Causes and Control of Overwintering Damage in Nursery Stock[1]

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Abstract.--The process of surviving through the winter in northern climates exacts a visible and invisible toll on tree seedlings. This affects their survival on the nursery, and in the field. The causes for and control of these adverse effects are summarized.

INTRODUCTION

I recently heard the thesis put forward that the "Greenhouse Effect" is in reality a "Ratchet Effect", not so much actively heating up the world's climate as limiting the "fall back" associated with the regular rise and fall of temperatures in the natural long and short term cycles of temperature change. The net effect of this in global terms amounts to heating, but the local effects are more along the lines of increased instability. If this thesis is correct, it means increasing problems for the nurseryman since it is frequently not the severity of conditions which proves to be damaging to stock but the rapidity of change. The prospect is then, if you subscribe to the theories of global climate change, that those nurserymen who have not already experienced damage to their stock will, and those who have, will experience more.

In northern climates winter is a period which can be particularly stressful for plants left in outdoor conditions. For the tree nurseryman the problem is the arrival at the time of shipping with a proportion of the crop in a physiological condition insufficient to ensure successful outplanting. The seedlings which began the overwintering period in apparently acceptable condition but have not survived, have "stressed out". They have succumbed to an accumulation of stresses beyond their resources to deal with. To successfully survive the inevitable stresses of overwintering, the seedlings must begin this difficult period with a minimum of accumulated stress and a maximum of stored reserves. The cultural implications of this are a secondary issue to this study. It must however remain, that our relative success, or lack of it to date, may have been strongly influenced by our ability to come to grips with the requirement to ensure a favorable physiological state.

The Nursery Technology Cooperative of the Oregon State University is currently using what they call "The Target Seedling Concept" as a focus for directed research studies. Simply stated it is:

targeting specific physiological and morphological seedling characteristics that can be quantitatively linked with reforestation success [Oregon State 1988].

It is the milepost at the transfer from nurseryman to field forester which will ensure the greatest likelihood of successful outplanting performance. This implies that the end product of the process of overwintering must not only survive but must possess characteristics assessed to be essential to the seedlings success beyond the nursery gate.

Leaving morphology aside and focusing on the successful plantation tree, what physiological characteristics are required of the seedling as it reaches the end of overwintering? Broadly speaking, stock must still possess sufficient dormancy and cold hardiness to carry it past the risk of frost damage in

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the field. Its' carbohydrate reserves must not be exhausted, and its' water relations should still be relatively favorable [Ritchie 1986a].

To complete a period of overwintering successfully, it follows that the seedling must begin with root and shoot sufficiently mature and acclimated to withstand the degree and rate of temperature decline which it will experience. It must have adequate carbohydrate reserves to cover losses to respiration during overwintering and have a substantial tolerance for desiccation of roots and tops without damage [Ritchie 1984 and 1986b]. Moreover, to fulfill "The Target Seedling Concept" it should be at a sufficiently low level of stress and possess such additional carbohydrate reserves as are needed to successfully establish on a plantation site even under adverse environmental conditions.

THE NEGATIVE IMPACT OF OVERWINTERING

Assuming that we are able to begin overwintering with a "Target Seedling", the critical step is to preserve that seedling until time of planting by providing an environment which protects against excessive demands. Such demands may contribute to a level of "stress accumulation" which results in failure after outplanting. This is difficult to predict and harder to measure. Less frequently the effects of overwintering damage will be more obvious, appearing as physical signs of damage or outright death. These mechanisms are as follows:

Winter Desiccation:

Desiccation occurs when the rate of transpirational loss exceeds the rate of water uptake. While roots do not become dormant, low temperatures do inhibit activity, reducing the ability of root tips to compensate for rapid transpirational losses by absorbing water. The increasing viscosity of water with falling temperature further reduces the efficiency of water uptake to the point where freezing of the soil water and media halts it altogether. So long as the top is not frozen, the rate of transpiration increases along with increases in light intensity, temperature and wind speed, and in response to decreases in humidity. The disastrous combination of actively transpiring tops and frozen root systems is a condition particularly probable very early and very late in the outdoor overwintering period [Green 1985].

Freeze Damage:

Boreal forest species are among the most cold hardy plants known. Properly conditioned, species such as Jack Pine have been observed to tolerate temperatures as low as -196 degrees Celsius [Green 1985, Dymock 1987]. On the other hand, lush new foliage of these same plants may be severely damaged by any sub-freezing temperature. Frost killing temperature will vary widely depending on the manner of temperature change, the growth stage, the season and the physiological state of the plant. If the plant is inhibited by any of these factors from preventing intracellular freezing, damage will occur.

