly (*Ilex*), species represent one of the most important groups of woody ornamentals grown in U.S. ornamental nurseries. There are numerous cultivars and hybrids with many different growth forms offered for sale. Hollies have originated in geographical regions with diverse climates and are frequently grown under conditions in the nursery that predispose them to disease. Therefore it is not unusual for disease epiphytotics to occur.

Some of the diseases that have been reported are restricted to a single species of holly (14), whereas other diseases occur on several different species (20). In addition, certain holly cultivars of a species have been reported to be more susceptible than others (5).

Under the intensive culture practices of high fertility levels, frequent irrigation, and high plant density currently employed in the nurseries in the east and southeast, holly is frequently predisposed by conditions favorable for disease development. During a particular year it is not unusual for growers to experience extreme cold, extreme heat and heavy rainfall of several days duration with resulting severe outbreaks of disease.

Foliar pathogens and soil-borne root rot pathogens have been observed to enter the nursery production cycle during propagation. High humidity and temperatures used during propagation are conducive to infection and disease. Some of the infected plants will be eliminated during propagation, but others will survive and serve as a source of infection at a later stage in the production cycle. Pathogens may reside on the leaves and stems, in the rooting medium, and on propagation containers, be splashed or blown up from the soil below the propagation containers, or be present in the water used for misting, or possibly be introduced by unsanitary practices employed by personnel during propagation.

Cooley reported that cuttings of American holly in propagation were infected by *Rhizoctonia*. Defoliation began 2 to 3 weeks after sticking (16). The stems were killed and a zonate leaf spot was characteristic of the disease.

Under culture in the field, holly is susceptible to root rots and parasitic nematode attack. Root rot organisms may be present in the soil in low populations with no apparent effect on plant growth. However, if the fields are not drained well or have impermeable sub-soils, excessively heavy rainfall may result in prolonged saturated soil conditions that favor rapid multiplication of water mold fungi like phytophthora. Plant susceptibility is also enhanced.

Fungi have been reported as pathogens of holly more frequently than any other group of organisms attacking the leaves, stems or roots. Bacteria are reported causing disease in landscape holly but have not been particularly damaging under nursery culture (32).

FOLIAR DISEASES

Containers of *I. crenata* grown under tightly crowded conditions of high humidity and temperature are highly susceptible to *Rhizoctonia* web or thread blight. It has been reported that during warm, humid weather, *Rhizoctonia ramicola* attacks the leaves and twigs (*I. crenata*). Dead leaves may be matted together or held suspended from the twigs by fungus hyphae, denser mats of which usually appear at the point of contact of diseases and healthy leaf blades, binding them together (46). Leaves have necrotic spots which may involve the entire blade. At maturity, the tan necrotic centers are surrounded by purplish-brown margins and the affected areas are brittle in texture, cracking and falling away under slight pressure. Diseased plants may be severely defoliated. The lowest and inner leaves and twigs are the most susceptible (Figure 1).

Figure 1. *Rhizoctonia* webblight of Japanese holly. Note dead leaves hanging from diseased twigs.

On Chinese holly, *I. cornuta*, spot anthracnose developed on the upper surface of leaves, producing lesions on the shoots and scabby lesions on the berries (38). Leaf spotting and defoliation of 'Burfordi', *I. crenata*, *I. opaca* and *I. vomitoria* may also be caused by *Cylindrocladium avesiculatum*. Small chlorotic spots appear on the leaves, turning purplish-black and enlarging to form circular lesions 10 to 15 mm in dia. Mature lesions are circular, frequently zonate, 10 to 15 mm on *I. crenata* 'Helleri', *I. opaca* 'Savanah', *I. vomitoria* 'Nana' (20) (Figure 2). English holly plantings in the northwest are susceptible to infection by a foliar phytophthora (*P. ilicis*) (14). Rust of American holly caused by *Chrysomyxa ilicina* has been reported but is not ordinarily a serious problem (40).

Tobacco ring spot virus was reported in nursery-grown *I. crenata* 'Rotundifolia' (45). Leaves on infected holly plants were permanently distorted although no observable reduction in plant growth occurred. Symptoms on older leaves consisted mainly of irregular leaf margins.

