Lilies are propagated by the stem bulbs which grow above the original bulb. Another way is by scaling the bulb. Give the scales a heat and cooling treatment, plant them, and grow for two years in the field. By then the bulb will be full size. This way stock can be built up rapidly. The newest cultivars are propagated by tissue culture. Commerical growers in the U.S. generally plant lilies in 1 gal. or in 6 in. containers. Plant 3 bulbs per pot, because this will give more show, and they will have a much longer shelf life.

ACCLIMATION AND WINTER PROTECTION OF CONTAINER-GROWN NURSERY CROPS

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Acclimation and freeze tolerance of woody plants was addressed at the meeting of the Southern Region, IPPS in 1977 by this author and published in the Proceedings (9). In that paper the mechanisms whereby plants acclimate to cold temperatures and survive freezing temperature and desiccation injury were discussed. In the present paper an attempt will be made to build upon that information by explaining a new model for plant cold acclimation as it relates to winter storage, with emphasis on container production.

A physiological model called "Degree Growth Stage Model" (°GS) has been proposed by Fuchigami *et al.* to describe the annual growth and hardiness of woody plants (3). Plants go from 0°GS to 360°GS in one calendar year (Figures 1 and 2). The °GS is not related to days in the year but to the physiological condition of the plant. For example, 180°GS may coincide with leaf fall may be October 1 in northern Ohio but October 15 in northern Alabama, depending upon the species in question. Another important point about plant development and responses to the environment is that plants are active physiologically even in the winter. Thus a proper understanding of these physiological events will assist the grower in protecting plants from winter injury.

Spring bud break starts at 0°GS and proceeds with rapid growth. During this time plants do not have the capacity to acclimate to freezing temperatures. The rapid growth phase is followed by a period where shoot growth slows and ultimately stops in response to decreasing photoperiod and warm temperature. This period starts at 90°GS (about August 15 in southern U.S.) and is complete at 180 G.S. when vegetative maturity is complete; plant tops have stopped growing, and stage 1 of cold acclimation has occurred. Plants can at 180°GS survive light freezing. A point of reference is the fact that vegetative maturity and the completion of stage, acclimation can occur for deciduous plants at the time of leaf fall although not always.

The development of vegetative maturity or the first stage of acclimation can be delayed by cultural practices such as applying high levels of N in late summer or early fall. Gilliam *et al.* (4) have shown leaf drop of *Acer rubrum* to be delayed with high levels of N. Late flushes of growth on plants such as *Ilex* and *Rhododendron*, and prolonged growth of plants such as *Forsythia* due to late applications of fertilizer are many times killed by the first freeze in the fall (personal observations). This injury can be related to the overriding effect of nutrition, which delays vegetative maturity and the completion of the stage 1 of acclimation.

The second stage of acclimation begins at 180°GS with the rate of acclimation being much more rapid than during the stage 1. Plants will acclimate at temperatures as high as 20°C but the rate of acclimation is increased at temperatures around 0°C Deacclimation does not appear to be a problem during this growth stage. Freeze injury may be a problem in years when temperatures remain abnormally high in the fall, which slows acclimation, In the same vein, nurserymen should delay the application of winter protection that may expose plants to high temperatures during this stage of acclimation. The decrease in acclimation rate could result in plant damage by early freezes. The main objective is to protect plants before temperatures occur that will kill roots of the species in question. On the other hand, if nutritional practices have prolonged vegetative growth late in the season, early protection may be necessary to prevent freeze damage of unacclimated plants. The role that roots play with winter injury of containerized plants will be discussed later.

