Short- and Long-term Effects of Antitranspirants on Water Relations and Photosynthesis of Woody Plants\textsuperscript{1,2}

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Abstract. Each of 8 antitranspirants reduced transpiration of 2 species of woody plants. Dow Silicone and CS 6432 were the most effective compounds on \textit{Fraxinus americana} and Dow Silicone was effective on \textit{Pinus resinosa}. Keykote, Folicote and Improved Wilt Pruf showed an increased effect on plant water loss and net photosynthesis (measured by net CO\textsubscript{2} uptake) of \textit{P. resinosa} up to 8 days after compound application. Thereafter there was no significant change in the effect of any compound on transpiration or photosynthesis. Effects on \textit{F. americana} of all compounds except Improved Wilt Pruf decreased with time after application. Scanning electron micrographs of treated leaves suggested that antitranspirant films on \textit{F. americana} leaves cracked over the guard cell pore, accounting for the decrease in compound effect with time. Antitranspirants apparently reduced water loss of \textit{P. resinosa} by combining with wax in the stomatal pore and forming an impermeable plug. The compounds tested were toxic to \textit{F. americana} seedlings and photosynthesis of treated plants decreased with time, even when direct physical effect of a compound had worn off. \textit{Pinus resinosa} seedlings showed no decrease in photosynthesis with time. \textit{F. americana} plants treated with Keykote exhibited low rates of water loss and transpiration/photosynthesis ratios that were not significantly different from those of control plants. Folicote was toxic, and Clear Spray increased water loss of \textit{F. americana} seedlings. Dow Silicone reduced water loss of \textit{Pinus} seedlings by about 80%, and plants treated with Dow Silicone, Improved Wilt Pruf, Keykote, or Folicote had favorable transpiration/photosynthesis ratios. The effects of antitranspirants on transpiration and photosynthesis were greatly influenced by environmental regimes and by species.

When transpiration exceeds water absorption, water stresses develop in plants and growth is reduced. This occurs under conditions of high evaporative demand, even when soil water is readily available (19, 20). The amount of water transpired from a leaf may be significantly reduced by: (a) limiting opening of stomata (17, 18, 37-42, 44), (b) coating transpiring surfaces with a monomolecular hydrophobic film obtained from the higher alcohols or silicone (1, 2, 14, 15, 22, 26), or (c) occluding stomata with a relatively thick film impervious to water vapor (8, 11, 24, 25, 27).

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woody and herbaceous plants (3, 21, 33, 34, 38). Higher alcohols, when applied to cotton plants had a greater inhibitory effect on photosynthesis than on transpiration (31). In contrast, some film-forming antitranspirants and silicone thin film compounds have shown usefulness. Silicone compounds reduced transpiration by about half in sunflower (2), while Parkinson (26) found an increase in the photosynthesis/transpiration ratio of silicone-treated sugar beet plants. Heinlein and Haigh (14, 15) reported significant reduction in transpiration of both gymnosperms and angiosperms treated with low concentrations of silicone emulsion. In addition, silicone apparently stimulated growth and fruit yield when continuously applied to pea plants.

Marshall and Maki (24) reported that leaf coatings injured and decreased survival of transplanted seedlings for an extended period, but with a concomitant reduction in plant growth. By comparison, decrease in water loss of F. americana seedlings following silicone application was of short duration.

Film-forming antitranspirants have reduced water loss of woody and herbaceous species to varying degrees. Under hot, dry conditions Phaseolus vulgaris and Pinus halepensis plants treated with latex sprays showed greatly increased growth but their transpiration rates were only negligibly affected (2, 27). Marshall and Maki (24) reported that P. strobos and P. resinosa seedlings treated with paraffin wax transpired less than 40% as much as untreated seedlings. Malcolm and Stolzy (23) found latex more effective than silicone in reducing transpiration. Davenport et al. (4) demonstrated increased growth and favorable internal water balance of antitranspirant-treated Prunus trees. However, Goren et al. (11) observed that polyvinyl leaf coatings injured and decreased survival of transplanted citrus nursery stock. In addition, Olofinboba et al. (25) found that several film antitranspirants reduced photosynthesis of field-grown P. resinosa seedlings. The available data suggest that the ultimate effects of film-forming antitranspirants on transpiration and photosynthesis depend to a degree on compound permeability and to a greater extent on environmental conditions. Most evaluations of antitranspirants were made under field conditions. Several investigators emphasize the importance of compound durability in determining ultimate effects of film-forming antitranspirants on plant growth (9, 28). Only a few experiments relate directly to this aspect of antitranspirant physiology.