A major problem in overwintering container grown plants is that the roots are significantly less cold-tolerant than the shoots. This is because while shoot and bud acclimation is dependent on an array of environmental cues, root growth regulation is entirely dependent on temperature. Since roots are never truly dormant, low temperatures (i.e. less than 3 to 5 degrees Celsius) promote hardiness, whereas higher temperatures, at any time, cause deacclimation. Some experts suggest that deacclimation can be complete within 24 hours while full root acclimation may take up to three weeks. As in the case of shoots, freezing conditions during the period when the plant is unable to control intracellular freezing will result in damage [Green 1985, Dymock 1987, Havis 1976, Fuchigami 19827.

Frost Heaving:

Heaving occurs when the soil surface freezes usually during overnight cooling. This frozen layer grips the stems of the seedlings. Soil moisture trapped under this layer then forms ice crystals which lift the surface layer pulling out or tearing the root system . This is particularly a problem in heavier soils.

Frost Cracking:

The bark and outer layers of some species may crack as a result of differential expansion when the exterior thaws or the xylem freezes.

Winter Burn:

The sun can raise foliage temperatures above freezing in winter even when the air temperature is below freezing. At sunset the thawed foliage refreezes rapidly. The rapidity of the freezing causes winter burn [Burke 1970].

Winter Scald:

Winter scald is similar to winter burn but occurs in the bark of the bole.

Frost Smothering:

When saturated media freezes, little or no oxygen can reach tree roots. Since oxygen must be available to support plant metabolism, seedlings may die unless the media thaws and is allowed to release the water occupying the macropore space, normally occupied by air. Damage usually occurs if the situation persists over 48 hours [Burke 1978].

The Key Points

Considering all of the discussed influences likely to adversely affect the state of the crop, the achievement of increased success in overwintering lies in the following key points:

1. Seedlings to be overwintered must be fit. That is, all unnecessary stresses must be minimized, plant reserves maximized, top development and hardening completed and root chilling requirements fulfilled before the plant is subjected to winter conditions.

2. Storage temperature must be, to some degree, controlled. Once freezing has been achieved, it is undesirable for either the root or the shoot to slip into and out of that state and especially not out of synchronization with each other. The rapidity of temperature change may be more critical than the degree.

3. Higher levels of solar radiation should be avoided.

4. Exposure to moving air (over 4 mph) should be minimized.

5. Ambient humidity's around the plants should be maximized.

6. Anaerobic conditions in the plant's rooting medium must be avoided.

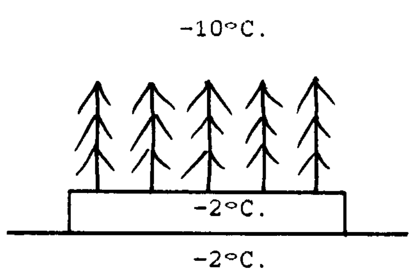
THE PRINCIPLES OF CONTROL

Temperature Control

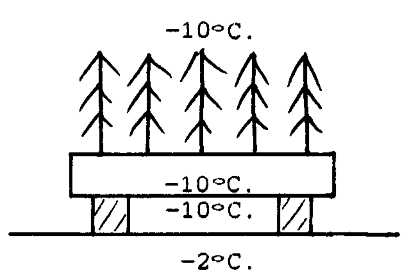
<u>Thermal Mass</u>.--The cheapest and most widely used means of temperature control is thermal mass. This is based on the principle that the greater the mass, the more calories of heat must be exchanged in order to affect a given change in temperature. Since the total amount of stored energy is proportional to the mass, the more mass that is involved the longer it will take to change temperature. In the case of container stock, by placing containers on the ground to create the least possible thermal barrier between the media and the ground we use the thermal mass of the earth to slow the rate of temperature change of the rooting medium.

<u>Thermal Barrier</u>.--Just as we minimize the thermal barrier between containers and the earth, we can also maximize the thermal barrier between any nursery stock and volatile conditions of the environment. This may take the form of a thin mulch barrier placed at the interface of shoot and root, permitting moderation of temperature change in the root and growing media but not the shoot. It can be deeper coverage which envelopes the entire shoot zone or it can be even deeper, resulting in the most extreme temperature conditions occurring well above the shoot zone.