Plant hardiness is at a maximum between 270 (about December 21 in the South) and 315°GS. Plant growth does not occur as long as temperatures remain low. Rest is ended when a sufficient number of chilling hours have accumulated and certain physiological requirements within the plant have been met. This time corresponds to 315°GS, after which increasing temperatures will cause the plant to deacclimate and resume growth. Thus, the growth cycle will be complete with bud break commencing at 360°GS. At 315°GS, the higher the temperature, the more rapid will be deacclimation in contrast to a

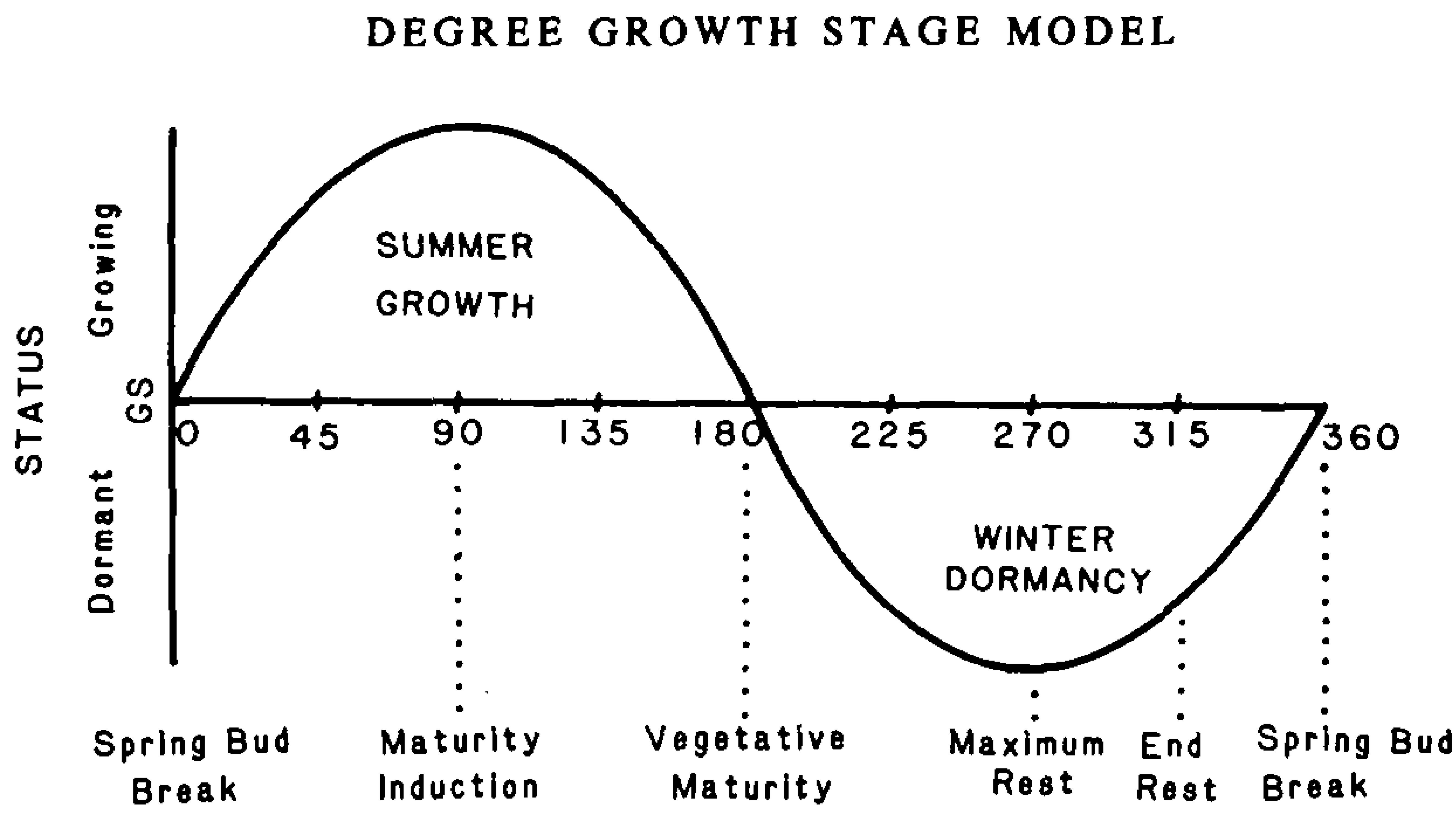

Figure 1. Degree growth stage and growth of plants.