Previous studies showed that F. americana had a high transpiration rate (6). In addition, F. americana seedlings exhibited poor stomatal control in response to changes in light intensity, humidity, and wind speed (5, 6), rendering this species especially susceptible to environmental stresses. It seems likely that if antitranspirants are to be generally useful, formulations must be developed which efficiently reduce transpiration of species such as F. americana. Pinus resinosa seedlings have been the subject of several antitranspirant evaluations (20, 22, 24, 25). Seedlings of F. americana and P. resinosa were treated with a range of film-forming antitranspirants. Differences in compound performance were considered in relation to structure of the stomatal apparatus of each species, differences in plant metabolism, and physical properties of the films.

Methods

Three-year-old seedlings of Fraxinus americana L. and Pinus resinosa Ait. potted in 2 parts soil/one part sand in 15 cm pots were maintained in a growth chamber under 14 hour days at 1200 ft c. (0.24 cal cm^-2 min^-1) and 25±1°C. In the case of P. resinosa, a cuvette 10 cm x 10 cm x 25 cm covered the whole plant while in F. americana a cuvette 18 cm x 18 cm x 5 cm enclosed a single leaf. A fan in the chamber provided air movement over the plant. Gas exchange was measured with a Beckman 15A infrared CO₂ analyser in conjunction with a Speedomax W recorder. The recorder scale corresponded to 0-600 ppm CO₂, and readings could be interpolated to 0.1% of full scale. Final CO₂ concentrations were converted by means of a calibration curve to ppm CO₂ and expressed with an accuracy of 1 ppm.

Changes in water vapor content of the air before and after passing through the cuvette were monitored using 2 differential thermocouple psychrometers (32). Thermocouples were connected to a Westronics 12 point recorder. Changes in relative humidity of the air of 0.5% could be detected.

Leaf and needle temperatures were measured with two, 0.003 inch Cu/Co thermocouples scotch taped to the plants, and air temperature was measured with 2 thermocouples situated in different positions in the cuvette. Air temperature in the cuvette could be maintained within ±1°C of the desired value.

The light source was a Lucalox 400/BU reversed spectrum Na vapor lamp, positioned a fixed distance from the cuvette. Air entering the CO₂ analyser was dried by passing it through a column of drierite (anhydrous CaSO₄·6 mesh). Removal of water from the air affected readings by about 1% on the recorder scale. Daily calibration of the CO₂ analyser was necessary to allow for changes in efficiency of the drierite and also to account for changes in atmospheric pressure. Relative humidity of air entering the chamber was maintained around 70%.

Air flow in the system was controlled by a pump and 2 Gilman flowmeters with a range of 0-5.0 liters per min. A mercury and a water manometer ensured that all measurements were made at a comparable pressure, since the CO₂ analyser was highly sensitive to changes in pressure. Flow rate of the air through the chamber was adjusted to 2 liters per min., and transpiration was determined in an open system. Immediately following this determination, net photosynthesis was measured in a closed system using the modified method of Sasaki and Kozlowski (29).

The plants were placed in the cuvette 45 minutes before measurements were taken, such that an equilibrium gas growth chamber after which they were sprayed to runoff with the antitranspirants. Control plants were sprayed with water. Both F. americana and P. resinosa seedlings were treated with 3CS6432, 2.5% (principal ingredient not given); Clear Spray, 33% (latex); Keykote, 5%, (plastic-wax); Folicote 5%, (wax emulsion); Dow Silicone emulsion XF-4-3531, 7.5%; Improved Wilt Pruf, 10%, (polyvinyl chloride). In addition F. americana seedlings were treated with Vapor Gard, 5% (polyterpene) and Wilt Pruf, 20%, (polyvinyl chloride). All concentrations were made up as volume of commercial preparation to volume of water, except Dow Silicone which is expressed as percentage of silicone in the final solution. A spreader/sticker (Tween 20, 0.5%) was added to all antitranspirant solutions to facilitate adequate needle/leaf coverage. The concentrations used were those determined from previous experiments to be least toxic to leaves, but effective in reducing transpiration. Five F. americana and 6 P. resinosa seedlings were treated with each compound. Plants were maintained in the growth chamber, under the conditions specified, for the duration of the experiment. At specific times after compound application (1, 4, 8, 16 and 32 days), rates of CO₂ uptake and transpiration of control and treated seedlings were measured. Determinations were made on whole P. resinosa seedlings and single, intact mature leaves from the upper whorls of F. americana plants.