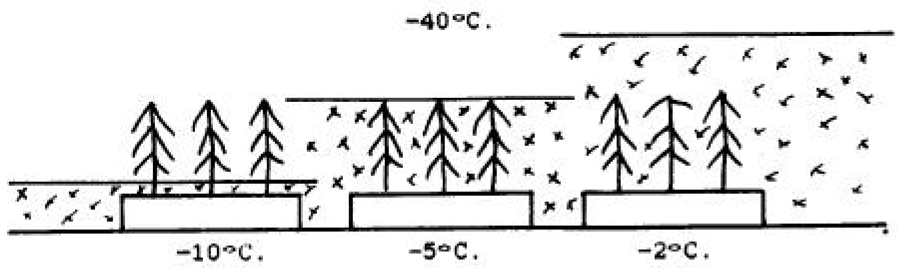
Any material possessing the property of thermal resistivity (R-factor) and inhibiting the exchange of air with the outside environment will insulate the conditions of the stock. The greater the R-factor of the material the slower will be the exchange of heat across it. The less the area of the material, the slower will be the exchange.



Media in trays in contact with the ground will show temperatures near those of the ground.



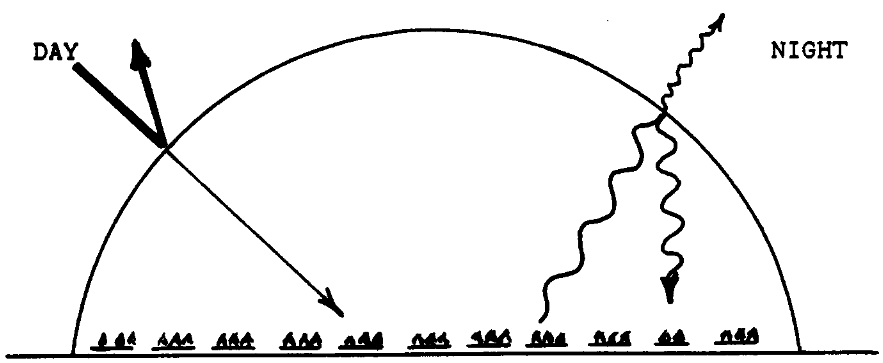
Media in trays not in contact with the ground will show temperatures near those of the air.



Increasing mulch/snow depth increases both the physical amount of the trees protected and the degree of protection afforded. (temperatures are examples only)

Radiant Energy Control.--The regulation of radiated energy by means of a light limiting barrier reduces daytime temperature rise caused by incoming sunshine converted to heat. It may also limit radiated heat loss by reflecting it inward, the overall effect of the two factors being to reduce the range of temperature fluctuation. Snow and mulch covers accomplish this as do most forms of structureless and structured cover.

Environmental Control Systems.--The temperature may be actively controlled by the provision of heating/refrigeration equipment capable of either partially or completely regulating storage temperatures. Provision of such support systems can probably only be practically accomplished within an insulated structure. The cold storage units used in many bareroot operations are good examples of this approach.



Even partial limiting of radiant energy exchange will dramatically moderate temperatures within the cover.

Wind Protection

Windbreaks.--The rule of thumb in windbreak management is that the wind shadow effect of a vertical barrier exists for a distance equal to two times the height of the windbreak upwind and five times the height in the lee [Baldwin & Johnston 198]. Following this assumption, any area encircled by a sufficiently high barrier is, to all intents, completely shielded from wind. If a non-solid material such as shade cloth is employed as the vertical barrier, performance is assumed to be somewhat reduced.

Shade Houses.--Complete enclosure within full walls and overhead cover of shade material may offer an additional increase in protection over walls alone of like material.

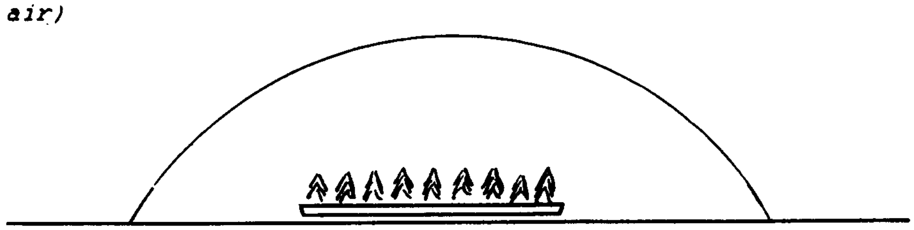
Envelopment.--Complete enclosure within an impermeable structure or within structureless covering materials offers complete exclusion of wind. However, free air space within structures may require internal barriers to convective currents.