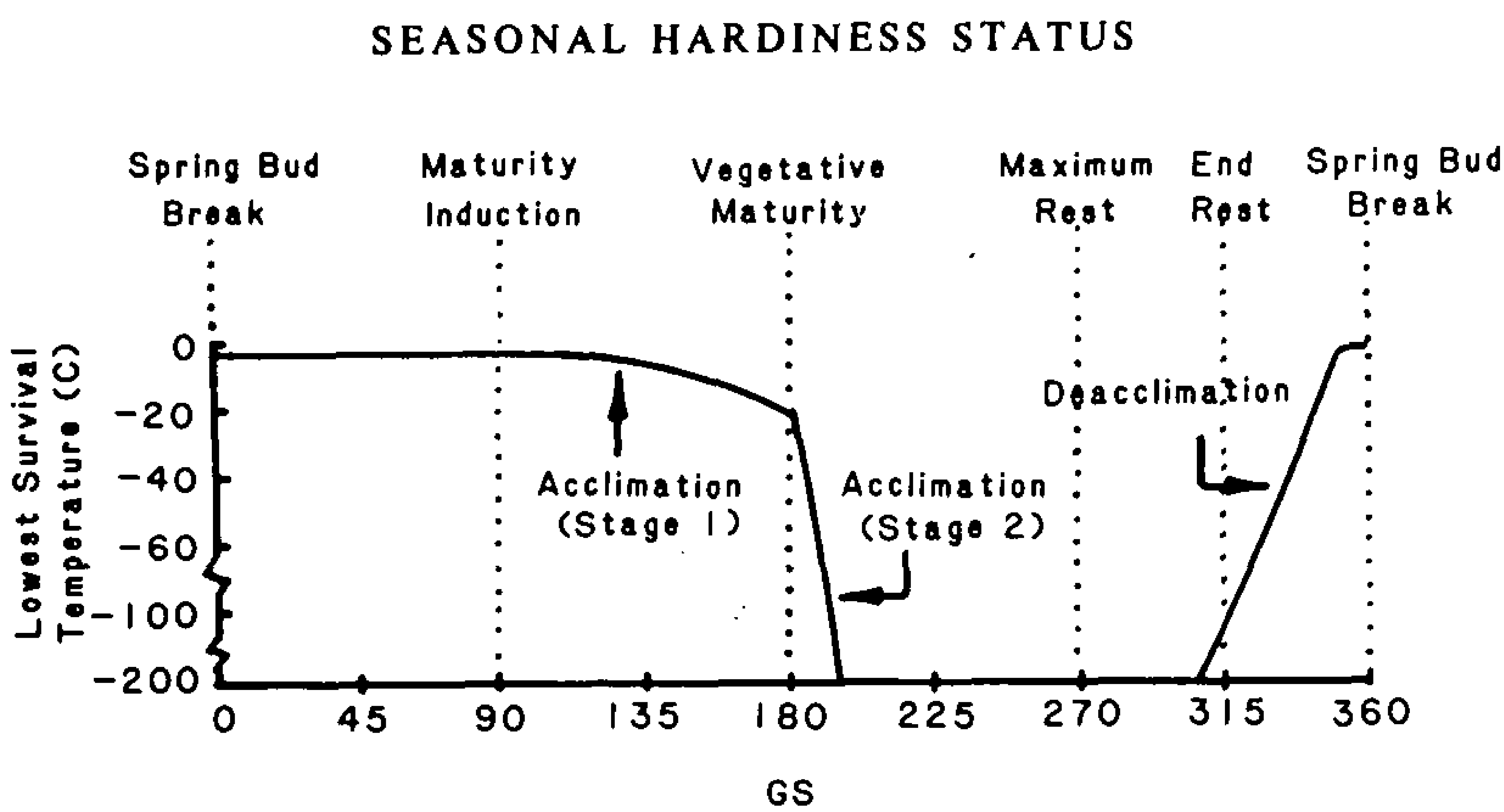

Figure 2. Degree growth stage and hardiness of plants.

more rapid acclimation rate in response to lower temperatures in the fall.

