ANTITRANSPIRANTS

. . . uses and effects on plant life

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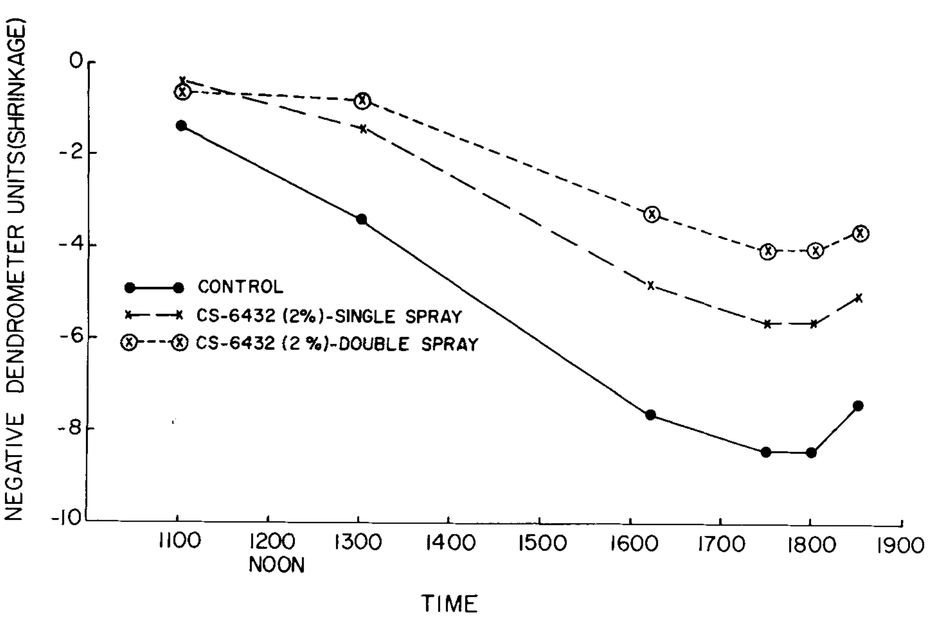
This review of recent research data on application, effects and potential uses for antitranspirants in plant growth shows particular possibilities for conserving irrigation water, aiding plant survival under dry conditions, and protecting foliage against fungus, insects, smog, and salt spray. This information is not to be considered a recommendation of the University of California. Continued research is necessary to determine which materials offer the maximum reduction in transpiration with minimum reduction in photosynthesis, as well as optimum concentrations and application methods. A list of some antitranspirant materials (naming manufacturers and addresses) is available upon request to California Agriculture, Agricultural Publications, University Hall, University of California, Berkeley, California 94720.

ANTITRANSPIRANTS are chemicals capable of reducing the transpiration rate when applied to plant foliage. Since water loss normally occurs through the stomatal pores in the leaves, antitranspirants are usually foliar sprays, although they may sometimes be used more conveniently as dips for immersing the aboveground plant parts. The idea of coating plant foliage with waxy materials to curtail transpiration, particularly for transplanted seedlings, is not new, but research in this field is relatively recent.

Foliar sprays may reduce transpiration in three different ways: (1) reflecting materials reduce the absorption of radiant energy and thereby reduce leaf temperatures and transpiration rates; (2) emulsions of wax, latex or plastics dry on the foliage to form thin transparent films (see photo) which hinder the escape of water vapor from the leaves; and (3) certain chemical compounds can prevent stomata from opening fully (by affecting the guard cells around the stomatal pore), thus decreasing the loss of water vapor from the leaf.

EFFECT OF EXPERIMENTAL FILM-FORMING ANTITRANSPIRANT (CS-6432), AS A SINGLE OR A DOUBLE FOLIAR SPRAY, ON THE DAYTIME SHRINKAGE OF ALMOND TREE TRUNKS
(One dendrometer unit = 508×10^{-5} mm.)



Effects

Since stomata serve as portals for both the loss of water vapor and for the intake of carbon dioxide (which is necessary for photosynthesis), an antitranspirant barrier against water loss also may reduce plant growth.