Transpiration and photosynthesis of seedlings were monitored in water-jacketed plexiglas cuvettes at 3,200 ft c. (0.24 cal cm^-2 min^-1) and 25±1°C. In the case of P. resinosa, a cuvette 10 cm x 10 cm x 25 cm covered the whole plant while in F. americana a cuvette 18 cm x 18 cm x 5 cm enclosed a single leaf. A fan in the chamber provided air movement over the plant. Gas exchange was measured with a Beckman 15A infrared CO₂ analyser in conjunction with a Speedomax W recorder. The recorder scale corresponded to 0-600 ppm CO₂, and readings could be interpolated to 0.1% of full scale. Final CO₂ concentrations were converted by means of a calibration curve to ppm CO₂ and expressed with an accuracy of 1 ppm.

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exchange rate was attained and recorded. At the conclusion of the experiment, dry wt of leaves and needles was determined and the area of the *F. americana* leaves were computed using a photographic/paper weighing technique (22). The rate of photosynthesis was expressed in mg CO$_2$/hr on a leaf area or needle dry wt basis and transpiration as mg H$_2$O/hr on a leaf area or dry wt basis. No attempt was made to account for changes in leaf or needle area, which were minimal during the 32 day measurement period. The transpiration/photosynthesis ratio was calculated for control and treated plants to show the effect of the antitranspirant on the amount of water lost per unit of CO$_2$ fixed.

Leaves and needles were prepared for observation in the scanning electron microscope (SEM). Fresh tissue was freeze dried, coated, and photographed as described by Kozlowski et al. (21).

Results

Effects of antitranspirants on F. americana. Although all of the applied compounds reduced transpiration of F. americana seedlings within 24 hours after application, water loss of plants treated with Clear Spray was not significantly different from that of control plants (Fig. 1). The effect of Clear Spray was of short duration, and 12 days after application, treated plants showed increased water loss over control plants (Fig. 1). Improved Wilt Pruf decreased transpiration for 32 days after treatment, with no obvious decrease in effect with time (Fig. 2). Immediately after application, CS6432 and Dow Silicone were significantly more effective than all other compounds in reducing water loss. Under the conditions of the experiment the effect of these compounds on transpiration was negligible after 32 days (Figs. 3, 4). Seedlings treated with Folicate, Wilt Pruf or Vapor Gard exhibited reduced transpiration for 8 days, while transpiration rates of plants treated with Keykote increased up to 16 days after treatment, but decreased thereafter (Figs. 5-8). After 32 days, transpiration was affected more by Keykote, Folicate, or Improved Wilt Pruf than by the other compounds tested (Figs. 1-8).

Twenty-four hours after application, all compounds significantly reduced photosynthesis (Figs. 9-16). Dow Silicone and CS6432 had more effect than all other compounds (Figs. 11, 12). Following an initial decrease in CO₂ uptake a subsequent increase in photosynthesis with time was apparent for plants treated with all antitranspirants except Improved Wilt Pruf (Fig. 9). Photosynthesis of plants treated with Clear Spray decreased from 8 days after application (Fig. 9), while photosynthesis of plants treated with other compounds decreased or showed no further increase 16 days after compound application (Figs. 10-16). While water loss characteristics of F. americana seedlings treated with Folicate or Keykote indicated that the direct physical effects of these compounds had worn off after 16 days (Figs. 5, 6), compound toxicity (as decrease in net photosynthesis) became apparent at this time (Figs. 13, 14). Thirty two days after application all compounds caused a significant reduction in photosynthesis, with Folicate and Improved Wilt Pruf the most inhibitory compounds.

Transpiration/photosynthesis ratios (T/P) of treated plants, with the exception of those treated with Keykote, showed a significant increase over the ratios of control plants (Figs. 17-24). In this situation, higher T/P values indicated lower water use efficiency of treated plants. One day after application, CS6432 and Dow Silicone were the only compounds which significantly decreased T/P, because photosynthesis was reduced more than transpiration (Figs. 19, 20). The increase with time in T/P of treated plants reflected an increase in transpiration as the compounds became less effective. This increase was accompanied by an initial relatively small increase in photosynthesis and a decrease thereafter, presumably due to phytoxicity. Keykote proved to be least toxic of the compounds tested since the T/P values of treated plants at 32 days after treatment were not significantly greater than those of control plants (Fig. 22).