During the time when plants are capable of deacclimation, temperatures as low as 5°C have been shown to cause some deacclimation. It is, therefore, important to remove winter protection or properly ventilate in order to maintain a low temperature environment and prevent premature deacclimation and growth. A good rule of thumb is to remove protection as soon as minimum temperatures are above that which will cause root injury. This precaution is especially critical if plants are to be marketed to the north of the growing area since they may have deacclimated to temperature above which they will be exposed at a new location. This same reasoning is why plants are normally marketed no more than two hardiness zones north of the production location.

The main concern with winter protection of container grown nursery crops is to provide adequate protection to the root system and to prevent desiccation of plant tops during winter. Freeze injury to plant shoots is normally minimal since only hardy species and cultivars should be grown. Roots do not have the capacity to acclimate to the same extent as shoots. The example of *Pyracantha coccinea* 'Lalandei' has been given often in which stems survive −15°F while older woody roots are killed at 2°F and young roots are killed at 22°F (8). Higher root-killing temperatures compared to shoots for both deciduous and evergreen azaleas have also been demonstrated (1). Alexander and Havis (2) found that roots of 'Springtime' azaleas grown at 18°C temperatures were not as hardy as roots grown at 2°C. Roots do not go dormant as do the buds on shoots and the rate of root growth is a function of temperature, provided other environmental and internal physiological factors are not limiting. The higher the temperature, regardless of the photoperiod or time of year, the more active the roots and the less hardy they are. Green and Fuchigami (5) have indicated that this physiological difference between roots and shoots is one major reason for the difference in hardiness between shoots and roots.

The root system of container-grown plants is poorly buffered against changes in temperature in contrast to field-grown plants. Container-grown plants are exposed to ambient air temperature and have a small quantity of medium surrounding the roots. Consequently the root temperature of container-grown plants fluctuates greatly in response to changes in ambient air temperature. Thus, every effort should be made to maintain temperature above that which will kill roots and, just as important, to prevent significant elevations in temperature which may cause roots to deacclimate and be injured by the next freeze. An ideal root temperature for over-wintering containerized plants would be just above freezing. This would be above root killing temperature (20 to 25°F for many species) (5) but cold enough to inhibit root growth and deacclimation. It is, therefore, important to apply winter protective procedures as late in the fall as possible to allow for maximum acclimation of the tops and roots. It is equally as important, and maybe more, to remove protection as early in the spring as possible to prevent deacclimation and freeze injury of shoots and roots.

As already mentioned, another key reason for providing winter protection for container-grown woody plants is to prevent winter injury of shoots due to desiccation. The factors that influence desiccation have been addressed in an earlier paper by this author (9) and by Green and Fuchigami (5). As temperature approaches freezing, the root system is not as effective in supplying water lost by transpiration from the shoots. This is due in part to an inactive root system and increase in the viscosity of water at lower temperatures. This condition is even more critical when the water, and the roots in the container medium, freeze resulting in no movement of water to the shoots. This frozen condition may exist for an extended time even though air temperature may be above freezing and loss of water from the tops via transpiration is possible.

Any factor that may increase the air temperature around the plant will result in a decrease in relative humidity and a greater difference between the relative humidity of the air and that of the internal part of the leaf. The result will be the loss of water from the leaf and desiccation if water is not resupplied by the root. The use of white co-polymers or microfoam is effective in winter protection since they maintain a more uniform temperature within or under the structure (6,7).

Desiccation can also be minimized if winter protection methods are employed to eliminate wind exposure or air movement around plants. The greater the wind velocity, the greater the loss of water vapor from the leaves. Care should be exercised to make structures or coverings as air-tight as possible. Elimination of air movement will also cause plant temperature to remain much higher since an increase in air movement results in the removal of large quantities of heat energy from the plant and container medium. The observation that plants along the northern edge of container beds are more prone to injury is partially due to the wind factor.

This paper attempts to present winter protection in a context that considers the physiological growth and development of a plant throughout the year. As one's knowledge of these relationships increases, greater success in overwintering containerized woody plants will be realized. It has been said that the person that knows how will always have a job. But the person that knows why will be the other person's boss. In respect to growing plants in containers, the person that learns all he can about plant acclimation and how plants respond to freezing temperature will most likely remain in business, have people to manage, and plants to sell.

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