Envelopment may be approached at any level:

-by packaging within closed containers

-by employing structureless covers

-by housing within a closed structure (although some moisture is then shared with the large volume of enclosed air)

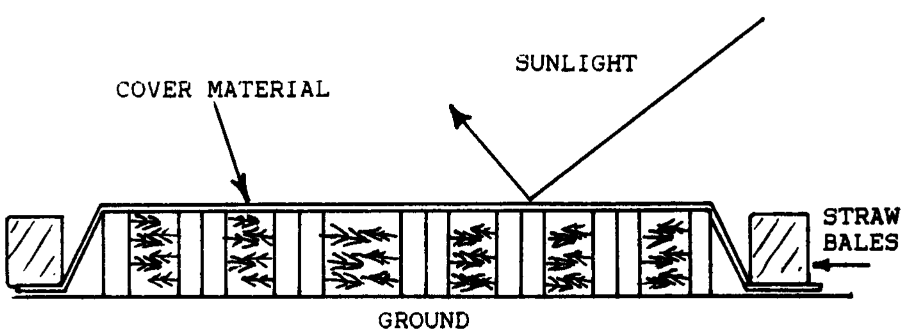


Moisture Control

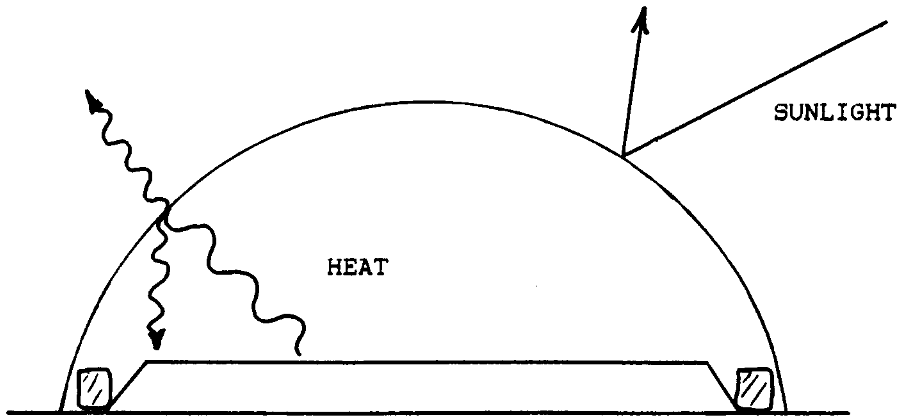
Permeable Cover.--Permeable covers will slow the escape of moisture from the plant environment. This includes fabrics, deep mulches, and snow. Of these, snow is probably the most beneficial. These covers are ineffective in the exclusion of undesirable additional moisture via rainfall.

Envelopment.--Closing the "system" within an impermeable cover retains the inherent plant moisture level. It is additionally effective in excluding unwanted additional moisture in the form of rainfall.

Mechanical Systems.--Mechanical systems designed to introduce humidity may be employed, but are difficult to operate below freezing point. As in the case of other mechanical systems, these are in practical terms best limited to formalized structures.



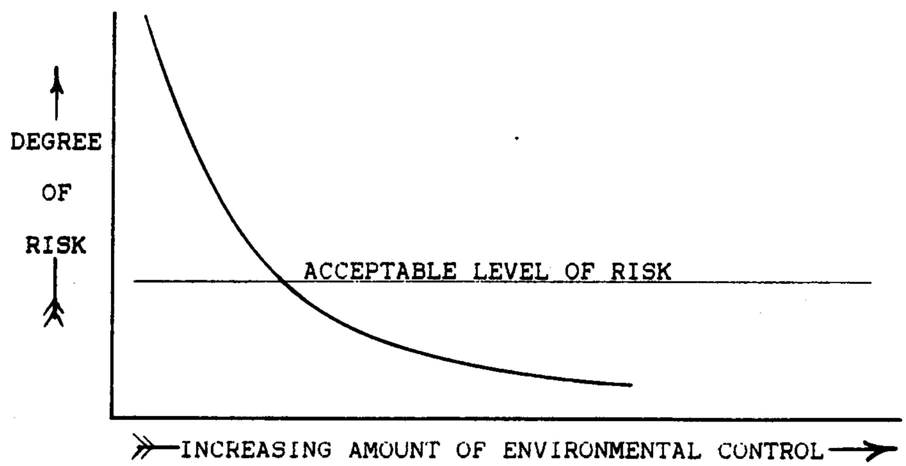
Containers which will stand on their edge facilitate the support of the cover materials. Rodent control can be critical since this is also an attractive overwintering place for such animals.



The use of a structured cover in conjunction with a structureless cover helps to further moderate the overwintering environment.

HOW MUCH CAN YOU AFFORD TO DO?

The bottom line for the nurseryman is not really what he can do but what he can afford to do. It is no surprise that by increasing our expenditure we can increase control and reduce risk. However, instability in weather means increased risk. The question could well become "how much can we afford not to do?"



Present overwintering practices would fall on the curve somewhere above the acceptable level line. Cold storage would be below the line. Placing of other methods requires more trial information.

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