Some variation in the effects of individual compounds was observed, since percentage coverage of leaves depended on leaf texture. For example, young waxy leaves often were only partially covered by the films. Often these compounds were particularly toxic to young leaves. They caused browning, and eventually death. Leaf temperatures of treated plants remained within ±2°C of leaf temperatures of control plants monitored under the same conditions.

Effects of antitranspirants on P. resinosa. Clear Spray, Dow Silicone, and CS6432 rapidly (within 24 hours) reduced transpiration of P. resinosa seedlings (Figs. 26, 29 and 30). Improved Wilt Pruf and Keykote caused an initial reduction in transpiration (after 24 hours) plus a further decrease for 8 days
after compound application (Figs. 25, 27). Folicote did not influence plant water loss 24 hours after application but subsequently reduced transpiration by more than half for the duration of the experiment (Fig. 28).

In striking comparison to the results obtained with *F. americana*, no decrease in compound effect was observed on *P. resinosa* during the experimental period (Figs. 25-36). Thirty-two days after treatment, all compounds significantly checked water loss of *P. resinosa*, with Dow Silicone causing about a 95% reduction. At 32 days the effects of Keykote and Improved Wilt Pruf were not significantly different from that of Dow Silicone.

Net photosynthesis rates of plants treated with Clear Spray, Dow Silicone, or CS6432 were significantly reduced 24 hours after treatment (Figs. 32, 35 and 36). The effects of Improved Wilt Pruf, Keykote and Folicote on photosynthesis (Figs. 31, 33 and 34) paralleled the effect of treatment up to approximately 8 days. Unlike *F. americana* seedlings, treated *P. resinosa* seedlings did not show a significant decrease in photosynthesis with time after 8 days.

All compounds significantly reduced photosynthesis at 32 days after treatment, with Dow Silicone-treated plants photosynthesizing at approximately one tenth the rate of control plants. The effect of CS6432 was not significantly different from that of Dow Silicone.

Immediately after treatment, plants treated with Improved Wilt Pruf, Keykote, or Folicote had higher T/P values than control plants (Figs. 37, 39, 40). The initial effects of Keykote and Folicote were statistically significant. Plants treated with Improved Wilt Pruf, Keykote, and Folicote also showed a small antitranspirant effect in the days immediately following treatment. *P. resinosa* seedlings treated with Clear Spray, Dow Silicone, or CS6432 showed an initially significant decrease in T/P value (Figs. 38, 41, 42). The subsequent effect of CS6432 and Clear Spray was to increase T/P. In both cases this trend was significant, and the result of gradually decreasing photosynthesis with time after treatment. The substantial reduction in transpiration following application of Dow Silicone resulted in the observed decrease in T/P. Needle temperature of treated seedlings remained within 1-2°C of that of control seedlings.

Electron micrographs showed that stomatal pores of untreated *P. resinosa* plants were filled with an amorphous wax (Fig. 46). Such deposits were observed in other species (12) and undoubtedly provide resistance to gas exchange. Micrographs of *P. resinosa* needles treated with Dow Silicone (7.5%) (Fig. 47) suggested that the silicone emulsion combined with cuticular waxes of the stomatal pore and formed an essentially impermeable plug. Micrographs of needles treated with other compounds also suggested that stomatal plugs were formed. A conventional film was observed covering the whole needle of plants treated with several of the applied compounds, but even in this situation the stomatal waxes assumed the appearance of a solid plug (Fig. 48—Improved Wilt Pruf 10%).

**Discussion**

It is evident that conditions occur in the field where an antitranspirant film might either remain intact and unaffected by the environment for some time, or be rapidly removed from a leaf by rain, irrigation water, wind, sun, or growth stresses. Therefore, it was considered important to evaluate not only the initial direct effects of the compounds, but also their overall long term effects on plants not subjected to environmental stress.

Seedlings of *F. americana* and *P. resinosa* responded very differently to antitranspirants. The compounds tested were
Figs. 37-42. Effects of 6 film-type antitranspirants on the transpiration/photosynthesis ratio of Pinus resinosa seedlings.

![Graph](image1)

Figs. 37-42. Effects of 6 film-type antitranspirants on the transpiration/photosynthesis ratio of Pinus resinosa seedlings.

![Graph](image2)

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![Graph](image3)

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![Graph](image4)

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![Graph](image5)

Figs. 37-42. Effects of 6 film-type antitranspirants on the transpiration/photosynthesis ratio of Pinus resinosa seedlings.