Reflecting materials do not cause blockage of stomatal pores when they are applied to the upper surfaces of leaves with stomata exclusively on the lower surfaces. However, such coatings may curtail photosynthesis on overcast days when light is limited.

Theoretical analysis and experimental data indicate that stomata-closing antitranspirants should cause reduced transpiration ratios (less water transpired per unit of growth) provided the applied chemicals do not damage the plant's internal photosynthetic mechanism. This was illustrated by measuring transpiration and dry weight of creeping red fescue grass, *Festuca rubra* (see table). Although dry weight was slightly reduced by a moderate concentration ($10^{-3.5}$M) of the stomata-closing antitranspirant, phenylmercuric acetate (PMA), the accompanying large reduction in transpiration resulted in a transpiration ratio lower than that of the control. On the other hand, a stronger ($10^{-3.2}$ M) solution of PMA increased the transpiration ratio because of the large decrease in dry weight caused by phytotoxicity.

Film-forming antitranspirants can cause large reductions in transpiration rates, but since the $H_2O : CO_2$ permeability ratios tend to exceed unity for currently available film materials, the transpiration ratios may not be reduced. Thus, 2 hours after application of an experimental film-forming material (CS-

6432, supplied by the Chevron Chemical Company) on oleander (*Nerium oleander*) leaves, the transpiration ratio was increased from 257 to 285, because of a greater reduction in photosynthesis than in transpiration (see table). Measurements on the same leaves two days later showed that the transpiration ratio had been decreased to 232 because photosynthesis was impeded less. The increased photosynthesis observed is probably the result of the decreasing continuity of the film on the leaf surface. It is difficult to maintain a continuous film over the entire leaf surface. This may actually be advantageous by preventing large reductions in photosynthesis, while still achieving a retardation of transpiration.

Reducing plant growth

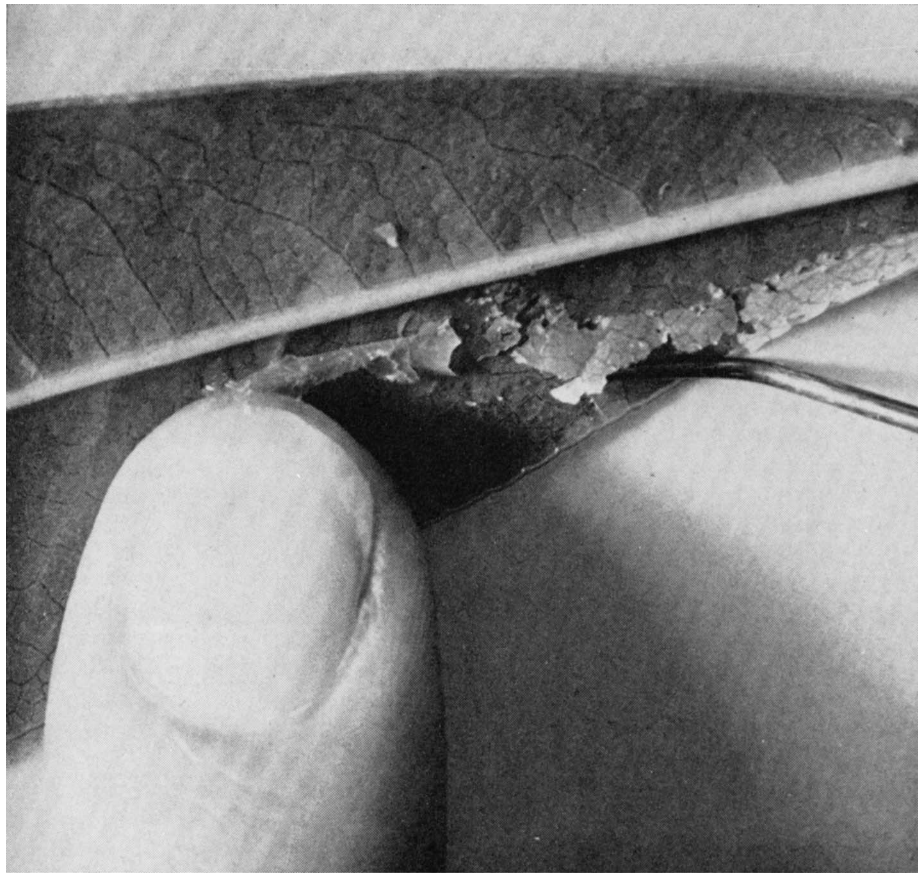
Reduced plant growth is not always disadvantageous. The possibility of using antitranspirants on grass to reduce both the frequency of irrigation and mowing is an attractive prospect which merits further investigation. The use of antitranspirants to decrease transpirational water losses from shrubs and trees on watersheds, where increased water yields may be more important than any harm caused by growth reductions, is a promising field for research and studies along these lines have been carried out in Connecticut and Utah.

