EFFECTS OF WAX COATINGS ON LEAF TEMPERATURES & FIELD SURVIVAL OF PINUS TAEDA SEEDLINGS 1

JOHN L. THAMES

SOUTHERN FOREST EXPERIMENT STATION, FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

This paper reports two experiments. The first was a field test of the effectiveness of wax foliage coatings in improving survival of loblolly pine (Pinus taeda L.) seedlings planted on dry sites. The second was a laboratory study of a suspected upset in the heat balance of wax-coated leaves.

The bulk of experimental evidence, as well as horticultural practice, supports the use of wax coatings for stock to be stored or transported. There is little agreement, however, that coatings can consistently improve the drought-resistance of growing trees. Coatings have materially reduced transpiration in some studies (4, 6, 10), but not in all (1, 8). In the field their net effects on survival sometimes have been beneficial (2, 11) and sometimes useless (7, 9, 12).

FIELD TEST. One-year-old nursery seedlings were planted near Oxford, Miss., in February 1957. The site was an actively eroding sandy loam with a moderate stand of bluestem (Andropogon spp.). The study design consisted of four randomized blocks of five treatment plots each. Tree spacing was 5 by 5 feet; each plot originally had 36 seedlings, but by first treatment in June the average was 34. A 25% water emulsion of Dow-wax was the transpiration retardant.

Treatments were: Sprayed once. Sprayed four times. Sprayed once and shaded with cedar boughs stuck in the ground. Not sprayed but shaded with cedar boughs. Not sprayed or shaded. The first spray, as well as the shading, was applied on June 26. Repeat sprays were made on July 16 and August 8 and 15.

RESULTS (FIELD TEST). The wax coatings had a highly significant adverse effect on survival. Mortality was generally proportionate to the number of sprays. Survival of trees sprayed four times averaged 57 ± 15.7%, as compared to 74 ± 2.9% for trees sprayed once and 96 ± 1.5% for untreated controls (fig 1). The cedar boughs lost most of their leaves by midsummer and had no significant effect on survival. Height growth varied from 0.64 to 0.74 foot among treatments, but none of the differences were significant.

Survival of the repeat treatment fell significantly behind that for the single application after the second spraying, but differences between the single applica-

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mocouples polished and threaded into two needles on each seedling. At least 1 cm of thermocouple was embedded in the needle on either side of the junction. The needles were individually held in a jig 8 inches from a 250 w incandescent lamp and the time required for each needle to reach constant temperature was recorded. The lamp was turned off and wax applied after the leaves had cooled back to equilibrium with the air. Because evaporation of the wax emulsion initially cooled the leaves 10 to 15° below air temperature, they were allowed to warm back to equilibrium before the lamp was turned on again.

The soil in each pot was sampled and needles of each seedling were clipped for determinations of moisture content.

Radiation received at the needle, as measured with a General Electric vacuum thermocouple radiation meter, was 1.1 gm cal./cm²/min. Laboratory air temperatures were between 78 and 80° F. Relative humidity varied from 24 to 38%.

RESULTS (LABORATORY STUDY). Under the lamp, uncoated leaves reached equilibrium with the laboratory environment within 4 minutes, while waxed leaves continued to heat slowly after 7 minutes. Equilibrium temperatures of waxed leaves averaged 4.4° F higher than those for normal leaves; the difference was highly significant.

There were no significant differences between seedlings from dry and wet soils. Moisture content of the dry soils averaged 9.9 % by weight (0.3 % above the 15-atmosphere value), while the wet soils averaged 37.1 %. Moisture content of needles from seedlings on dry soils averaged 116 % of oven-dry weight, as compared with 192 % for needles from watered seedlings. At full turgor, needles averaged 232 % moisture.

Figure 2 shows the average increase in leaf temperature for the four treatments. The relationships between leaf temperature and time for all four treatments were fitted to a function of the form

\[ Y = b_0 + \frac{b_1}{X} + b_2 X^2 \]

where \( Y \) is the difference between leaf and air temperature and \( X \) is the number of minutes after heat is applied. Correlation coefficients for the \( \frac{1}{X} \) variable were highly significant for all treatments, and ranged from 0.934 to 0.993. Coefficients for the \( X^2 \) variables were highly significant for both wax treatments, significant for the normal dry leaves, and not significant for the normal wet leaves.

Differentiating the time-temperature equations shows that heat absorption decreases from an infinite value to a minimum point for the normal curves in about 5 minutes (table 1). Absorption decreases to a point of inflection for the waxed leaves at 7 to 8 minutes.

As figure 2 indicates, normal leaves from seedlings on dry soil behaved similarly to those from seedlings on wet soil—analysis of regression coefficients indicated no significant differences between the normal-leaf curves. Yet as the seedlings from wet soils were presumably transpiring much more rapidly than those from dry soil, the cooling effect of transpiration appears to have been minor—certainly not enough to explain the highly significant difference between waxed and unwaxed leaves. In other studies (3, 5, 13) the effect of transpiration on leaf temperatures was so small as to be overshadowed by the intensity of radiation and the angle of incidence, and by the emissivity of the leaves.

Since the mass of the leaves was not appreciably increased by the wax, their heat capacity was not altered. It seems possible that the coatings served as heat traps which permitted the passing of visible radiation but prevented much of the heat loss by

![Figure 2. Excess of loblolly pine needle temperatures above air temperature at radiation intensity of 1.1 g cal/cm²/min. Treatments represented by ten needles. At equilibrium, temperatures of replicate leaves did not vary more than 2.4° F from the mean of any of the treatments.](image)

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<td><strong>Instantaneous Rates of Change of Leaf Temperature With Time for Seedlings Growing in Wet Soils</strong></td>
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radiation in the infrared. Even a small rise in leaf temperature is accompanied by a large increase in the vapor-pressure gradient between leaf and atmosphere. Thus, any reduction in transpiration resulting from clogging of the stomata or interference with cuticular transpiration might be overbalanced by the greatly increased potential for moisture loss.

If possible toxic effects of the wax are discounted, disturbance of the heat balance between the trees and their environment may explain the heavy mortality of waxed seedlings in the Mississippi field study.

**Summary**

Survival of loblolly pine seedlings planted on a sandy soil in Mississippi was diminished when a wax transpiration retardant was applied once in late June, and was greatly reduced when treatments were repeated several times during the summer. Losses for both single and repeat treatments increased as the soil approached the wilting point. Height growth was unaffected.

Under radiant heat in the laboratory the temperature of waxed leaves rose an average of 4.4° F above that of normal leaves. Rates of heat absorption of the waxed leaves were considerably greater than for the normal leaves. The relationship of the increase in temperature with time under constant radiation for both waxed and normal leaves was found to be best expressed by the equation $Y = b_0 + b_1 \frac{X}{X_0} + b_2X^2$.

The amount of water available for transpiration had no apparent effect on leaf temperature.

Mortality of treated seedlings is attributed to a unfavorable upset of the heat balance between leaves and atmosphere under high insolation.

**Literature Cited**