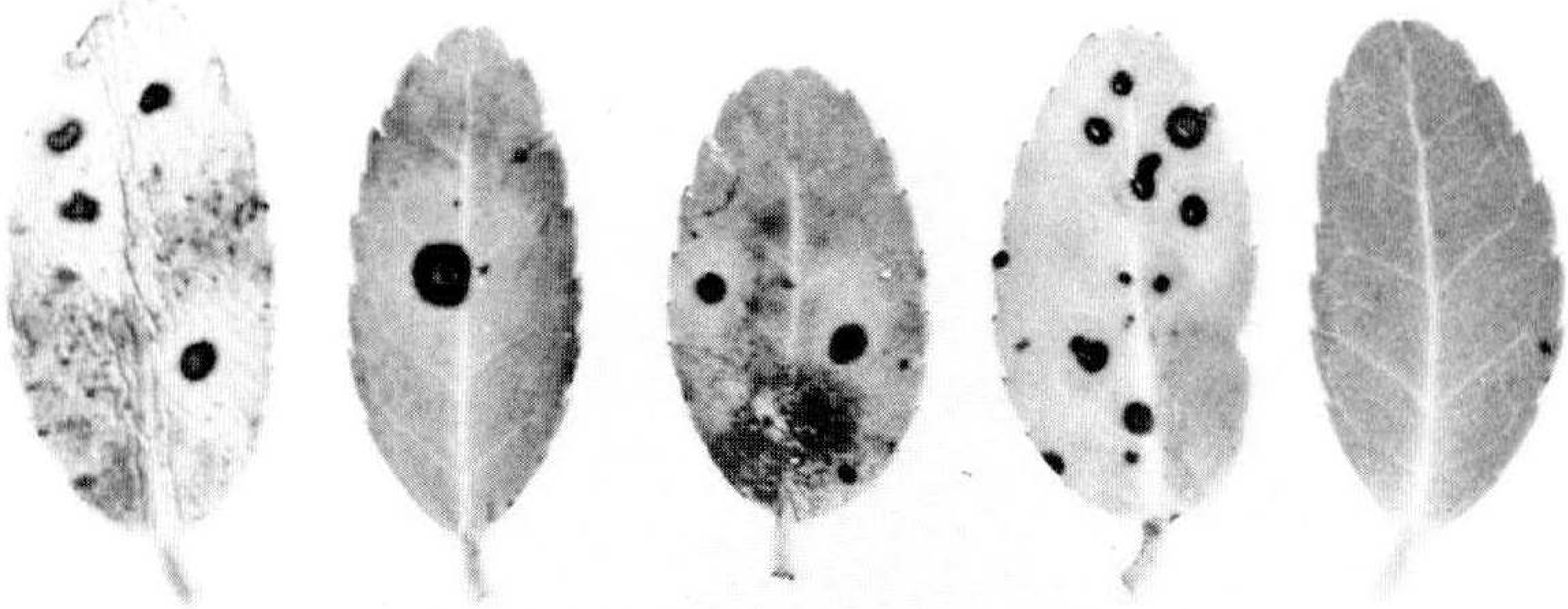

Figure 2. Cylindrocladium leaf spot of vomitoria holly.

CANKERS AND DIE-BACK DISEASES

Canker and die-back were reported on *I. cornuta* 'Burfordii' caused by a *Gloesporium sp.* Stem discoloration on terminal twigs and defoliation occurred. Sunken necrotic lesions were present in the cortical tissues of the twigs (41). We have observed a die-back of *I. crenata* in Virginia especially where heavy pruning for shaping has been practiced.

ROOT ROT DISEASES

Phytophthora cinnamomi was pathogenic on Japanese holly (*I. crenata*) causing dark streaks extending up the crown and lower stem (25). Similar symptomology has been reported on other woody host plants. English holly growing in Virginia in the field under conditions of poor drainage was susceptible to infection by *P. cinnamomi* (27) (Figure 3).

Biesbrock, et al. reported that under conditions of water saturation, *Pythium vexans*, induced root damage in *I. crenata* 'Convexa'. *P. vexans* damage was not much affected by different soil temperatures. In contrast, *Pythium irregulare* was more pathogenic to Japanese holly at certain temperatures (9). Container media containing 100 percent pine bark infested with *P.*

Figure 3. *Phytophthora* root rot of English holly. *Left:* Field soil; *Right:* Pasteurized soil.

irregulare produced larger plants than containers of 100 percent coarse sand infested with *P. irregulare* (22).

