COLD PROTECTION OF LOW-GROWING PLANTS

C.H. HENDERSHOTT

Department of Horticulture, University of Georgia
Athens, Georgia 30602

HEAT TRANSFER

In order to make the most effective use of the methods available to us for protecting plants in the nursery, it is helpful to have some knowledge of how heat is transferred. There are 3 ways heat moves — by *radiation, conduction,* and *convection.*

Radiant energy is energy in the form of short waves above the visible region of our spectrum. These waves travel in a straight line at the speed of light, 186,000 mps. This energy is not heat as it moves through the atmosphere, and it does not become heat until it strikes a solid object. It is, therefore, not affected by wind. On a cold, calm night a plant loses heat by radiation since any object warmer than its surroundings will lose heat to the colder objects which, in this case, would include the atmosphere. If we could prevent the loss of radiant energy from the plant, it would stay at its same temperature and would not be damaged by the cold. During the day the plant is absorbing radiant energy from the sun. It is protected from overheating by evaporative cooling during the transpiration process through the stomates.

Conduction is the method of transferring heat by actual physical passage of heat energy from one molecule to another. Although the rate of transfer depends on the thickness and chemical nature of the material through which it is moving, probably more important is the heat differential from one side of the layer to the other. When we consider this in relation to greenhouse coverings, we find that we are working within such a narrow range of thickness that the differences in coefficients of heat conduction of glass, fiberglass, and polyethlene are not important. The heat transfer coefficient is so close that we can use the same factor in calculating heat loss through a single layer covering.

Convection is another way we can move heat. Large mass movements of air transfer heat from one area to another. We use wind machines to move heat by convection.

Convection and radiation are the methods by which heat is lost when frost or freeze occurs. We have advective or radiation type freezes. When cold northern air masses move in with winds of 12, 15 or 20 mph, heat is removed by convection. We call this an advective type freeze. If, on the other hand, we have a still night with a cold, clear sky above, plants and other objects lose heat rapidly by radiation. This is usually a localized situation of extreme cold and is termed frost. It is a radiation type freeze. Even if the weather prediction is for 3° or 4° C (38° or 40°F), it is possible to get severe damage on a still night as plants lose heat rapidly by radiation. Their temperature can easily drop 10 to 12 degrees below the surrounding air.

It is assumed, when speaking to a group of plant propagators, that we will be concerned with cold protection of low growing plants and the primary objective will be protection from cold injury and not ideal conditions for rooting or plant growth. Furthermore, if we assume that the damaging temperature for most succulent plant material is at or near 0°C (32°F), then our main objective is to prevent, for a short period of time, the temperature from going below this point and thus avoid damage.

With this in mind we have a few alternatives open to us that can be employed to prevent damage. Among these are (1) erection of a temporary cover over the plant material under which heat in some form may or may not be supplied, and (2) sprinkling (overhead irrigation).

TEMPORARY STRUCTURES

Since propagation is usually done in beds having side walls of varying heights to hold the media, it becomes very easy to place some sort of temporary superstructure over the beds to support a covering material, which is pulled over the plants on a cold night. It is important that the covering not touch the plants.

There are two things we must keep in mind if this structure is not supplied with supplemental heat. We are trying, first, to stop heat loss by radiation and, second, to trap heat being brought to the surface of the soil by conduction. Since many of the covering materials are permeable to long wave radiation, we can enhance a structure's effectiveness by thoroughly watering the soil prior to covering the plants. This serves two purposes. The air over a wet soil in a closed structure is at or near 100% relative humidity. Thus, when the temperature begins to drop, condensation occurs on the cover, and this becomes a very good inhibitor of radiant heat loss. Contrary to common belief, high humidity does not increase the incidence of disease. The disease was already present. It is true, of course, that moist conditions do provide a good environment for its growth. There is some heat released as a result of condensation, which retards the drop in temperature. Also, wet soils are better conductors of heat than dry soils. Therefore, by wetting the soil, more heat is conducted upward and trapped within the cover. Employing this principle will effectively give you from 5 to 10°F protection depending on the nature of the cold, whether it's windy or calm, for example.

On a windy night heat loss will be greater from any structure than on a still night. Heat moves across the covering by conduction and is then transferred rapidly by convection, which in turn speeds up the loss through the covering. It is impossible to say specifically how much heat loss can be reduced by any of these methods since it depends on wind velocity as well as other factors such as cloud cover. However, we have found that if we thoroughly wet a cold frame early enough to allow plant materials to dry, then cover the frame, we can maintain temperatures 12 to 14°F above outside air. This technique is used routinely by bedding plant producers.

More protection can be gained if some sort of insulating material can be conveniently placed over the outer cover. This can be straw, leaves or cloth material. If the expected temperature low is below your protection level then a source of heat can be added. This can be provided rather quickly by stringing light bulbs inside the structure. The lights can be connected to a thermostat if desired. An ordinary incandescent light bulb will give off approximately 3.5 BTU's per watt. Thus, a 100 watt bulb will give off about 350 BTU's of heat per hour. You can put 18 of these bulbs (1800 watts) on a 20 amp circuit. Therefore, a string of 18 100-watt bulbs will generate about 6,300 BTU's of heat. In addition there will be some radiant heat emitted from the bulbs. With this system, we have been able to protect tender plant material down to an outside temperature of −8°C (18°).

OVERHEAD IRRIGATION

Another means of frost protection that is usually readily available to the growers, particularly on a small basis, is overhead irrigation. The principle is based on the fact that heat is released when there is a change in phase of water. Thus, when water changes from a liquid to a solid (ice) approximately 144 BTU's of heat are released per pound of water. A gallon of water weighs about 8 lbs. and, therefore, when a gallon of water freezes, 1,152 BTU's of heat are released. On an acre-inch basis this would equal 38,000,000 BTU's of heat. The problem with overhead irrigation is twofold. First, water must be applied at a rate such that there is always liquid water present. As long as there is liquid water changing to ice, the temperature of the plant tissue underneath the ice will remain at 0°C (32°F), or the freezing point of the water. This means then that you must have sufficient water to withstand the low temperature regardless of how low below the predicted minimum it may drop. As soon as 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

R.C. LAMBE

Department of Plant Pathology and Physiology
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Holly (*Ilex*), species represent one of the most important