![Graph](image6)

Figs. 37-42. Effects of 6 film-type antitranspirants on the transpiration/photosynthesis ratio of Pinus resinosa seedlings.

much more effective in reducing transpiration of *P. resinosa* than of *F. americana*. It was apparent from a survey of several leaves, that antitranspirant coverage of treated *F. americana* leaves was incomplete. It seems likely that the surface tension and convex relief of stomatal cuticular lips of *F. americana* in many cases might have disrupted continuous antitranspirant films as they formed and prevented coating of some guard cells. *P. resinosa* needles were more completely covered by film antitranspirants and treated needles had antitranspirant/wax plugs in the majority of stomatal pores.

The effect of Clear Spray on *F. americana* leaves was of short duration and treated plants eventually exhibited an increased rate of water loss over control plants (Fig. 1). This might indicate that partial covering of the leaf with an antitranspirant led to a general increase in leaf turgor with resultant stomatal opening (4). Stomata not covered by the antitranspirant film thus lost an increased amount of water. The other compounds tested did not increase transpiration relative to control plants, presumably because of their greater initial influence over plant water loss.

Haigh and Heinlein (12) reported that Dow Silicone emulsion did not form a hard film on leaf surfaces. Rather, it appeared to be effective in reducing water loss by entering leaves through stomatal pores and forming a monomolecular liquid film on the mesophyll cell surface. It seems unlikely that silicone emulsion could penetrate the relatively small stomata of *F. americana*, coat the extensive mesophyll cell surface, and reduce transpiration by as much as 80% (Fig. 4). The large initial reduction in transpiration caused by Dow Silicone might be
explained by direct occlusion of stomatal pores by the liquid emulsion. Subsequent evaporation of the emulsion from the leaf surface would lead to the observed reduction in compound effect with time. Such a hypothesis might also explain the discrepancy between results of the present study and those of Lee and Kozlowski (22). The latter experiments, which reported that Dow Silicone reduced transpiration of *F. americana* for only a short time, were conducted during the month of June in the extreme environment of a greenhouse. Under such conditions the antitranspirant might be expected to evaporate more rapidly from the leaf surface than in the present experiments. These results emphasize the importance of defining environmental regimes before recommendations for use of antitranspirants can be made.

The initially reduced effect of Improved Wilt Pruf, Keykote, and Folicote on water loss (Figs. 25, 27, 28) and CO₂ exchange (Figs. 31, 33, 34) of *P. resinosa* may be explained by scanning electron micrographs. It has been postulated that antitranspirants may reduce water loss of *P. resinosa* seedlings by infiltrating and, in some cases, combining with amorphous wax in stomatal pores. Possibly some compounds require more time than others to infiltrate the wax, and reduce water loss. The greater efficiency of antitranspirants with time may reflect increased stomatal pore infiltration.

It seems likely that if these initial effects of Improved Wilt Pruf, Keykote, and Folicote could be explained by compound toxicity, then the observed decreases in photosynthesis would have continued beyond 8 days. This was not the case. Further, T/P values of plants treated with these compounds were favorable (Figs. 37, 39, 40).

Some of the differences between the long term effects of the antitranspirants on *F. americana* and on *P. resinosa* may be explained by Figs. 43-48. The formation of a plug in the stomatal pores of *P. resinosa* apparently accounted for the persistent reduction in transpiration and photosynthesis of treated seedlings. Evaporation from the leaf surface apparently explained the relatively brief effect of Dow Silicone on *F. americana*. Electron micrographs suggested that antitranspirants which form a hard film over the leaf might crack directly over the guard cell pore, possibly as a result of guard cell movement. Incidence of film cracking increased with time after application. Such cracking would explain the decrease with time of the effect of all compounds except Improved Wilt Pruf. Application of this compound to *F. americana* leaves caused a persistent reduction in transpiration. *Fraxinus americana* leaves treated with Improved Wilt Pruf showed only minimal cracking of the antitranspirant film. Different degrees of film cracking could be interpreted as a function of time after compound application and in addition were seen to vary according to the compound applied. For these reasons, and the fact that the samples were coated for protection, it was considered unlikely that cracking could be due to the high vacuum of the scanning electron microscope rather than to an *in situ* breakdown of the antitranspirant. Leaves treated with Improved Wilt Pruf exhibited a decrease in photosynthesis with time after application. In addition to the direct physical effect of the film on gas exchange after 24 hours, reduction in photosynthesis might be attributed to poisoning of the photosynthetic system by accumulating toxic products. These would be unable to escape from the leaf as a result of the persistent antitranspirant film.