I. crenata is susceptible to infection by *Thielaviopsis basicola* (28). Damage to roots of *I. crenata* is seen as black lesions on the tips of infected roots but may occur elsewhere on the roots. The foliage of infected container grown *I. crenata* exhibited chlorosis and the roots were stunted (Fig. 4). The roots of colonized plants bear conidia and chlamydospores on the surface and in the root tissue. Six cultivars of *I. crenata:* 'Helleri',

Figure 4. *Thielaviopsis* black root rot of Japanese holly. Healthy plant in center and disease plants on right and left.

'Hoogendorn', 'Nigra', 'Green Cushion', 'Mobjack Supreme' and 'Hetzii' are moderately to highly susceptible.

I. vomitoria and *I. opaca* are moderately resistant. *I. aquifolium* and *I. cornuta* are highly resistant (29).

NEMATODE PROBLEMS

I. crenata 'Rotundifolia' was more tolerant than 'Convexa' or 'Helleri' to the root knot nematode *Meloidogyne arenaria*. Soil containing high populations of *M. arenaria* killed Japanese holly (5). In a nematode-host study, Chinese holly (*I. cornuta* 'Rotunda') was seriously stunted by the nematodes, *Meloidogyne arenaria*, and *Tylenchorhynchus claytoni*. *Ilex vomitoria*, 'Nana' was damaged by *T. claytoni*. However, *I. cornuta* 'Burfordii' was resistant to *M. arenaria* in contrast to *I. cornuta* 'Rotunda' (6).

In greenhouse studies the nematode, *Criconemoides xenoplax* was damaging to *I. crenata* 'Helleri', 'Convexa' and 'Rotundifolia' (2).

Aldicarb and DBCP — two nematicides — controlled nematodes on Japanese holly growing in microplots for up to 12 months after treatment. *Paratrichodorus* and *Meloidogyne arenaria* were controlled up to 8 months in the root zone of Japanese holly with either nematicide. Stunted Japanese hollies infected with *M. arenaria* failed to make significant recovery 12 months after treatment (8).

PROTECTION AGAINST DISEASES

Holly should be propagated from healthy stock plants. The cuttings should be rooted in pathogen-free media, preferably on raised benches. Some fungicide application over the cuttings may be necessary to prevent root, stem and foliar diseases caused by soil-borne fungi like *Rhizoctonia*, *Pythium* and *Phytophthora*. It may be necessary to treat the propagation and container media with fumigants or heat. Consideration should be given to chlorination of irrigation water if the only water source is pond water that must be recycled. The containers used to propagate or grow in should be new or thoroughly disinfected before using.

Under field culture, poorly drained areas are likely to result in root rots caused by *Pythium* or *Phytophthora spp.* Nematodes are capable of causing severe damage to the roots of holly. Therefore, preplant field fumigation may be feasible to prevent root rots and nematode damage.

Containers in the field should be placed on crowned or well drained beds. Water used to irrigate these containers should be free of plant pathogens. Close spacing or crowding may create the proper conditions for *Cylindrocladium* leaf spot or *Rhizoctonia* web blight. Providing air movement between the plants will usually alleviate the problem. Foliar fungicides are also suggested in some regions.

Fields with a history of plant parasitic nematodes scheduled to be used for growing holly should be fumigated before planting. Contact-type nematicides should be considered if these are registered.

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QUESTION BOX

The Southern Region Question Box was moderated by Richard Stadtherr and Jake Tinga.

JACK SIEBENTHALER: What is fly ash? Several growers are using it in their media.

JAKE TINGA: It is a slate-like waste product resulting from coal combustion and was formerly readily available.

TED RICHARDSON: Fly ash is still available from coal-burning power companies.

RICHARD VAN LANDINGHAM: Calcined clay is another product that can be used as a medium. It is manufactured by heating clay as is done with vermiculite and perlite. It is then light and sterile and is comparable to perlite.

DON CLAY: The clay is similar to Fuller's earth.

JUDSON GERMANY: We are able to buy styrofoam, which is considerably cheaper than perlite.

PETER GIRARD: It works well and is cheaper than perlite.

JAKE TINGA: It might be possible to use the waste from hot drink cup manufacturing. In addition to improving aeration I have also read a report from Germany that formaldehyde is a