University experiments are now being conducted with antitranspirant sprays on oleanders planted in the median strips of California's freeways to reduce the frequency of irrigation—an expensive and hazardous operation. Growth reductions from the use of antitranspirants should not be disadvantageous once the oleanders have attained a height effective for screening headlight glare.

Growth retarded

Growth is retarded by natural stomatal closure when an untreated plant wilts, because of low soil water potentials and/or high evaporative demand. By slowing down the rate at which water is lost, antitranspirants will help to prevent or at least will delay wilting. Therefore, treatment with an antitranspirant must be made as a preventive measure *before* the onset of wilting.

Measurements with dendrometers have shown that the trunks of trees may shrink considerably during the day when water uptake lags behind transpiration. When the foliage of five-year-old almond trees was sprayed with an experimental film-forming antitranspirant (CS-6432) the amount of daytime shrinkage of the trunks was reduced by over 50 per cent, indicating that the water balance of the tree had been improved by the curtailing of water loss from the leaves (see graph). Radial trunk growth was reduced by 30 per cent, but no measurements have yet been made on the yield of nuts.



Film-forming antitranspirant (polyvinyl chloride complex) was applied to the entire leaf surface but only that portion of the film loosened by the needle is visible in photo.

While antitranspirants of the reflecting type cause a reduction in leaf temperature, the film-forming and stomata-closing types tend to increase leaf temperature by curtailing transpiration rates and thus reducing evaporative cooling. However, under normal conditions the increase in leaf temperature is not very great since thermal emission, rather than evaporative cooling, is the most important means of heat dissipation.

Although it is known that the rate of mineral nutrient transfer within the plant is related to mass flow of water, the use of an antitranspirant, and the resulting reduction in transpiration (which is unlikely to exceed 30 per cent under field conditions), should not reduce the rate of mineral supply to the leaves sufficiently to retard growth. Present evidence suggests that antitranspirants will affect growth much less by altering leaf temperature and mineral nutrient supply than by retarding carbon dioxide supply to leaves.

Application

It is important to use the correct concentration of the stomata-closing materials to avoid phytotoxicity effects. Phenylmercuric acetate (PMA), in particular, must be used with care since it is a mercury containing metabolic inhibitor. Optimum concentrations may vary from

EFFECTS OF ANTITRANSPIRANTS ON TRANSPIRATION RATIOS OF CREEPING RED FESCUE AND OLEANDER PLANTS—RATIO OF WATER TRANSPIRED (T) TO DRY-WEIGHT PRODUCTION (DW) OR TO PHOTOSYNTHETIC ACTIVITY (P)

CREEPING RED FESCUE (*Festuca rubra*)

Treatment	T (mg/pot)	DW (mg/pot)	T/DW
Control	93360	45.5	2052
PMA $10^{-3.5}$ M (moderate concentration)	76970	44.4	1734
PMA $10^{-3.2}$ M (high concentration)	65940	29.8	2213

OLEANDER (*Nerium oleander*)

Treatment	T (mg $H_2O/dm^2/h$)	P (mg $CH_2O/dm^2/h$)	T/P
Control	1270	4.95	257
CS-6432 (3%) (One hour after treatment)	870	3.05	285
CS-6432 (3%) (Two days after treatment)	890	3.83	232

10^{-4}M (dilute) to 10^{-3}M (strong), depending on plant species. Plants differ considerably in their sensitivity to these chemicals so it is advisable to make visual observations of a few test leaves prior to any extensive use. Film-forming and reflecting materials are not likely to pose problems of phytotoxicity, although some browning may occur on leaf tips if high concentrations of emulsions flow to the leaf tip and congeal there. When seedlings are dipped in a film-forming emulsion, it is important to see that the roots are not coated by the solution since water uptake may then be retarded.