The study indicates that the direct physical effects of most of the antitranspirant compounds applied to *F. americana* wore off after 16 days. At this time compound toxicity became apparent. Toxicity may be attributed to a phytotoxic component of the antitranspirant compound, or to accumulation of metabolites within the leaf as discussed previously. Reduction of the cooling effect of transpiration might be expected to cause an increase in leaf temperature. Such increases, however, were minimal and toxicity as a result of high temperature was discounted.

In marked contrast to *F. americana* seedlings, treated *P. resinosa* seedlings did not show a significant decrease in photosynthesis with time after 8 days. Thus antitranspirants apparently were less toxic to *P. resinosa* than to *F. americana* seedlings. Repeated application of an antitranspirant is often recommended for control of a long-term water stress problem. The present study emphasizes the possible danger of such recommendations for some species under certain environmental conditions. In addition, Gale and Hagan (9) and Poljakoff-Mayber and Gale (28) emphasized the desirability of developing antitranspirant compounds which show durability after application to leaves. Such durability, however, may be undesirable because of associated phytotoxicity.

The results of this experiment contrast with a report by Olofinboba et al. (25) on the effects of film-forming antitranspirants on photosynthesis of *P. resinosa*. It should be noted that while the present study was carried out under the controlled conditions of a growth chamber, with well-watered seedlings, the experiment noted above was performed in the field where periodic water stress and rainfall would be likely to affect the antitranspirant film. The importance of defining environmental conditions when reporting and recommending antitranspirant treatment is reemphasized.

Although T/P has been criticized as a value which depends on environmental rather than plant characteristics (16), the environmental conditions of the present study were constant. This ratio was thus considered appropriate for comparing effects of antitranspirants.

Ideally antitranspirants should cause a decrease in T/P. However, the permeability properties of the antitranspirant compounds mean that complete leaf coverings can only act to increase T/P. As discussed above, incomplete leaf films may account for survival of plants under conditions of water stress under which they would otherwise die. In considering the initially high T/P values of *F. americana* seedlings treated with Dow Silicone or CS6432 (Figs. 19, 20) the substantial reduction of transpiration after treatment suggests thorough leaf coverage by the films. In this situation, permeability of the film would influence importantly T/P of treated plants. Less complete leaf coverage, apparently resulting from application of the other compounds, might be expected to have less effect on CO₂ exchange.

The increase in transpiration with time, relative to photosynthesis, exhibited by *F. americana* seedlings (Figs. 17-24) was a function of greater water loss as the compounds wore off or cracked. The increase was accompanied by an initial relatively small increase in photosynthesis up to about 16 days and a decrease thereafter, presumably due to phytotoxicity.

Immediately after compound application, *P. resinosa* seedlings treated with Keykote, Folicote or Improved Wilt Pruf exhibited increased T/P values over control plants. It has been suggested that Keykote, Folicote and Improved Wilt Pruf may take time to infiltrate stomatal pores and become fully effective. It may be postulated that before infiltration occurs, the antitranspirant compounds form a continuous liquid or semi-liquid film over the stomatal pore. In this situation, permeability of a given antitranspirant is critical. Since even the most promising antitranspirants are 4 times more permeable to water than to CO₂, the film might be expected to have more effect on CO₂ exchange than on water loss. As the compound penetrates and dries, minute pores might be expected to open in the stomatal plug such that the antitranspirant reduces water loss, and incidentally CO₂ exchange by producing essentially non-selective resistance to CO₂ and water transport. Thus T/P might be reduced, since increasing stomatal resistance will affect transpiration more than photosynthesis because of the mesophyll resistance in the CO₂ diffusion path. In addition to
maintaining a favorable plant water balance, an antitranspirant might act to reduce mesophyll resistance (35) and consequently increase the rate of photosynthesis over that of control plants. 

*Pinus resinosa* seedlings treated with Clear Spray, CS6432, or Dow Silicone exhibited a greater decrease in T/P over control plants. Subsequently CS6432 and Clear Spray increased T/P. In both cases this was a result of gradually decreasing transpiration, due to permeability properties of the compound. It is suggested that CS6432 and Clear Spray may form a more complete genuine film than Dow Silicone, reducing transpiration while reducing photosynthesis to a greater degree.

This study emphasizes that both the environment and species importantly influence the efficiency and usefulness of antitranspirants. Both factors should be carefully evaluated prior to recommending use of film antitranspirants. Because phytotoxicity and "suffocation" may eventually occur with antitranspirants, these compounds may be less desirable than those coatings, which do not completely cover leaves, or which eventually crack or are lost by volatilization.

**Literature Cited**