Stomata

Stomata-closing sprays are effective in extremely dilute concentrations. Thus, they may be expected to be less expensive to use than other antitranspirants if their unit costs do not appreciably exceed those of other types of materials. For example, PMA at 10 cents per gram used at the rate of 15 grams per acre (diluted in 100 gallons of water) would cost only $1.50 per acre. The volume of spray to be used per acre will depend on the nature of the vegetation since the primary consideration (at least for the film-forming and stomata-closing antitranspirants) is coverage of the *stomata-bearing surfaces* of the leaves. On the 15-foot almond trees, about 1 gallon of spray per tree was applied with a mist blower, ensuring that the lower leaf surfaces were wetted (there are no stomata on the upper surface of an almond leaf). In one of the treatments the trees were sprayed a second time, about one hour after the first spray had dried (see graph). This resulted in less trunk shrinkage than in the control or single spray treatment because more complete coverage by the spray was obtained, and perhaps because thicker films were formed on the leaves.

The duration of antitranspirant effectiveness determines the frequency with which respraying is necessary and its economic usefulness. The duration depends on the efficiency and durability of the material, effectiveness of the spraying operation, environmental conditions, and the amount of new foliar growth produced by the plant after spraying. Thus, the effect may last from only a few days to several weeks.

Complete coverage of the stomata-bearing surfaces of leaves is impossible to achieve on a field scale, partly because of difficulties in wetting the leaves (which can be overcome by the use of surfactants) and partly because of crop geometry. It is not likely that all the lower and inner leaves of a crop will be hit by the spray. Since the highest rates of transpiration occur from leaves in the outer periphery of the plant where radiation and ventilation are greatest, these leaves should receive most of the spray.

The most obvious use of antitranspirants is to conserve soil water and thereby reduce irrigation frequency. However, applications for this purpose would be justified only if water costs are sufficiently high and if possible water savings are relatively large in comparison with application losses during irrigation. Antitranspirant treatment of watersheds or grassed areas where plant growth is not a prime factor is being investigated. Other possibilities include their use to aid survival of established and valuable plants in drought situations, to increase survival of transplanted seedlings, to extend the range of environments in which favorable growth and yield can be obtained from plant types sensitive to water deficits, to reduce winter kill, to treat plant material for shipping, and to reduce the rate of desiccation of cut Christmas trees. There is some evidence that an antitranspirant film on foliage may provide a physical barrier against fungus and insect attack and that it may also reduce injury from smog and salt spray. Incorporation of an antitranspirant in a pesticide spray, assuming there is no incompatibility between the two materials, would greatly reduce application costs. Some film-forming sprays polymerize slowly on the leaf surface, thereby increasing the residual effect of the incorporated insecticide or fungicide. Numerous potential uses of antitranspirants are yet to be investigated.

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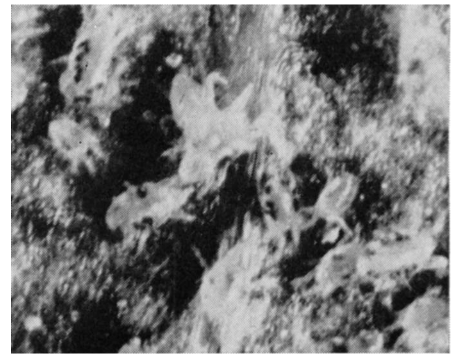

SPIDER

Photo magnification (above) of the Pacific mite, *Tetranychus pacificus* McG. White-stippled type of injury shown in photo below resulted from light to moderate spider mite infestation on soybean leaves.